16TH CONFERENCE ON SUSTAINABLE DEVELOPMENT OF ENERGY, WATER AND ENVIRONMENT SYSTEMS

October 10–17, 2021, Dubrovnik, Croatia


# BOOK OF ABSTRACTS

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INTERNATIONAL CENTRE FOR SUSTAINABLE DEVELOPMENT OF ENERGY, WATER AND ENVIRONMENT SYSTEMS

# 16th CONFERENCE ON SUSTAINABLE DEVELOPMENT OF ENERGY, WATER AND ENVIRONMENT SYSTEMS

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**October 10 – 15, 2021, Dubrovnik, Croatia**
**(hybrid event)**

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# Conference Venue: Dubrovnik

*„Those who seek paradise on Earth*

*should come to Dubrovnik and see Dubrovnik.“*

*Oscar Wilde*

Dubrovnik is situated in the southernmost part of the Republic of Croatia. Founded in the 7th century, Dubrovnik is rich with cultural and historical monuments and is included in the UNESCO World Heritage list. The city is surrounded with the walls built between the 11th and 17th century. Its cultural and scientific institutions include Museum at Rector's Palace, Cathedral Treasury, Pinacotheca, Franciscan monastery and cloister, with one of three oldest pharmacies in Europe (14th c.), the Cathedral (initial funds given by King Richard the Lionheart), one of the European oldest Synagogues, Marin Drzic Theatre, Dubrovnik Symphony Orchestra, Interuniversity Center. Nature lovers can find here true Mediterranean landscape, and "enjoy the cleanest sea in the Mediterranean" (Jean Jacques Cousteau). Dubrovnik International Airport is situated 22 km from the city center.

# Scope and Objectives

The 16th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES) is dedicated to the advancement and dissemination of knowledge on methods, policies and technologies for increasing the sustainability of development by de-coupling growth from the use of natural resources and by a transition to a knowledge-based economy. All taking into account the economic, environmental and social pillars of sustainable development.

"History teaches us that men and nations behave wisely once they have exhausted all other alternatives"

*Abba Eban*

One of the main issues of the coming decades is to improve efficiencies by integrating various life-supporting systems, using excess from one, as resource in another in the correct moment. Integrating electricity, heating, cooling, transport, water, buildings, waste, wastewater, industry, forestry and agriculture systems will be pivotal towards sustainable development.

Sustainability being also a perfect field for interdisciplinary and multi-cultural evaluation of complex system, the SDEWES Conference has become a significant venue for researchers in those areas to meet, and originate, discuss, share, and disseminate new ideas:

- Sustainability comparisons and measurements (metrics and indices; multi-criteria analysis; external costs; exergy analysis; footprint methods; emergy; life cycle analysis)
- COVID-19 and energy transition
- Green economy and better governance (circular economy; low carbon development/economy; resource efficiency; water reuse; jobs and regional development; financial and regulatory mechanisms; models and tools; rebound effect; energy economics; environmental economics; development economics; sustainability economics; blue economy)
- Smart energy systems (demand response; power-to-X; integration of power, heating/cooling, transport, water and waste sectors; smart grids; markets; dynamic electricity pricing, microgrids; prosumers; digitalisation; blockchain)
- Energy policy (security of supply; climate change mitigation; energy transition; renewable energy support schemes; energy efficiency policy; employment creation; carbon pricing; markets; fossil fuel subsidies; coal regions in transition)
- Smart transport systems policy and management (transport system analysis; fuel/carbon economy; transport electrification; congestion and road pricing; multimodal management; alternative fuels; social aspects; autonomous mobility; railways; shipping; aviation)Water-energy nexus (water management; water system analysis; water pricing; water desalination; hydro energy; water-renewables integration, water resources; river basin management; arid areas)

"You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete."

*Buckminster Fuller, philosopher, futurist and global thinker (1895 - 1983)*

- Environmental policy and management (waste management; wastewater management; climate change mitigation; climate change adaptation; air pollution policy; water pollution policy; land management; biomass management; rewilding; social aspects; strategic environmental impact assessment, environment and corporate social responsibility, quality management systems; environment management systems; eco management and audit schemes; occupational health and safety assessment systems; hazard analysis and critical control point; integrated management systems)
- Agricultural policy (energy and water use in agriculture and food processing; food vs. biofuels; sustainability of biofuels production)
- Social acceptance (reform; NIMBY; nuclear; wind; biofuels; hydrogen; hidden and special interests; cost based pricing; inclusion; fossil fuel subsidy; green economy and employment; gender issues; energy poverty; energy affordability)
- Sustainable resilience of systems (resilience of energy systems; resilience of water systems; resilience of environmental systems; resilience of agricultural systems; resilience of social systems; resilience of engineering systems )
- Sustainable tourism (green hotels; certification)
- Urbanism (smart cities; urban planning; zoning; transport; zero energy buildings/districts; sustainable energy action plans; district heating/cooling)
- Regional planning and cooperation (sustainable islands; regions and cities; 100% renewable regions)
- Research, innovation and development (industry-academia partnership; quadruple helix; knowledge based society; knowledge management; learning curve; technology foresight; science diplomacy)
- Education in sustainable development (governance; environmental awareness; higher education; engineering education)
- Energy system analysis (energy planning; power system planning; smart energy systems; smart energy networks; natural gas system planning; 100% renewable energy systems; high penetration of renewables; island energy systems; development of energy planning tools; internalizing environmental externalities; electrification of transport; storage vs. grids vs. demand management; long term demand planning; integration of power and district heating systems; integration of power and water systems; integration of power and transport systems; power to gas)
- Transport management (transport system analysis, dynamic road pricing; electrification of transport)
- Renewable energy resources (biomass; hydro; wind; solar; geothermal; wave and ocean; technical and economic potentials; barriers; cost and benefits; integration)
- Primary energy resources (oil peaking; gas; coal peaking; nuclear fuels)
- Renewable electricity generation systems (biomass; hydro; wind; offshore wind; high altitude wind; photovoltaic; concentrated solar thermal power; geothermal; wave; tide; ocean thermal)
- Thermal power plants (clean coal; combined cycles; advanced cycles; flexible operation and cycling; carbon capture and storage/sequestration/reuse; nuclear)
- District heating and/or cooling in smart energy systems (integration of renewable heat; cogeneration; industrial waste/excess heat; waste to energy and CHP; power to heat; electric boilers; heat pumps; integration of CHP with district heating and electricity markets; heat maps; distribution)

- Nano and micro technologies and science for sustainable development of energy, water, and environment systems
- Advanced sustainable energy conversion systems (fuel cells; thermoelectric; thermionic; organic; ORC; waste/excess heat recycling; thermoacoustic; piezoelectric)
- Renewable heat systems (biomass; biofuels; biogas; solar; geothermal)
- Biofuels and biorefineries (biodiesel; bioethanol; biogas; second and third generation biofuels; waste to biofuels; algae; anaerobic digestion; BTL; biorefineries; alternative fuel vehicles; infrastructure; sustainability assessment; pyrolysis; torrefaction; coproduction)

"If there are to be problems, may they come during my life-time so that I can resolve them and give my children the chance of a good life."

*Kenyan proverb*

- Alternative fuels (hydrogen; electro-fuels; power to gas; synthetic fuels; BTL; DME; CNG; resources; production; vehicles; infrastructure)
- Hybrid and electric vehicles (first generation hybrid; plug in hybrid; charging; batteries; infrastructure)
- Water treatment for drinking water
- Water desalination (distillation; reverse and forward osmosis; electrodialysis; energy recovery; discharge management)
- Waste and wastewater treatment and reuse (avoiding waste; composting; recycling; waste to energy; anaerobic digestion; gasification; mechanical biological treatment; mechanical heat treatment; plasma arc waste disposal; pyrolysis; RDF/SRF; combustion modelling)
- Modelling for pollution avoidance and energy efficiency (CFD models; air pollution spreading; water pollution spreading; heat and mass transfer modelling combustion modelling)
- Cogeneration, trigeneration, polygeneration (heat/cold and power; water and power; biofuels and power; transport and energy; food and energy; applications and operation strategies)
- Storage (heat/cold storage; hydrogen storage; hydropower as storage; pump storage; compressed air storage; batteries; water storage; biofuels storage; storage optimisation modelling; financial support mechanisms; power market arbitrage)
- Electricity transmission and distribution (grid extension and robustness; long distance transmission; power quality)
- Gas security of supply (diversification; shale gas; extension of transmission pipelines; LNG; Southern Corridor)
- Energy and water efficiency in industry and mining (cement and lime; construction materials; glass; pulp and paper; food industry; metallurgy; chemical industry; process optimisation; kilns; boilers; heat exchange networks; pinch analysis; exergy and exergoeconomic analysis; energy audits; water use and waste minimisation; eco-innovation; total site integration; life cycle assessment; eco-design and eco-labelling; product cycle assessment; cleaner production, environmental impact assessment)
- Energy efficient appliances (smart appliances; labelling and standards; user behaviour)
- Buildings (nearly zero energy buildings; passive buildings; smart buildings; smart metering; ICT; load and demand side management; green buildings; building codes and standards; buildings certification; HVAC; insulation; renewables integration; heat pumps; storage; sustainable architecture)

- Energy markets (market/price coupling; liberalisation/deregulation; modelling; demand response; role of district heating; desalination and water pumping; storage; retail markets; grid parity; net metering)
- Emission markets (emission trading system; cap and trade; transport participation)
- Political aspects of sustainable development (long term planning; sustainable development goals; the role of political leaders and of voters; international conflict vs. sustainable development; security and sustainability; resource and political security)

"Then I say the Earth belongs to each generation during its course, fully and in its right no generation can contract debts greater than may be paid during the course of its existence"

*Thomas Jefferson, September 6, 1789*

In addition, acknowledging that regional coordination is the only feasible solution for gaining synergy effects for the small and only partially connected emerging energy markets of the Southeastern Europe, the Conference will address the core goals of the Energy Community and the wider region:

- Competitive integrated regional energy market (regional cooperation, market opening, price reform, regulatory framework and independence, coordination on regional projects, market coupling)
- Security of supply (diversification of fuels, energy efficiency, oil and gas storages, regional emergency response, energy and water scarcity)
- Climate change and environment (regional emissions reduction plans, fuel mix in power generation - renewable energy - gasification - energy efficiency, intelligent use of energy)
- Infrastructure development (Mediterranean power ring, Southern Corridor, investment projects of regional interest - minimum definition criteria, investments in the gas sector, electricity interconnections, grid access and integration of renewable energy)
- Social dimension (energy poverty, definition of vulnerable customers, protection schemes, stepwise phasing out of regulated energy prices, fossil fuel subsidies)
- External relations in light of sustainable development (enlargement - EU neighbours, cooperation with other international organizations)

# Preface

The objective of the series of conferences on Sustainable Development of Energy, Water and Environment Systems (SDEWES) is to provide a forum for world-wide specialists and those interested in learning about the sustainability of development, to present research progress and to discuss the state of the art, the future directions and priorities in the various areas of sustainable development. This includes the improvement and dissemination of knowledge on methods, policies and technologies for increasing the sustainability of development, taking into account its economic, environmental and social pillars, as well as methods for assessing and measuring sustainability of development, regarding climate, energy, transport, agriculture, water and environment systems and their many combinations. The reason for the forum having such a wide scope is due to the need for holistic integrated solutions encompassing several or all.

Prof. Maria da Graça Carvalho

*Chair of the International Scientific Committee*

Prof. Ivo Šlaus

*Chair of the Scientific Advisory Board*

Prof. Neven Duić

*Chair of the Local Organising Committee*

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# BOOK OF ABSTRACTS

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## Plenary lectures

### SDEWES2021.0661

# Enabling Pathways Towards Sustainable Urban System Scenarios for Effective Climate Mitigation

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The Scientific and Technological Research Council of Turkey (TÜBİTAK), Turkey (*siir@kth.se)

## Abstract

Urban areas were responsible for about 28.6 $GtCO_2eq$ of greenhouse gas emissions at the global level in 2020, including direct and indirect emissions from energy use as well as embodied emissions. With such an important share, capturing a turning point and rapid decrease in urban emissions at sufficient scale and pace is crucial for enabling pathways that are better aligned with the critically sensitive bounds of a 1.5°C global warming target. This lecture will first focus on urban emission scenarios that are constructed in the context of the SSP-RCP framework using data from over 10,000 urban areas as well as urban emission trends. The findings have significance for comparing urban emission scenarios that are able to reverse the drivers of urban emissions in a way that benefits from an urban advantage for accelerating climate mitigation. These include supporting the penetration of renewable energy in energy systems, integrating efficient urban energy infrastructure, and mobilizing sustainable behavioral change. Based on these scenarios, indices based on an urban identity that involves an integrated urban energy planning perspective are introduced to support the translatability of global targets to the local level. An original synthesis across multiple datasets is continued to obtain local urban emission scenarios for the top 10 urban areas in each of the main world regions plus South East Europe that is harmonized with parameters from the Global Human Settlement Layer. Connections across spatiotemporal dimensions are used to emphasize the need for diffusing effective urban climate mitigation action that takes into account the progress of pioneering urban areas for climate neutrality as well as climate positivity. The role of urban areas in integrating sectors for providing flexibility in 100% renewable energy scenarios is underlined as well as opportunities for further improving the SSP1-RCP1.9 scenario with a transition to renewable energy based, resource efficient and compact urban areas. The multi-dimensional feasibility of such options is put forth as well as the presence of tools to enable the vision for a SDEWES-Aware City for sustainable urban systems. Enabling the integration of energy, water and environment systems in urban areas is crucial for better safeguarding life-support systems for the well-being of the entire planet.

## SDEWES2021.1059

# Flexibility and Resilience from Multi-Energy Systems

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## Abstract

The aim of this plenary lecture is to discuss the main concepts about provision of flexibility and resilience from the so-called multi-energy systems (MES) whereby electricity interacts with other energy vectors and sectors such as heating, cooling, transport, gas, hydrogen, etc. Specific use cases and applications, covering technical, commercial, and regulatory aspects, will refer to a number of recent projects in the UK, Europe and Australia. These include ongoing work with electricity and gas system operators, transmission and distribution network operators, and energy regulators and policy makers to address how MES could support an affordable, reliable and resilient transition towards low-carbon and even net-zero energy systems, including potential futures dominated by green electricity-hydrogen systems.

## SDEWES2021.1022

# Status of Renewable Energy Systems in the World

S. Kalogirou*

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## Abstract

This presentation examines the current status of renewables in the world. The presentation starts with some facts about climate change, global warming, and the effects of human activities, such as the burning of fossil fuels on the climate problem. It then outlines the status of renewables in the world, which includes their shares with respect to conventional fuel use for power and for electricity production alone, and their social dimension in terms of jobs created. Then the basic forms of renewables are examined in some detail, which includes solar thermal, both for low and high-temperature applications, photovoltaics, hydropower, onshore and offshore wind energy systems, and biomass/biofuels. In all these the basic technology is presented followed by the current status, the installed capacity in the last decade, which reveals their upward trend, as well as the prospects of the technology and some new research findings.

## SDEWES2021.0689

# The ESSence of Geography in Energy Sciences

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## Abstract

As renewable energy shares increase with decreasing costs, available land may be the next stop block for the development of sustainable energy systems. Energy planning is therefore increasingly a matter of spatial planning as well.

For more than 20 years, geographical information systems have been used to describe and model current and future energy systems. Energy data has been disaggregated to local geographical scales and made available to the research community on massive scale. A magnitude of studies addresses the space-dependent distribution of sustainable energy resources, captures the spatial spreading of energy needs and consumption, and analyses the access to energy infrastructures.

What is often missing, though, is the intricate link between location suitability, and the quantification of potentials and costs. The present paper suggests a generic approach to assess these main constraints of local sustainable energy options. For each geographical entity, suitability mapping identifies available land by environmental constraints or political preference; potentials are quantified and located by technical limitations; and location-specific costs are assessed for place- and logistics-dependent technologies. The paper introduces to the methods of such analysis, and presents examples from past and current research.

## SDEWES2021.1085

# The Impact of Sector Coupling on Future Energy Systems

M. Münster*

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## Abstract

In order to adhere to the Paris agreement, decarbonisation is needed in all sectors. Decarbonisation is possible through high biomass consumption with potential effects on biodiversity and food supply - or through electrification. Decarbonisation of sectors such as the heat, transport and industry sectors will require a high degree of direct and indirect electrification, coupling the power sector closely to these sectors through Power-to-Heat and Power-to-X technologies. To undertake this, there will be a large increase in power demand, which will to a high degree be served by variable renewable energy such and wind and solar power. This requires great flexibility from the energy system, which may be supplied through flexible generation and transmission - as well as energy storage and flexible demands provided by the coupled sectors. The plenary keynote lecture illustrates important concepts and benefits from sector coupling with examples from large scale integrated energy system analysis applying the linear optimization model, Balmorel.

## SDEWES2021.1083

# The Ipcc Sixth Assessment Report: a New Milestone for Our Understanding of Human-Caused Climate Change

J. Rogelj*

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## Abstract

The Intergovernmental Panel on Climate Change (IPCC) is tasked to transparently and comprehensively assess our best scientific understanding of the risks of human-caused climate change. It consists of 195 individual countries, and is therewith the organisation with the greatest global influence on bringing science and scientific evidence into the international climate change negotiations. Every five to seven years, the IPCC publishes authoritative assessment reports on the physical science basis of climate change, impacts and adaptation, and mitigation of climate change. In this presentation, we will look at the latest assessment report of the IPCC, published in August 2021, on the physical science basis. This Sixth Assessment Report (AR6) of the IPCC represents a new milestone in our consolidated understanding of human-caused climate change and provides the scientific backdrop against which the political discussions at the next climate summit (COP26) will take place, November 2021, in Glasgow in the United Kingdom.

## SDEWES2021.0996

# Untying the Knot: Explorations to Meet Climate and Sustainability Goals

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## Abstract

The world is facing several sustainable development challenges at the same time, including the challenges to deal with climate change, biodiversity loss, hunger and access to energy and safe drinking water. The challenges are linked: solutions for climate change can have consequences for biodiversity and the other way around. Many scenarios in the literature, for instance, to keep warming below 1.5 or 2°C include land-use-based mitigation options, including bio-energy, with possible consequences for water and land. In the presentation, we look into this default climate mitigation approach, emphasising nexus challenges and discussing how these are coupled to the SDGs. Alternative routes that can limit reliance on land use for mitigation, including rapid electrification of energy demand based on renewable energy and lifestyle change. Although there are also challenges involved, these pathways could alleviate some of the stresses on nexus issues while providing essential co-benefits. Finally, the lecture will conclude with some of the critical challenges in the integrated assessment of global change: 1) how to deal with feasibility issues beyond technical and economic issues and 2) how to link issues across the scale. Scenario analysis has an instrumental role in guiding ways of addressing nexus issues in the context of climate change mitigation and sustainability goals. Through this lecture, it will be possible to explore what is needed to meet the Paris Agreement to sustain our future.

## Special session: Bio-Electrochemical Systems as Sustainable Technologies for Implementing Innovative Remediation and Energy Harvesting Technologies

The special session is part of an itinerant networking program within the EU COST Action PHOENIX CA19123 H2020, a European research framework among the topics of sustainable urban development and environment protection with a key focus on bio-electrochemical systems (BES).

BES are cost-effective biotechnologies that could be used as bio-remediator, biosensor and bioreactor. BESs are exploited in multiple fields, here we focus on Microbial Fuel Cells (MFCs) as bio-electrochemical converters for rendering organic waste, polluted soils, and water, into a useful resource that is transformed in energy and nutrients. Such technologies rely on the microbial metabolism for reduction of organic content as well as electricity generation as well as being used as electrolyzers. Such systems have the capability to work symbiotically with their surrounding environment, combining decontamination with electrical usage thus practically facilitating an eco-circular concept. Although MFCs – of all types of BES – is the only type that generates (as opposed to consume) electricity, this is currently less than what would be required by conventional power consumer electronics. Recent advances in the field of low power electronics enable the exploitation of these sustainable and environmentally friendly technologies, bringing the “power gap” for direct use and improving their capability to work as energy harvester, feeding network of sensors or acting as a sensor themselves.

Decontamination of polluted soils and water represents the natural field of application of such systems, the integration of biotechnologies in the urban context represents a priority for appropriate rational urban planning and minimum environmental impact.

This session will be focused on:

Biological aspects like bioremediation techniques and surface science related to BESs which can lead to environmental sustainability. In particular electro-remediation, bioremediation, bioprocesses, electromagnetic interactions on biofilm, BESs and electrodes materials, bioresource valorization, electro-fermentation, biological interaction, water valorization for coffee industry, drilling waste biodegradation, gene expression of microbial communities of MFCs, kinetic modelling of regulatory mechanisms of microbial communities involved in MFCs.

Electrical management aspect of energy harvesting techniques with MFCs. Assuming as primary objective the improvement of electrical outputs performance and energy storage systems: develop MFC systems with higher than state-of-the-art power outputs, considering miniaturization of systems, increase in capacity and decrease in energy losses.

Papers focused on the aforementioned aspects, possibly integrated and applied to any context (marginal lands, wastewaters, degraded urban landscape, etc.) are welcome.

### Session organizers:

**Prof. Domenico Borello**, Sapienza University of Rome, 00184, Italy

**Dr. Valeria Ancona**, Italian National Research Council, Water Research Institute (IRSA-CNR), Bari, Italy

**Dr. Paola Grenni**, Italian National Research Council, Roma, Italy

**Prof. Ioannis Ieropoulos**, University of the West of England, Bristol, Bristol, United Kingdom

**Dr. Andrea Pietrelli**, Universite Lumirere Lyon 2, LYON, France

*Domenico Borello* - Domenico Borello is Professor of Power Systems at Sapienza University of Rome. He's got his Ph.D. in 2000 in Energy Systems. He has a specific interest in energy conversion processes with a specific focus on innovative, sustainable technologies. He is currently managing a research group including one Assistant professor, 3 Post Docs, 3 Ph.D. students. He is leading the Fuel Cells and Biomass Gasification labs at DIMA. In the first one, experiments on terrestrial microbial fuel cells are currently carried out aiming at understanding their capabilities for soil decontamination as well as for energy harvesting. He is a member of the PHOENIX Cost Action CA19123, where he is leading the Working Group 4 Point of Load. In the biomass gasification lab experiments on gasification and energy valorisation of biomass from phyto-assisted bioremediation are currently carried out aiming at understanding the syngas properties as well as the fate of the phyto-extracted contaminants. He is author of >90 peer reviewed research contributions to international papers&conferences. His Scopus H-index is equal to 19.

*Valeria Ancona* - Valeria Ancona is Research Scientist at Water Research Institute –National research Council (IRSA-CNR), Bari – Italy. She's got her Ph.D. in Agricultural Chemistry, in 2008. She studied the decontamination processes of soils as a result of the synergistic action between plant species and soil microorganisms through the integrated use of microbial ecology techniques, aimed at assessing the structure and composition of soil microbial communities, and by means of analytical techniques for the determination of contaminants (organic and inorganic). Also, she is currently studying the effectiveness of BES techniques in promoting soil decontamination from organic toxic compounds. She has been involved in regional and national projects on plant-assisted bioremediation for recovering soil pollution and producing renewable energy from biomass. She is currently managing a research group including 2 Post Docs, 2 PhD students and 1 research fellowship. She is the Lead Researcher of "GREEN SOLUTIONS" project (funded by Apulia Region in the framework of the INNONETWORK call) and responsible of a WP on Plant-assisted bioremediation techniques for soil depollution in the framework of "Energy for Taranto Technology And pRocesses for the Abatement of pollutaNts and the remediation of conTaminated sites with raw materials recovery and production of energy tOtally green (TARANTO)" project, funded by the Ministry of Education, University and Research, grant number ARS01_00637. Her scientific activity has produced more than 80 contributions: papers published in national and international scientific journals (ISI), conference proceedings and technical reports. Recently she is involved in the Phoenix Cost Action (CA19123 - Protection, Resilience, Rehabilitation of damaged environment). Tutor and co-tutor of students for master and PhD degree theses. Referee for various international scientific journals. Her Scopus H-Index is equal to 8.

*Paola Grenni* - Dr Paola Grenni is a Research Scientist at Water Research Institute –National research Council (IRSA-CNR), ROME – ITALY. She obtained the master Degree (M.Sc.) in Natural Science (summa cum laude) from University of Trieste and the Ph.D. in Environmental Science from the Milano Bicocca University. Her main field of interest has been microbial ecology in soil, sediments, surface and groundwater. Experimental activity includes methods for assessing microbial activity and diversity, as well as molecular methods, together with ecotoxicological methods. She is the author of about 100 publications including research papers in peer-reviewed journals and some book chapters (Scopus h index 23). She has been involved in national and international projects on ecosystem contamination (pesticides, their transformation products and fertilizers; pharmaceuticals; PCBs; anionic surfactants; metals) and in bioassisted remediation processes. Among other, she is also involved as Italian MC Member of the Phoenix Cost Action (CA19123 - Protection, Resilience, Rehabilitation of damaged environment). Expert consultant in the evaluation of research projects and referee for various international scientific journals; Editorial board of various Journals and editor of books. Tutor and co-tutor of students for master and PhD degree theses. She received the Atlas Award from the Elsevier in 2017.

*Ioannis Ieropoulos* - Ioannis A. Ieropoulos is Professor of Bioenergy & Self-Sustainable Systems and co-founder and Director of the Bristol BioEnergy Centre, Bristol Robotics Laboratory, UWE. He has an interest in waste utilisation and energy autonomy and produced the EcoBot family of robots and RowBot, which have their own MFC microbiome and operate completely devoid of conventional power sources. He has been an EPSRC Career Acceleration Fellow (2010-2015) and is currently a Bill & Melinda Gates Foundation grantee on the "Urine-tricity/PEE POWER®" project, advancing the MFC technology for sanitation improvement in Developing World Countries. He leads projects, focusing on robotics, biodegradable & functional materials, funded by the Leverhulme Trust, and the European Commission (FP-6, FP-7 and H2020) with a focus on living architecture. He has published >100 peer reviewed journal papers, generated >£10M of research income in the last 10 years and holds 2 patents on MFC stack development, configuration, modulation and control.

*Andrea Pietrelli* - Dr Andrea Pietrelli is Research Scientist at University Lyon 2, Lyon, France. He was awarded with two PhD titles from the Department of Information, Electronics and Communications in ICT at Sapienza University of Rome, Italy, and from the Ampere Laboratory in Electrical, Electronics and communications engineering at the Ecole Centrale de Lyon, France. He obtained the master Degree (M.Sc.) in Communications Engineering from Sapienza University of Rome. His research activity has focussed on bio-electrochemical systems, energy harvesting technologies, low power electronics, wireless sensor networks, ground penetrating radar systems, microbial fuel cells scaling-up, and environmental monitoring applications. He is the Chair of the H2020 COST Action (CA 19123) PHOENIX Protection, Resilience and Rehabilitation of Damaged Environment.

Invited submissions

## SDEWES2021.0058

# Development of Bio-Digital Interface Powered by Microbial Fuel Cells

J. You*[1], A. Mendis[1], J. Greenman[1], J. Freeman[2], S. Wolff[2], R. Armstrong[3], R. Hughes[4], I. Ieropoulos[1]

[1]UWE Bristol, United Kingdom; [2]Translating Nature, United Kingdom; [3]Newcastle University, United Kingdom; [4]KU Leuven, Belgium (*jiseon.you@uwe.ac.uk)

## Abstract

This paper reports the first relatable bio-digital interface powered by microbial fuel cells (MFCs) that was developed to inform the public and introduce the concept of using live microbes as waste processors within our homes and cities. An innovative design for MFC and peripherals system was built as a digital data generator and bioreactor, with a custom-built energy harvesting controller that was connected to the system to enable efficient system operation using adaptive dynamic cell reconfiguration and transmit data for the bio-digital interface. This system has accomplished multiple (parallel) tasks such as electricity generation, wastewater treatment, resource recovery and autonomous operation. Moreover, the controller demonstrated that microbial behaviour and consequent system operation can benefit from smart algorithms. In addition to these technical achievements, the bio-digital interface is a site for the production of digital art that aims to gain acceptance by a wider interest community and potential uptake audiences by showcasing the capabilities of living microorganisms in the context of green technologies.

## SDEWES2021.0165

# Microbial Activity and Energy Production of Terrestrial MFCs in Presence of Compost and Persistent Organic Pollutants

D. Borello[1], G. Gagliardi[2], A. Barra Caracciolo*[3], G.L. Garbini3[4], A. Visca[5], L. Rolando[5], G. Aimola[6], V. Ancona[7], P. Grenni[4]

[1]Sapienza University of Rome, Italy; [2]sapienza Università di Roma, Italy; [3]Italian National Research Council - Water Research Institute (IRSA-CNR), Italy; [4]National Research Council, Italy; [5]Italian National Research Council - Water Research Institute, Italy; [6]Italian National Research Council, Italy; [7]Italian National Research Council, Water Research Institute (IRSA-CNR), Italy (*barracaracciolo@irsa.cnr.it)

## Abstract

Microbial Fuel Cells (MFCs) transform energy stored in the chemical bonds of organic compounds into electrical energy thanks to exo-electrogen microorganisms naturally occurring in soil, which catalyse oxidation and reduction reactions in the area between two graphite electrodes. The dispersion of contaminants in polluted soils can interact with microorganisms activity. How the use of contaminated soils in MFCs can alter energy harvesting and/or pollutant degradation is an open research question.

This work aimed at a) assessing the energy harvesting and b) identifying electrogen microorganisms involved in energy production, in terrestrial MFCs with enriched carbon content with and without the presence of persistent organic pollutants (polychlorinated biphenyls-PCBs). Two main experimental conditions were performed: a natural soil with a relatively low organic carbon content (ca. 1.5%) amended with a municipal waste compost (3% w/w) and the same soil spiked with polychlorinated biphenyls (PCBs). The latter experimental condition was performed for assessing the possible degradation of this class of persistent organic pollutants.

MFCs designed at the DIMA lab were maintained in a refrigerated thermostat at 25°C. The water content was monitored and refilled daily. The electric performance of the MFC was measured using an electronic device developed and realised by the DIMA research team in cooperation with other groups at Electronic and Telecom Engineering Dept. in Sapienza. The device was able to operate in open and closed-circuit condition, varying also the Ohmic resistance.

The Open Circuit Voltage (OCV) and Polarisation curves were measured for monitoring the cell performance over the experiment time. It was assumed that the MFC life was terminated when the OCV and the power curves drastically reduced their values.

In particular, the polarisation curve was obtained by varying the circuit Ohmic resistance in a range between 100 and 10000 Ohm aiming at detecting the condition of maximum power where the external and internal resistance were similar. In order to find a relation between electric performance and soil microorganisms, microbial abundance, activity and structure were evaluated in the initial soil and at the end of the experiment. In particular, each microbiological parameter was evaluated at anode (A), cathode (C) and soil (S) inside the MFC. The overall results will be reported and discussed.

## SDEWES2021.0240

# Power and Electrofiltration Characteristics of Scalable and Low-Cost Microbial Fuel Cells for Resource Recovery from Urine

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## Abstract

Microbial Fuel Cells represent an innovative recovery platform of energy, nutrients and production of disinfectants from wastewater and urine through the simultaneous treatment and electrosynthesis of catholyte within the cathode half-cell. The quality of electrofiltrated catholyte is greatly impacted by the MFC power output as well as the membrane characteristics (thickness, composition, porosity). This work was aiming to examine the performance of several low-cost ceramic membranes as functional separators for improved power in scalable MFCs as well as their impact on catholyte production and its quality. The test rig consisted of 12 identical MFCs constructed (4 experimental groups in triplicates), inoculated and operated in identical manner where the anodes were made of carbon veil, and the cathodes were based on activated carbon. The experimental setup was designed in such a way, that the ceramic cylinder could be removed from the MFC, without interrupting the biofilm electrode and allowing the introduction of a new ceramic membrane in order to test its performance for the purpose of power output as well as the electrofiltration of urine into newly formed filtrate within the cathode. The results show that both ceramic composition as well as its porosity has a direct impact on the power output as well as the properties of the electro-synthesised filtrate and should be taken into account for scaling up multi-functional MFCs for the recovery of power and synthesis of valuable chemicals from recovered nutrients in waste-streams.

## SDEWES2021.0274

# Stacked Air-Cathode MFCs for Small Sensors Power Supplying

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## Abstract

Microbial fuel cells (MFCs) are playing an important role in the context of sustainable energy development. They can be considered as a future option for the treatment of organic wastes and the recovery of bioenergy from wastes. However, the low output voltage and the low produced electricity limit their applications as energy supply systems. The scale-up of MFCs is not a valid solution for improving these performances because a greater distance between the electrodes, that can occur in bigger reactors, involves a reduction in power density. Therefore, more attention is paid to the development of MFCs systems based on modular configurations that allow increasing the power production as well as assuring a good power density.

In this study different stacked microbial fuel cells configurations, consisting of 4 reactors, have been designed, developed and tested in order to estimate the best one. These configurations differ in terms of electric connection modes (series, parallel/series and series/parallel connections).

Results have highlighted that the stacked parallel/series-based configuration assures both the highest volumetric power density (normalized with respect to the total volume of the reactors), that is 2451 mW/m$^3$, and the highest electric power production equal to 274.6 µW. These performances result to be about 1.8-fold higher in terms of volumetric power density and 7-fold higher in terms of power production, if compared to a single MFC.

## SDEWES2021.0345

# Composite, Recycled Polypropylene-Coated Ceramic Membranes for Microbial Fuel Cells

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## Abstract

Increasing interest in sustainable electricity generation through microbial fuel cell technology reinforces development of new and cost-effective materials for their assembly. Such a goal can be reached with inexpensive ceramic materials as separators. In this study, we present a new approach for increasing their lifetime, while using recycled polypropylene (PP) coating. PP-coated ceramic composites were prepared by using two different ceramic materials and tested in a single chamber air-cathode MFCs. A comprehensive characterization of all devices revealed, that among two of the studied ceramics (labelled as 468 and 373), the highest power, exceeding 200 μW was reached for PP/373 composite and was 40% higher than unmodified 373. In the last stage of the experiment (60-80 days), PP/373 remained at 250-390% higher level of power when compared to unmodified clay suggesting strong antifouling effects of ceramic modification. Water absorption and surface analyses of the materials revealed that these effects were rather related to the hydrophobic nature of the coating than three-dimensional structure of the surface exposed to the anolyte. A proposed method represents increasing long-term efficiency of the MFCs, while using recycled plastics and circular economy approach.

## SDEWES2021.0514

# Biodegradation and Biosorption Potential of Organophosphorus Pesticides in the Presence of Hydrochar and Biochar

S. Maletic*, M. Kragulj Isakovski, D. Tamindžija, D. Radnović, M. Grgić, T. Apostolović, I. Jevrosimov, S. Rončević

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## Abstract

Due to high performance and low-cost organophosphorus pesticides (OPP) is one of the pesticides class widely applied. To test biodegradation and biosorption of OPPs was tested in batch experiments with addition of bacterial strain Bacillus megaterium BD5 in mineral medium. Results indicated that Bacillus megaterium BD5 efficiently biodegraded fenitrothion, malathion and parathion methyl in batch experiments in mineral medium, while abiotic degradation was predominant mode of removal for disulfoton and fenthion ($p < 0.05$). Next, batch experiments with sediment amended with biochars and hydrochars of sugar beet shreds and Miscanthus×giganteus with and without bacterial biofilm were conducted. Influence of biostimulation was also tested by addition of nutrients. Results indicated that OPPs addition of amendments cause OPPs longer persistence in sediments ($p < 0.05$). While addition of amendments colonised with BD strains efficiently degraded all investigated OPPs ($p < 0.05$).

## Special session: Clean energy technologies and systems for sustainability

The growing demand for energy and associated environmental issues are crucial global challenges that have been attracting increasing attention from a diverse range of academic, industrial, government and policy stakeholders. Clean energy technologies and systems can tackle these important challenges and support sustainable development and growth. This special session focuses on research advances, case studies and practices to improve clean energy supply and energy efficiency in a variety of applications, which covers methods, processes, components, and systems for the high-efficiency and low-emission collection, recovery, utilisation, conversion and storage of energy for heating, cooling and power provision, with emphasis on innovative technologies and renewables exploitation including solar, wind, geothermal and biomass, amongst other. The themes of this special session include, but are not limited to the following topics:

Advanced solar energy technologies for heating, cooling and power provision

- Carbon capture and storage (CCS)
- Decarbonisation of heating and cooling
- Energy policy and economic assessment for sustainability
- Energy saving strategies in buildings
- High-performance energy conversion devices/components
- Hydrogen related technologies including generation, storage, transportation and utilisation
- Renewable energy technologies and hybrid renewable energy systems (HRES)
- Thermal energy storage and large-scale electrical energy storage via thermal processes

Waste-heat recovery and conversion to heating, cooling and/or power with advanced cycles

### Session organizers:

**Prof. Christos N. Markides**, Imperial College London, London, United Kingdom

**Dr. Jian Song**, Imperial College London, London, United Kingdom

**Prof. Pietro De Palma**, Politecnico di Bari, Bari, Italy

*Christos N. Markides* - Christos N. Markides is Professor of Clean Energy Technologies in Department of Chemical Engineering of Imperial College London, where he heads the Clean Energy Processes (CEP) Laboratory. He is the Editor-in-Chief of Applied Thermal Engineering, on the Editorial Board of the UK National Heat Transfer Committee, the Scientific Board of the UK Energy Storage SUPERGEN Hub, and is a member of the Assembly of World Conferences on Experimental Heat Transfer, Fluid Mechanics and Thermodynamics, the Global Energy Association, and the International Energy Storage Alliance. His current research interests focus on high-performance processes, technologies and systems for the recovery, utilisation, conversion or storage of energy for heating, cooling and power, with emphasis on renewable, solar and waste heat, thermodynamics of and heat/mass transfer effects in heating/cooling devices and heat-to-power conversion technologies, and advanced experimental techniques for detailed flow, heat/mass transfer in turbulent, multiphase and interfacial flows.

*Jian Song* - Dr. Jian Song is a Research Associate in the Clean Energy Processes (CEP) Laboratory at Imperial College London. He received his B.Eng. degree and Ph.D. degree in Power Engineering and Engineering Thermophysics from Tsinghua University in 2013 and 2018. He is Managing Editor of journal Applied Thermal Engineering and Reviewer Editor of Frontiers in Energy Research. Dr. Song's research interests focus on clean and high-performance process, devices and systems for energy conversion and renewable energy technologies and systems for heating, cooling and power provision, with emphasis on solar, geothermal, waste-heat recovery and other relevant areas.

*Pietro De Palma* - Pietro De Palma is professor of Energy Systems at Politecnico di Bari since 2003. His main research interests are: 1) energy systems; 2) wind energy; 3) alternative fuels for internal combustion engines; 4) combustion and ionized-flow modelling; 5) design of numerical methods for compressible and incompressible flows; 6) stability analysis of wall-bounded flows; 7) turbulence and transition modeling; 8) numerical analysis of complex flow in turbomachinery; 9) microfluidics and particle methods. He has co-authored about 90 journal papers and book chapters, and about 100 conference papers. He is group leader for the research line "Advanced numerical methods for the solution of the Navier-Stokes equations" of the Center of Excellence in Computational Mechanics at Politecnico di Bari. He has been invited to present his research work at several international conferences: in Europe (1998, 2000, 2005); in India (2005); in US (1997, 2000); in Japan (2000). He is or has been: 2009-2012: member of the Board of Directors of Polytechnic of Bari. 2012-2018: Deputy head of the Department of Mechanics, Mathematics, and Management. March 2017-: Director of the Ph. D. School of Polytechnic of Bari. December 2017:- Member of the "Apulian Science Academy" and from 2019 member of the Boards of Directors.

Invited submissions

## SDEWES2021.0077

# Exergy Analysis of Seawater Desalination Through Reverse Osmosis Driven by a Otec Plant

A. Liponi[1], A. Baccioli[1], F. Guidi[1], D. Vera Candeas[2], L. Ferrari*[1]

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## Abstract

Seawater desalination is an effective way to reduce water scarcity in several remote areas of the world. However, desalination processes require a huge amount of power which might not be available in several areas of the world, especially in insular zones. Ocean Thermal Energy Conversion (OTEC) is a technology that perfectly suits the energy needs of seawater desalination in tropical areas: the constant energy production, the high number of equivalent hours, and the zero carbon emissions of this technology make OTEC a very interesting technology to be coupled with reverse osmosis (RO). In this study, a polygenerative system made of OTEC and RO for electricity and water desalination is proposed to assess the thermodynamic feasibility and determine the optimal design parameters of the plant. The study is carried out by creating a numerical model of the system in Aspen Hysys. The Hysys model allows OTEC to be simulated in all its main parts, including heat exchangers, pumps, turbine, and seawater pipes. For the RO system simulation, average performance parameters were considered from the literature. The system is optimized by maximizing second law efficiency. Optimal values of OTEC variables such as evaporation and condensation temperatures, riser pipe length, and temperature differences of seawater at the condenser and evaporator were evaluated. A sensitivity analysis on the fluid and the electric production of the plant was performed. Results show that the second law efficiency depends on the ratio between the electric power and the water produced in the range between 4.5% when no electric power is produced and 25% for a 10 MW electric output. As for the fluid, ammonia generally provides the best second law efficiency.

## SDEWES2021.0106

# Complex Fluid Flows in Mini and Microchannels with Micro and Nano Enhanced Surfaces for Advanced Heat Recovery Systems

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## Abstract

This paper addresses a multiscale approach for heat recovery systems, used in two distinct applications. Both applications use a microscale approach (microchannel heat sinks and heat pipes) for macroscale applications (cooling of a PV cell and using thermal energy of exhaust gases of an internal combustion engine for thermoelectric generators with variable conductance heat pipes. Several experimental techniques are combined such as visualization, thermography with high spatial and temporal resolution and characterization of the flow hydrodynamics, such as the friction losses. The analysis performed evidence the relevance of looking at the physics of the observed phenomena to optimize the heat sink geometry. Hence, the results show n improvement of nearly 80% in the dissipated power at the expense of controlled pumping power, for the best performing geometries. In both cases, the analysis performed here evidences the potential of using two-phase flows. a.However, instabilities at the microscale must be accurately addressed to take advantage of liquid phase change. In this context, the use of patterned biphilic interfaces such as those recently proposed in our research group may significantly contribute to solve the instabilities issue as they are able to control bubble dynamics.

## SDEWES2021.0112

# High-Temperature Solar Energy System with Thermally-Actuated Passive Solar Tracking

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## Abstract

As traditional fossil energy sources are continuously diminishing, the demand for optimizing output from renewable energy sources is gaining particular importance. Among these, solar energy is certainly one of the most prominent technology and it is widely used in a variety of applications, either concerning electricity and heat production. Despite this, the global efficiency of the systems converting sunlight to energy still must be improved, as well as generation costs must be lowered, in order to make solar an even more relevant source of clean energy.

In modern Photovoltaic (PV), Concentrated Photovoltaic (CPV) as well as Concentrated Solar Power (CSP) generation plants, accurate and optimal exploitation of sunlight is ensured by appropriate positioning of the solar panels/mirrors using solar tracking. This is typically realized by means of electromechanical motors, which are designed to align the incident solar radiation with the optical axis, thus enhancing the energy conversion efficiency.

Also, CSP systems typically incorporate in-built thermal energy storage (TES), which provides flexibility of production and use of electricity. Among the materials used in CSP-TES, molten salts are currently the most widespread, although phase change materials (PCMs) are becoming a quite common choice in industry, given their potential lower cost and higher efficiency. Moreover, their solid-to-liquid phase transition results in a significant volumetric expansion which was recently considered as a driving force for passive solar tracking.

The main objective of this study is to provide a comprehensive technical assessment on the use of the volumetric expansion of PCM for solar tracking purposes in CSP-TES integrated plants. Such a concept is then compared with standard electromechanical tracking. A proper numerical model is developed for the evaluation of the expected performance of the overall plant during a typical year of operation. Furthermore, a preliminary economic analysis is carried out to evaluate the effective profitability of the proposed solution.

## SDEWES2021.0113

# Theoretical and Experimental Characterization of a Scroll Expander Operating in an Orc-Based Power Unit and Technological Improvement

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## Abstract

The main driver of the research in on-the-road transportation sector is certainly the development of technologies which allow to reduce $CO_2$ emissions of Internal Combustion Engines (ICEs). This sector, in fact, participates in a significant way to these emissions, being responsible for 20% of total emissions. Among the efforts done on many energy-related engineering sectors, the ICEs have very severe commitments, whose eventual non-compliance is sanctioned with fines able to put out of the market specific classes of vehicles. As technological answer, several innovations are under development, both to increase global conversion efficiency and to favor the Wasted Heat Recovery, WHR.

WHR from exhaust gases into mechanical energy through ORC-based power units is one of the most promising option, being the exhaust gases a source of a thermal energy equal to 30-35% of the fuel chemical energy. This technology is quite conventional for large scale and steady state applications, but several issues raise when the recovery unit is scaled down and thermal source is characterized by an intrinsic transient nature. In ICEs, in fact, the thermal energy of the exhaust gases significantly varies according to mass flow rate and temperature, which are linked to engine speed and load. This represents the most critical operating aspect which must be faced to avoid an operation of the unit always far from its design point.

The choice of the components is very important to successfully overcome this issue. A fundamental role is played by the expander technology which definitively converts thermodynamical into mechanical energy. Volumetric expanders are retained the best option for this specific application, thanks to their capacity to deal with transient conditions. Inside this class of machines, scroll expanders are one of the most suitable candidates. Nevertheless, these machines have not yet been optimized as expanders, being the available units more derived modifying some parameters when they acted as compressors than the result of a specific design originally conceived as expander.

Dual Intake-Port (DIP) technology is a novel solution which can be introduced in scroll machines to enhance the recovered power without modifying the in-out pressure ratio of the expander. The effectiveness of this technology was assessed thanks to a comprehensive experimentally validated theoretical model of the scroll, developed to catch the physical processes occurring inside the expander.

The model demonstrates as the scroll expander with a DIP technology is able to produce an increase of 25% of the mechanical power with respect to the baseline machine, ensuring a sensible ORC-based plant operability gain, without modifying sensibly its inlet pressure.

SDEWES2021.0149

# Study on Hybrid Heat and Power Co-Generation System

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## Abstract

In the process of energy revolution, the development of renewable power has become indispensable and inevitable in the modern power industry, and yet been restricted by many practical problems as well. The instability of renewable energy makes the whole power generation system unable to maintain stable output, causing fluctuations in the power grid system, and ultimately affecting the user side. So far only limited research on hybrid heat and power co-generation system being applied to the regional power supply is reported. Current systems convert electric energy to thermal energy to meet the heating demand of users, but the energy quality is often reduced.

Hybrid two or more kinds of renewable energy is a way to eliminate instability of renewable energy power generation system. In this paper, a solar-geothermal power generation system is built to achieve stable output. ASPENPLUS software is employed to build the co-generation model and to run the calculations under certain working conditions. The output power entropy and energy efficiency is analyzed to optimize the system.

Furthermore, a hybrid heat and power co-generation system is designed to reach both heat and power demands of users. Feasibility analysis is carried out to examine whether the output heat and power can reach the standard of heat and power supplement. According exergy analysis shows that the hybrid heat and power co-generation system is much more efficient than the original system.

## SDEWES2021.0158

# Numerical Investigation on Thermochemical Behaviour Improvement of Corrugated Heat Storage Unit with Porous Metal Support

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## Abstract

Salt hydrate-based thermochemical energy storage (TCES) under low-temperature (<150°C) is currently a prospective strategy used for long-term heat storage due to the facile reversible gas-solid reaction. The poor heat and mass transfer ability of the storage bed usually caused the sluggish reaction and therefore, the performance of the storage unit was drastically degraded. In order to solve the limitation of heat and mass transfer in closed storage system, a cylindrical corrugated storage unit in which imbedding a porous metal support was proposed in this study. Corrugated external channel improved the heat transfer between the heat transfer fluid (HTF) and the thermochemical material wrapped inside; and the presence of the metal support in reaction bed further enhanced heat transfer. Compared to the storage unit with straight external channel and no metal bracket in the reaction bed, the new one reduced ~22.7% in heat charging time. The simulation results indicated that the corrugated shaped thermal storage unit with porous metal support inside is an efficient module for thermo-chemical energy conversion.

## SDEWES2021.0174

# Dynamic-Mode-Decomposition of the Wake of a Nrel-5MW Wind Turbine

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## Abstract

Dynamic mode decomposition (DMD) has been applied to the wake of the NREL-5MW wind turbine, to investigate the most dynamically relevant coherent structures characterizing this flow. The decomposition has been applied on a snapshot dataset obtained by Large-Eddy Simulation of the flow impinging on the wind turbine, whose tower and nacelle are modeled by the immersed boundary method, whereas rotor blades are modeled using the actuator line method. The Sparsity-Promoting DMD algorithm allows one to select a limited number of dynamic modes optimally reconstructing the snapshot sequence. Among the largest-amplitude selected modes, we found the tip vortices, oscillating at an angular frequency equal to three times therotational frequency of the turbine. Interestingly, the remaining selected modes are characterized by low frequencies and large-scale spatial structures, reaching the frequency range of the wake meandering. This small set of dynamic modes is highly relevant for the formulation of reduced-order models.

## SDEWES2021.0221

# Developing of an Offline Monitoring Method for the Electric Energy Demand of a Healthcare Facility in Italy

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## Abstract

The energy demand of hospitals and healthcare facilities is characterized by specific features, as it is the result of activities in operation 24 hours a day, 365 days a year. Hospitals are among the most energy intensive facilities in the service industry. Consequently, the development and implementation of energy saving strategies could lead to not negligible reduction of energy consumption.

Nevertheless, the development of energy saving strategies must pass through a detailed analysis of the energy demand of each specific activity. The healthcare facilities are characterized by different activities, which require a variety of energy vectors. It is difficult to define general reference characteristics in terms of energy requirements because they are strongly connected with the specific activities carried out within each building.

In a previous study carried out by the authors on a healthcare facility located near Florence (Italy), it has been investigated the correlation between energy demand, information on healthcare activity and weather conditions.

Building on this premises, the present activity extends the healthcare energy demand analysis by introducing new data about the building electrical energy consumption, in order to realize an offline monitoring method through a CUSUM control chart.

A correlation study has been performed on the available data related to the year 2019, to establish which parameters influence energy demand the most. Information obtained through the correlation study is then used to develop a numerical model capable to predict the building electrical energy consumptions based on the values assumed by the selected parameters during a specific time step.

As a result, the study has led to the development of an offline monitoring method that, through the exploitation of the prediction model, can be applied to the future healthcare energy requirements to find any change in the energy consumption trend of the facility. In particular, the prediction model defines the standard energy consumption of the healthcare facility, allowing to realize a CUSUM control chart which includes the energy consumption data related to the year 2020 as well. The proposed method allows to find any variation of the actual electric energy consumption in comparison to the reference one and could be a useful tool to modify the energy system control strategy, aiming at pursuing a continuous optimization of the building energy demand.

## SDEWES2021.0318

# Design and Assessment of a Large-Scale Integrated Power-to-Gas Plant for Renewable Sng Production in Remote Areas

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## Abstract

The ongoing energy transition calls for a radical shift in energy generation and use. For many applications, the reliance on a storable and movable fuel or energy vector remains a critical operational aspect. In this context, natural gas is alternatively criticized for the involved carbon emissions or appreciated for the versatility and the reduced carbon intensity with respect to other fossil fuels. An interesting solution to decarbonize some uses that currently adopt natural gas with minimal changes is the production of synthetic natural gas (SNG) from renewable sources. As an alternative to local small-scale plants, large-scale plants in remote areas where the resource availability is high and the infrastructures for hydrocarbons transport are a relevant asset can be considered.

This work investigates a renewable SNG production plant composed of a solar photovoltaic field, an electrolysis system, and a methanation reactor, aiming to design an effective plant scheme and assess the performance from a techno-economic point of view. The analysis considers a location in the Middle East, where solar irradiance is favourable in terms of both peaks and year-long variability. In addition, this is an area from which long-distance gas transport already exists. As a $CO_2$ source for methanation, flue gas capture from nearby power generation plants is compared to direct air capture. In order to cope with the limited flexibility of the methanation systems while relying on a daily-fluctuating resource for hydrogen production, three system design schemes are proposed and compared. These exploit combinations of electrical energy storage, hydrogen storage, as well as $CO_2$ storage, while adopting different methods to supply electricity to the balance of plant.

Simulations assume a constant output of 1 MW in the form of ready-to-transport SNG at the operating pressure of the methanation system (30 bar). Results show that the alternative of using $CO_2$ from a power plant equipped with carbon capture is favourable from an economic point of view. At current cost assumptions, the levelized cost of such renewable SNG is not competitive with the fossil sources, with a strong impact from investment costs. However, future scenarios of further PV cost reduction and high carbon tax on $CO_2$ emissions predict a viable development for this kind of plants.

## SDEWES2021.0319

# Modelling and Experimental Investigations of Solar Thermal and Air Source Heat Pump System for Domestic Water Heating

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## Abstract

Solar and "air-to-water" heat pump water heating are energy efficient and environmentally friendly heating technologies for the domestic sector. Clean energy transition programs are promoted in almost all countries today and sustainable heat supply is being developed along with renewable electricity. This work focuses on clean combined heat supply technologies for single-family households in mild and continental climates. Different modeling approaches of the energy efficiency and performance of the combined solar thermal/air source heat pump system are employed. Modelling approaches includes Engineering Equation Solver (EES) for vapor compression "air-to-water" heat pump, TRNSYS 18.0 for time variable system simulation. Simulation results show that a solar water heating and "air-to-water" heat pump system can provide domestic heating in mild climates without a backup system; while a solar water heating, "air-to-water" heat pump, and auxiliary heater are suitable for domestic heating in continental climate regions due to intermittent solar energy and the limitations of ambient air temperature to air source heat pump. An experimental installation of a combi, solar thermal and "air-to-water" heat pump water heating system was assembled and tested in Almaty, Kazakhstan. R32 is a suitable alternative to the R410A. "Air-to-water" heat pump's COP with R32 refrigerant is 2.75 at 268 K outdoor temperature and 323 K heat delivery temperature. TRNSYS analysis showed that for regions, where the average monthly outdoor temperature is not less than 269 K, in the SAASHP system, solar collectors and ASHP could supply the required heat demand in the heating season from 47.8% to 100%.

## SDEWES2021.0320

# Study on the Uniformity of Phase Distribution in Two-Phase Flow Heat Exchangers with Small Channels

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## Abstract

Heat pump technology, which possesses the characteristics of strong heat exchange capacity and rapid system response, has significant potential as a battery thermal management technology for pure electric vehicles. However, the uniformity of the two-phase refrigerant in a header and each branch channel is one of the key issues that restrict the performance of the heat pump system. In this paper, a two-phase flow visualization phase separation experimental platform, with R1233zd(E) as the working fluid, was built largely based on a cold plate type two-phase flow heat exchanger structure with small parallel channels (3 mm). Three inlet configurations (upper inlet, middle inlet and lower inlet) are set, and two types of operating conditions are tested (inlet quality range 0.01-0.07, inlet mass flux range 300-500 kg $m^{-2}$ $s^{-1}$). Moreover, the gas-liquid two-phase boundary in the channel, captured by a high-speed camera, is extracted to calculate the average void fraction based on the OpenCV graphics processing function libraries. The results show that the lower inlet method can achieve improved gas-liquid two-phase distribution, followed by the middle inlet method, and finally the upper inlet method which achieves the worst phase separation uniformity, due to different combinations of gravity and inertial force among these three inlet configurations. Additionally, a superior gas-liquid two-phase distribution in channels can be achieved under lower inlet quality (0.01) and inlet mass flux (300 kg $m^{-2}$ $s^{-1}$) due to the influence of two main forces (inlet liquid phase inertial force and gas-liquid interface shear force). Finally, it is also found that average void fraction in each channel is positively correlated with the average pressure gradient under most flow patterns.

## SDEWES2021.0412

# A Transient Simulation-Based Approach for Hydrogen Production Assessment from Concentrating Solar Thermal Collectors

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## Abstract

In this paper, a novel mathematical model purposely developed to assess the energy performance of solar-driven thermochemical reactors for green hydrogen production is presented. To this aim, a theoretical analysis about materials, operating principle and geometry of a suitable system consisting of a thermochemical reactor coupled to a solar dish concentrator is conducted. Specifically, the carried-out study refers to iron oxides and cerium reactors since different activation temperatures are observed for them (iron oxides devices allow producing hydrogen at around 640°C, whilst much higher temperatures are necessary for cerium). The obtained dynamic simulation code, written in MatLab, is based on a detailed transient finite-difference thermal network where both the thermochemical reactor and solar dish concentrator are discretized in several sub-volumes. Details about the heat transfer through the thermochemical reactor - dynamically assessed via a customised resistive-capacitive thermal network – are also provided.

## Special session: Developing energy-efficient and environment-friendly process equipment, process control and maintenance solutions for sustainable process manufacturing

Sustainable process manufacturing (chemical, petrochemical, pulp&paper, food, beverage, pharmaceutical, biotechnology, etc.) is expected to use minimum resources while minimizing environmental impact and keeping costs to society at an acceptable level. In this context, the availability of energy-efficient and environmental-friendly process equipment, process control approaches and maintenance practices is of primary importance. Applications of methods and tools to support engineering decisions, such as mass-balance, thermodynamic and environmental-impact analyses, process integration techniques, advanced simulation methods and optimization techniques, is also a key issue to highlight the importance of choosing the best options. This Special Session is focused on research advances, case studies and practices to improve energy and resource efficiency of process industries, and to reduce their environmental impacts through applications of innovative process equipment, process control strategies and maintenance approaches. The themes of this special session include, but are not limited to: design and operation of process equipment to facilitate sustainable performance of process plants, process control approaches to enhance energy efficiency and reduce environmental impact, as well as maintenance solutions to safeguard safe and efficient operation of process systems.

### Session organizers:

**Dr. Marian Trafczynski**, Institute of Mechanical Engineering, Faculty of Civil Engineering, Mechanics and Petrochemistry, Warsaw University of Technology, Płock, Poland

**Prof. Krzysztof Urbaniec**, Warsaw University of Technology, Plock, Poland

**Prof. Mariusz Markowski**, Institute of Mechanical Engineering, Faculty of Civil Engineering, Mechanics and Petrochemistry, Warsaw University of Technology, Płock, Poland

*Marian Trafczynski* - Assistant Professor at the Faculty of Civil Engineering, Mechanics and Petrochemistry, Warsaw University of Technology (WUT) in Poland. Prior to joining regular WUT staff in 2013, he has gained industrial experience as process engineer with engineering companies and has also served as industrial audit expert for The Polish National Energy Conservation Agency (KAPE) in Warsaw. His research interests include rational energy utilization in industrial equipment, and mathematical modelling of heat and mass transfer equipment. He has been lead author of several articles published in, among others, Applied Energy, Applied Thermal Engineering, Energies, Energy, Energy Conversion & Management, Renewable & Sustainable Energy Reviews, and several more papers presented at major international conference series including PRES, SDEWES and Int. Conf. Heat Exchangers Fouling and Cleaning. He is a reviewer of several high-impact research journals and of the abovementioned conferences.

*Krzysztof Urbaniec* - Professor emeritus at the Faculty of Civil Engineering, Mechanics and Petrochemistry, Warsaw University of Technology (WUT) in Poland; founder and former head (2004-2019) of the Faculty's Centre of Excellence in the Reduction of Environmental Impact of Process Industries. Before joining WUT in 1989, he has gained industrial experience as head of R&D with engineering company CHEMADEX, Poland, and has also served as a lecturer at Lund University, Sweden. In the period 1989-2021 he has been active at WUT Department of Process Equipment, teaching and conducting research on equipment units for various processes of chemical and food-processing industries and environment protection systems, as well as contributing to, or coordinating international projects on university-level education, technological research and technology transfer. Author or co-author of 16 monographs and handbooks published by a.o. Bartens, Elsevier, Springer, Wiley, Woodhead and of more than 200 papers including ones published in high-impact journals Applied Energy, Applied Thermal Engineering, Energy Conversion & Management, Int. J. Hydrogen Energy, J. Cleaner Production, J. Environmental Management, Renewable & Sustainable Energy Reviews. He has presented papers at major international conference series including PRES, SDEWES and World Hydrogen Energy Conference. He is a member of the International Scientific Committees of conference series PRES and SDEWES.

*Mariusz Markowski* - Professor at the Faculty of Civil Engineering, Mechanics and Petrochemistry, Warsaw University of Technology (WUT) in Poland, and head of Faculty's Department of Process Equipment. Before joining WUT in 1998, he has gained 12 years industrial experience as process designer in the engineering companies specialized in oil refining and petrochemical works, and heat and power systems. He has also served as industrial audit expert for The Polish National Energy Conservation Agency (KAPE) in Warsaw, and as a lecturer at continuing education courses organized by KAPE. His main research field is energy integration and efficient use of energy in process plants. He is author or co-author of articles published in, among others, Applied Energy, Applied Thermal Engineering, Energy, Energy Conversion & Management, Renewable & Sustainable Energy Reviews, and of papers presented at major international conferences including PRES and Int. Conf. Heat Exchangers Fouling and Cleaning. He has also contributed to the monograph Process Systems Engineering Vol. 5: Energy Systems Engineering published by Wiley-VCH.

Invited submissions

## SDEWES2021.0005

# The Dynamic Model of a Rectification Heat Exchanger Using the Concept of Heat-Integrated Distillation Column (Hidic)

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## Abstract

A dynamic model of the apparatus used for thermal rectification of mixtures was developed assuming the apparatus is based on a new technology, where in the channel-type exchanger thermal separation of substances is accompanied by diaphragm heat exchange. It should be added that exchangers of this type are not yet used in industry, as they are still in the research phase. On the other hand, their application in Heat-Integrated Distillation Columns (HIDiCs), would allow reducing heat consumption by 40-60 % compared to the existing industrial solutions. Taking into account that distillation processes require about 3 % of global energy consumption, it means a potential decrease about 1.5 % of global energy consumption and hazardous gas emission.

In the description of the channel-type exchanger, a novel mathematical model was used combining the model of thermal resistance (in the description of the diaphragm heat exchange) and the theoretical tray model (in the description of the mass transfer). The dynamic properties of the new apparatus should be taken into account already in the early stages of its design; if this is not the case, then process control may require the use of a very complex control system. In modelling the dynamics of the channel-type exchanger, it was divided into a set of cells treated in accordance with the lumped-parameter approach. Each cell was described using differential equations obtained from the balances of mass, energy and momentum. After linearization, these equations were subjected to Laplace transformation, and the operator transmittances of all cells were related by signals thus forming a block diagram of the tested apparatus. The obtained scheme was implemented as a model of the Simulink program in the Matlab environment. This model shows the structure of the channel-type exchanger system and gives directions of signal flow and relations (determined by operator transfer functions) between the input and output signals of individual parts of the system. The dynamic properties of the considered model were examined on the basis of the determined transient characteristics. From the transient characteristics states that the channel-type exchanger is dynamically stable under industrial constraints, such as grow up of deposits on the heat transfer surface or hold up of liquid inside the channel of exchanger. Moreover, the model confirmed that the dynamic change of distillate purity was negligible from the point of view of industrial applications.

As the obtained results prove the stability of the tested model, it may be used for developing control systems of the channel-type heat exchanger for thermal separation of substances

## SDEWES2021.0006

# Energy Analysis of the Operation of an Industrial Nozzle with Variable Outlet Conditions During Compressible and Transient Airflow

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## Abstract

The nozzle which is applied in industrial pneumatic pulsators is an object of study. It is the last element of a system for unclogging the drains and outlets of silos and hoppers for loose materials. The nozzle requires the lowest energy losses while directing the airflow, which impacts the loose material bed. The energy rate transferred inside the silo mostly depends on differences between temperature and pressure between the inlet and outlet of the nozzle. In this study, the available energy and exergy are determined during compressible and transient airflow through the nozzle, which is a part of the industrial pneumatic pulsator. The study is based on numerical simulations by using the OpenFOAM Computational Fluid Dynamics (CFD) toolbox. Energy analysis is carried out with Reynolds Transport Theorem for specific energy for the variable temperature inside the silo. Parameters of air at the outlet of the nozzle are, in fact, the ones inside the silo. The exergy is determined accordingly by using the mean values of the flow parameters at the outlet. The results show that more than half of inlet energy could not be converted into work. The outlet exergy tends to increase with temperature, which means that the higher temperature is inside the silo, the higher effectiveness of the nozzle is.

## SDEWES2021.0007

# Impact of Uncertainty in Methods for Determining the Thermal Resistance of Fouling on the Scheduling of Heat Exchangers Cleaning

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## Abstract

Energy-saving heat recovery in an industrial heat exchanger network may be impaired by fouling build-up on heat transfer surfaces of the exchangers. During longer periods of network operation, monitoring of fouling growth based on measurement data makes it possible to schedule and perform exchanger cleaning if needed for the mitigation of adverse effects of fouling. The present work is an extension of the authors' previous research, where three different methods of measurement-aided fouling monitoring were outlined and studied: two simple methods known from literature and a least-squares based method introduced by the authors. In the present work, the authors used the previously estimated characteristics of thermal resistance of fouling, based on historical measurement data recorded during three-year continuous operation of the real-life network of 26 shell-and-tube heat exchangers in a Crude Distillation Unit. Three mentioned methods for measurement-aided determination of time characteristics of fouling thermal resistance were studied with the aim of evaluating their impact of uncertainty on optimizing the cleaning of individual exchangers through scheduling. While all these methods rely on the recorded values of operating parameters of the exchangers, they differ in the approach to pre-processing of input data and in the complexity of data processing algorithms, and therefore, generate different results in the scheduling of cleaning interventions in heat exchanger networks. The least-squares based method of measurement-aided fouling monitoring was found to be best suited for the evaluation of effectiveness of cost-optimal cleaning interventions in heat exchanger networks.

## SDEWES2021.0009

# Experimental Investigation of an Impact of a Finned Pipe Inclination on the Cooling System Efficiency in Boiling Investigation Stand with Minichannel

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## Abstract

As technology evolves, heat exchangers become smaller in size and the requirements for their efficiency grow. Flow boiling in minichannels is a modern way of heat transfer enhancement leading to a substantial growth of heat transfer coefficient. Long-term heat transfer investigations conducted by the authors on the dedicated minichannel flow boiling experimental stand have indicated the need to reduce the dimensions and simplify the design of the cooler used so far. The specific design of the stand necessitated the replacement of a typical heat exchanger with a finned copper pipe. The goal of the presented research was construction of the cooler maintaining high efficiency on a required level independently of its spatial orientation. A set of circular fins was installed on a copper pipe with 2.5 mm internal diameter. Experiments were conducted for different inclination angles of both the minichannel and the coupled cooler. The dispersed heat flux was measured for varying thermal input for three selected positions of the channel and the finned pipe: vertical, horizontal and at 45 degree inclination. The collected data were used to validate the numerical model of flow boiling heat transfer in the minichannel. Examination of the heat transfer conditions is particularly important in the efforts to reduce energy consumption by machines. It matters into ensuring the healthy functioning of the world economies.

## SDEWES2021.0010

# Application, Optimization and Upscaling of Compact Trickle Bed Bioreactors for Removal of VOCs and H2S in Biological Wastewater Treatment Plants

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## Abstract

Odors emitted by biological wastewater treatment plants (WWTPs) can be mitigated using various technologies such as adsorption, absorption, thermal or catalytic combustion, and biofiltration. Problems encountered in their applications may include secondary air pollution, the need to use expensive catalysts, the need to replace, utilize or regenerate reactor or filter bed, and high operating and investment costs. The biodegradation of WWTP odors using biotrickling filtration makes it possible to avoid problems of this kind. A pilot-scale Compact Trickle Bed Bioreactor (CTBB) with a total volume of 1.07 m3, diameter 0.80 m, and height 2.13 m, was installed in a municipal WWTP. Mobile measuring devices were used for volatile organic compounds (VOCs) and hydrogen sulfide (H2S) detection in the gas at the bioreactor inlet and outlet. At constant liquid phase flow and pH=7, and the flow rate of the gaseous phase ranging from 7 m3/h to 30 m3/h, the average conversion factor of H2S bio-purification was between 71% and 97%. For the degradation of VOCs, the conversion factor was between 82% and 94%. The research results confirm the application potential of CTBB technology in the municipal sector and will facilitate CTBB applications for odor and VOCs removal from the air in other sectors.

## SDEWES2021.0011

# Gene Activity Control to Identify Biological Pathways of N2O Production by Activated Sludge in Bioreactor Under Limited Do Conditions and Nitrite Presence

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## Abstract

Biological nitrogen removal processes at municipal wastewater treatment plants may be a significant source of $N_2O$ emission. Despite the recent research into the mechanism and dynamics of $N_2O$ formation and emission from the wastewater treatment processes it is still unclear as to the contribution of ammonia oxidation, nitrifier denitrification and heterotrophic denitrification pathways to the total $N_2O$ production under nitrifying conditions and varying DO concentration. In the present study a number of batch tests using activated sludge under nitrifying conditions were used to quantify the contribution of each process to total $N_2O$ formation at variable DO set points.

A series of laboratory experiments were carried out in a sequencing batch reactor (SBR). The reactor was equipped with the systems for continuous monitoring of pH, temperature, $N_2O$ and DO concentration. The duplicate nitrification tests were run at different DO (dissolved oxygen) set points: 0.4; 0.7 and 1.0 g $O_2/m^3$. Observed $N_2O$ production was inversely correlated with the AURs, whereas the DO decrease and $NO_2$-N presence stimulated $N_2O$ production. The activity levels of nirK and hao genes were significantly lower compared to nirS gene. This observation supports the hypothesis with regard to the nitrifying bacteria, that hydroxylamine oxidation, rather than autotrophic denitrification, is the main contributor to $N_2O$ production under the DO-limited conditions. The significant nirS gene induction, confirmed that limited aeration induced heterotrophic denitrification simultaneously to nitrification.

The obtained results revealed that the gene activity control may be a useful tool for recognizing the different biochemical pathways of $N_2O$ production and developing strategies for $N_2O$ control in bioreactors. Based on the measurement results, a statistical model was developed to model $N_2O$ emissions considering the operating parameters of the bioreactor and gene activity. The obtained model allows for optimal selection of bioreactor operating parameters and reduction of greenhouse gas emissions to the environment.

ACKNOWLEDGEMENT

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## SDEWES2021.0012

# Non-Random Method of Cleaning Schedule Optimization for Heat Exchangers in a Hen

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## Abstract

A method of scheduling of heat exchangers cleaning from fouling in heat exchanger networks (HENs) is presented. The objective function (OF) was formulated, taking into account the savings associated with the increase of heat recovery in HEN (as a result of on-line cleaning of the heat exchangers), reduced by the costs of cleaning operation of the exchangers. The decision variables are the set of N integers $\{n_1, n_2,..,n_i,..n_N\}$, expressing the number ($n_i$) of cleaning interventions from fouling of any i-th heat exchanger. OF maximization belongs to the category of INLP (integer nonlinear programming) programmingfor which optimization techniques are commonly based on random search methods. The disadvantage of the methods is the random arrangement of the HEN cleaning schedule by a computer program that implements the imposed algorithm by the programmer.

The authors propose a new approach to the OF optimization issue, enabling plant staff to make cleaning decisions for selected heat exchangers, taking into account computer aided suggestions. In the new approach, random search methods were abandoned. Namely, the authors propose to determine HEN schedule based on an analysis of the OF's sensitivity to the number ($n_i$) of cleaning interventions of any i-th heat exchanger.

The proposed method was used to optimize HEN cleaning schedule for a Crude Distillation Unit, processing 800 t/h of crude oil. The analyzed HEN is composed of 26 heat exchangers serving for the heat recovery from hot to cold process streams. The non-random method of the HEN scheduling was used and the calculated savings amounted to 3,14 mln USD per year. For comparison, when a random method (Monte Carlo method) was used to determine HEN cleaning schedule, the savings amounted to 2,8 mln USD per year.

## SDEWES2021.0021

# Impact of Temperature Approach on the Behavior of the Rectification Heat and Mass Exchanger Under Fouling Constraints

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## Abstract

In industrial applications, thermal separation of substances is carried out in rectification columns equipped with condensers and reboilers. Such technology is energy-consuming, i.e., it requires high heat supply to the reboiler, and significant waste heat discharge through the condenser, to the environment. In this study, an alternative technology is considered. The new approach assumes thermal separation of substances carried out in a system of channels where heat distribution is sustained through a diaphragm, i.e. channel walls. This type of apparatus serves for heat transfer and simultaneous thermal separation of substances, thus mathematical model of rectification heat and mass exchanger (HME) exercises the concept of heat-integrated distillation column (HIDiC) in a channel-type geometry.

In applications to rectification and distillation, such types of exchangers are not yet found in industrial applications, however their technology and operation are under development and testing on a laboratory scale. As it has been shown in previous studies, such technology has a potential of reducing energy consumption by 40-60% compared to rectification columns currently used in industry. The model of the channel-type exchanger uses a theoretical tray model for describing mass transfer, combined with our in-house mathematical description of diaphragm heat transfer that takes fouling resistance into account.

Numerical calculations carried out in this work were focused specifically on the impact of fouling on the operation of channel-type heat and mass exchanger. Key issues covered in this work included the impact of fouling on the purity of collected fractions (which have to meet guidelines given by process designer) and the intensity of internal heat streams (which are decisive for energy-saving). In the parametric study, the minimum temperature difference between mixture streams in the stripping and rectifying sections was also included.

The simulation results showed that for considered mixture of fractions, assuming a realistic range of fouling thermal resistances, the sensitivity of rectification heat exchanger to fouling is negligible, and the purity of distillate is hardly affected.

## SDEWES2021.0300

# Game Theory Based Method for Payoff Sharing in District Energy System with Industry Under Uncertainty

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## Abstract

Utilization of industrial waste heat in the district can effectively reduce energy consumption. However, industries and district energy providers usually belong to different enterprises, and the benefit distribution between enterprises will affect whether the district utilization of industrial waste heat can be implemented. However, the benefit distribution is rarely involved in current researches. In this regard, this article proposes a two-level trade analysis method based on Stackelberg model for industrial waste heat utilization in a district. The goal of the lower-level is to maximize the benefits of the alliance of industry and district, the goal of the upper-level is to maximize the trade benefits of district energy provider, and finally the benefit distribution of industry and district are determined. In the case study, the industry gains 17673.76$ benefit from the trade, and the district gains 7992.91$. In addition, this paper studies the impact of industrial energy supply on the trade price. The results show that the higher the industrial energy supply, the lower the trade price.

## Special session: From particle physics to sustainable world: Celebrating the achievements of Ivo Šlaus

Contemporary global interconnected crises of epidemics, economy, environment, society and institutions are getting more complex than ever, which requires urgent measures based on knowledge. This session is devoted to brainstorming for new educational, scientific and technological approaches including circular economy and supply chains, sustainable consumption and production as well as new approaches in education for sustainable development. The session should also reflect the legacy of Professor Ivo Šlaus on the occasion of his birthday with respect to all above-mentioned topics. Special emphasis will be given to advances in applications of physics, nanotechnologies and quantum technologies in sustainable development, and the social impact of these activities. The session is organized in cooperation with the World Academy of Art & Science, Club of Rome - European Research Centre and National Associations, and European Roundtable on Sustainable Consumption and Production Society.

### Session organizers:

**Prof. Aleksander Zidanšek**, Jožef Stefan International Postgraduate School, Ljubljana, Slovenia

**Prof. Uroš Cvelbar**, Jožef Stefan Institute, Ljubljana, Slovenia

**Prof. Rebeka Kovačič Lukman**, University of Maribor, Celje, Slovenia

*Aleksander Zidanšek* - Aleksander Zidansek is Professor of Physics at University of Maribor, researcher at Jozef Stefan Institute, and Secretary General of the Jozef Stefan International Postgraduate School. Dr. Zidansek holds Ph.D. in Physics and Master Degrees in Physics and Business Administration, with specialization in sustainable development management. Prof. Zidansek is active in both solid state experimental physics and in research of renewable energy. He has been involved in a number of national and international research and education projects in solid state physics, security and in sustainable development. He received a Fulbright Grant for research at Montana State University with Prof. V. H. Schmidt in 1995/1996. He became associate member of tt30 in 2001 and associate member of the Club of Rome in 2005 (www.clubofrome.org). He is Fellow of the World Academy of Art & Science since 2012 and Trustee since 2021.

*Uroš Cvelbar* - Uroš Cvelbar is Professor of Nanotechnologies and researcher at Jožef Stefan Postgraduate School and head of Department of Gaseous Electronics (F6) at the Jožef Stefan Institute, Ljubljana. He is Fellow of the World Academy of Art and Science, an executive board member of Electrochemical Society associated editor to several international journals from the field, etc. Prof. Cvelbar holds Ph.D. in Material Science, MScBA and BC in Physics, and specialises in nanotechnology, plasma processing, quantum technologies, environmentally sustainable processes, monitoring and energy harvesting. He has been involved in numerous domestic and international projects, has many patents, invited talks and over 200 scientific papers.

*Rebeka Kovačič Lukman* - Assoc. prof. dr. Rebeka Kovačič Lukman, she has a PhD in chemical engineering of University of Maribor. She has an outstanding number of citations (considering her age and research field). She has over 1500 pure citations; her h-index is 12. Her papers are in 1% highly cited papers in the research field in WoS. She is an invited conference speaker and invited lecturer at foreign universities, she has evident record of being a coordinator over 25 of international projects (including, Erasmus +, H2020), national projects as well as research projects financed by the Slovenian Research Agency. From 2016 she is a guest editor in the Journal of Cleaner Production, and 2019 Sustainability journal. Rebeka is a member of international committees (e.g. a member of the International Committee of European Round

Tables for SCP, a board member of ERSCP Society, and a member PREPARE network, where she was a president from 2016–2018). Rebeka was involved in establishing a study programme and curriculum of circular economy courses. Rebeka was from 2013-2015 a president of the supervisory board Snaga, a waste management company. It is necessary to mention that was a visiting researcher at the University of Manchester, GB, and carried out a study visit to Yale University, USA, TU Delft (NL). After completing doctoral studies, she was a visiting researcher at the Norwegian Technical University (NTNU) in Trondheim. In addition to her doctoral studies she completed a postgraduate study of Industrial ecology at the NTNU. From 2010-2016, she was employed in the industry at the managerial positions. She has been a mentor by bachelor and master thesis, and is a mentor currently to 4 phd students. She has been lecturing life cycle assessment and circular economy (also at the University of Technology Graz), innovations in supply chains, including CE at the University of Maribor (at all levels, BSc, MSc, and PhD). She is also lecturer at the Doctoral School at the University of Maribor. Currently she is a core group member by the European Commission for financing CE in all the EU Member States. In 2019 this working group published a document “Accelerating the transition to the circular economy: improving access to finance for circular economy projects“.

Invited submissions

## SDEWES2021.0460

# Circular Economy Indicators for Ports: a Case Study of Slovenia

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## Abstract

The circular economy has become an essential perspective throughout Europe since the European Commission published the first circular economy Action Plan in 2015. However, a shift towards a circular economy is also essential for seaports. Seaports encompass a large number of products and materials that represent a range of interconnected logistical services and activities, providing an opportunity to move towards a circular economy practice. Therefore, seaports represent an ideal place to implement and test a transition to the circular economy. A review of relevant and existing literature on the Web of Science revealed a lack of research addressing the circular economy of seaports. Furthermore, approaches to measuring the circular economy of seaports remain relatively unexplored.

Our research focuses on circular economy indicators in the port of Antwerp to measure and better understand existing circular economy practices. This paper addresses the development of circular economy indicators for seaports. The challenge was multidimensional, as we want to quantitatively assess and evaluate the process of seaports moving towards a circular economy. An objective assessment of the current state of the circular economy in seaports would enable their convergence towards the circular economy. Therefore, it is necessary to process a large amount of information (indicators) and combine them into more concise and straightforward information that is important for stakeholders and decision-makers. A methodology based on an Analytical Hierarchical Process was used to define the importance of each circularity strategy and incorporate it into the calculation of the port circularity index. Such information allows comparison between seaports, assessing development trends towards circular economy, identifying critical points within processes, and searching for improvement opportunities.

## SDEWES2021.0511

# Terahertz Technology Towards Future Sustainable Buildings

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## Abstract

Construction and demolition waste are one of the largest waste streams generated in the EU by volume. They consist of materials such as concrete, bricks, gypsum, wood, glass, metals, foams, plastics, solvents, asbestos, asphalt, and excavated soil. Nowadays many of them can be recycled, some even endlessly. Terahertz radiation allows the differentiation between some construction materials, the detection and identification of some foreign and hazardous substances, which is important for their separation in the recyclate according to the type of the material. We demonstrate that terahertz technology allows an inside view into some of the non-conducting building materials. By combining the terahertz imaging and spectroscopy, we performed analytical characterization of selected building materials by evaluating the acquired data obtained using analysis algorithms. We believe that the only way to reduce construction and demolition waste in the future is to encourage the adoption of innovative technologies like terahertz spectroscopy in combination with traditional methods. This approach can bring some changes also to the construction design philosophy towards more sustainable buildings with minimum end-of-life demolition.

## SDEWES2021.0531

# Vessel In-Water Cleaning and Wastewater Treatment

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## Abstract

With recent globalization trends and massive growth in the world trade over the past few decades the need for an efficient and cost-effective transport of goods is on constant rise. The maritime traffic nowadays represents the most significant portion of all goods volume. However, the increased traffic has a negative impact on the environment: $CO_2$ emissions, toxic organic pollutants and the introduction of allochthonous species in the local habitats. Here, we present an innovative approach to minimize the environmental damage by introducing the vessel in-water cleaning, therefore removing the biofouling from the hull in a safe and environmentally friendly way. By doing so the drag force is significantly reduced, resulting in decreased fuel consumption and $CO_2$ emissions. Moreover, the release of toxic pollutants from antifouling paints and the introduction of allochthonous species in local habitats is eliminated by pumping the wastewater produced during the cleaning procedure to a special wastewater treatment plant located on a supporting vessel or dock. The economic and environmental benefits of the vessel in-water cleaning represent a step in a more sustainable and environmentally friendly cargo ship traffic.

## SDEWES2021.0555

# Happiness as a Tool for Sustainable Development

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## Abstract

The first systematic measure of happiness in nations was introduced by Veenhoven who created a home page with a systematic review of correlations between happiness in nations and other indicators of wellbeing. Although positive correlations between happiness indicators and sustainability indicators are well known, the causal relations have still not been clearly demonstrated. Here, the focus is on the need for a significant behavioural change that is necessary for a transition to the circular economy and a green future. In this context, the psychology of happiness is explored as a tool for the necessary behavioural changes in the context of novel educational approaches. A recent study of happiness performed at Harvard University over the time period since 1938 revealed the predictors of happiness. They found that happiness originates from personal choices, fulfilling, deep personal relationships as well as taking care of yourself physically, financially, and emotionally. In this contribution, the systematic monitoring of competences is presented that allows for the determination of causal relations between individual happiness on one hand and sustainable skills and behaviours on the other hand. The significance of these results for strengthening the necessary behavioural changes toward a sustainable future is discussed.

## SDEWES2021.0563

# Transforming Our World

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## Abstract

While change has always been present in human history, it has accelerated significantly in recent decades. On one hand, this accelerated change is causing a plethora of threats and challenges, while simultaneously providing new innovative opportunities to resolve the challenges and significantly improve the quality of life for future generations. The fast development of information and communication technologies is leading us on the path to the technological and societal singularity, where artificial intelligence is expected to reach and exceed human intelligence. The progress in artificial intelligence coupled with the progress in biotechnology promises a seamless integration of smart machines with human beings. The development of quantum computing and quantum communications will further accelerate these trends, which provide opportunities for significant breakthroughs both in human health and in environmental health. The described acceleration of change will also affect the institutions, which will have to adjust to the fast-changing new realities. These opportunities are however not without danger and, to paraphrase H. G. Wells, in a race between catastrophe and education our collective actions, research, knowledge, science, and wisdom along with art and ethics will determine the outcome. We present several innovative solutions for transforming our world that provide significant potential to improve the future of humanity.

## SDEWES2021.0586

# Leadership for a New Paradigm: Planetary Moment and Momentum

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## Abstract

This is a unique moment in human history. It is a unique opportunity to generate the momentum needed for rapid transformation of national and global policies and institutions. We are confronted by challenges of a magnitude and urgency greater than ever before at precisely the moment when humanity faces a global leadership vacuum. These complex, multidimensional, interrelated challenges have already generated unprecedented awareness of fundamental flaws in prevailing ideas, values and institutions; a growing recognition of the need for a radical reordering of values and priorities; a greater willingness to embrace new policies; and a groundswell of public support among the younger generations for new solutions to safeguard their future.

Leadership is needed to seize the moment and harness the momentum of the awakened energies to generate a shared vision, aspiration and social preparedness. Catalytic strategies are needed to overcome the inertia of established practices and the resistance of entrenched powers and vested interests. This will require the integration of knowledge about diverse fields, unprecedented cooperation between sectors and nations, and unparalleled coordination between the multitude of multilateral institutions. The transformation should culminate in a global social movement guided by the universal values of human security, human rights, wellbeing for all and harmony with nature.

Such a radical and massive change cannot be achieved solely on the initiative of superpowers, national governments or by a few outstanding individuals. It will require the active involvement and support of all major stakeholders In each field and at every level it will also require people-centered catalytic leadership strategies to overcome the inertia, obstruction and vested interests of entrenched elites. All these will have to be founded on a new value-system as a source of its ideas, power and action. Ultimately it must release the energy and collective initiative of the entire global society for rapid transition to a new paradigm.

This paper explores the conclusions and recommendations of a one-year research project carried out by World Academy of Art and Science (WAAS) in collaboration with the United Nations Office in Geneva in a search for catalytic to accelerate progress toward a new paradigm in human development. This is a Planetary Moment and a time for global leadership to generate Planetary Momentum.

## SDEWES2021.0731

# On-Grid Photovoltaic System in Banja Pejës the Recreational Toursitic Enterprise – Comparative Analysis of Software Calculated Values and On-Site Measured Ones

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## Abstract

This paper deals with a theoretical, numerical as well as an applied-empirical analysis of photovoltaic systems of renewable ie solar energy for electricity generation. The analysis have been applied in the case study of the concrete solar photovoltaic system installed in the Touristic Rehabilitating and Recreational Center Onyx in Banja Pejës which is one of the largest photovoltaic systems in the country.

Software simulation and analysis of the PV-system systems have been carried out by applying appropriate software packages for simulating various operating regimes of these systems of electricity generations from solar renewable sources. By applying the PV-Syst Version 6.43 software package various operating regimes have been simulated for this case study and relevant results have been for the On-Grid PV System. These obtained simulation results have then been compared with the real measured values of generations of the photovoltaic system that have been monitored during the case study.

The PV system analyzed was of the type "SolargLog2000" and has an installed capacity of 500 kWp and has been monitored by measuring concrete electricity generation values during this study for the period of April-September 2017. The enerated electricy from this PV system, after the dc-ac conversion has been fed into the grid thru an appropriate 0.4/10 kV substation transformer.

## SDEWES2021.0837

# How Covid-19 Could Help Climate Change Mitigation, Energy Transition and Sustainable Development?

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## Abstract

We know for more than a century that fossil fuels cause climate change, and we know for five decades that the climate change will bring upon us and habitats devasting effect during XXI century, but a joint endeavour of fossil fuel industry, financial institutions and involved governments have blocked mitigation. Fortunately, the World is divided on 200 sovereignties, so some of them saw interest in moving forward, by investing in learning curve of technologies needed for mitigation: renewables, energy efficiency, clean mobility. The process was slow due to lack of global effort, and intensive work of fossil fuel lobbies on blocking the effort on international, multilateral, and national levels, but by 2008 we had technologies able to compete and replace fossil fuels. Some of the sovereignties went forward, financial institution who suddenly saw profit in saving climate obliged, but relentless progress made the transition too slow to help against climate change reaching point of no return, even though it became clear that fossil fuel interests are losing the war on climate. The enemy will be defeated, but patient will eventually have to adapt to catastrophic 3-4 degrees higher temperature, which may spell the end of civilisation and the World as we know it. What COVID-19 did was amazing. It brought short but relentless stop to travel and much non-essential economic activity, and with it fall of marginal energy use, which means mainly fossil fuels. It will not have per se lasting effect on climate change, since the rate of growth of carbon dioxide concentration in atmosphere will be only negligibly reduced, but it brought much more profound change, it has shown the fragility of fossil fuel investment. Price of oil tumbled, for the first time making oil countries aware of the end of century of oil. Coal and oil investments collapsed, coal power plants started to shut down in masses, slowly creating snowball effect. Can we do it? We need to reduce greenhouse gas emissions in European Union for 55-60% by 2030, and at least 45% on global level. That means we need to rapidly invest in renewables and phase out fossil fuel technologies for which we have alternative, such as coal power plants, gas boilers and internal combustion engine cars. Fossil fuel industries will put up heroic fight, but they lost an important ally, financial sector. Can we save climate by reducing our impact on environment by voluntary measures? No! We need to reduce emissions by 100% and we cannot do that by change of lifestyle. We can only do that by rapid investment in clean technologies. Should we change lifestyle? Probably yes, because human happiness is perhaps not proportional to the quantity of material things after some minimum has been satisfied, but this is NOT a way to save climate.

## SDEWES2021.0917

# Expert System for Systematic Monitoring of Sustainability-Related Competences in Higher Education

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## Abstract

The need for a systemic change towards green and digital future requires a significant improvement in the level of competences both in formal and in non-formal education. Therefore, we developed an expert system from a competence model, which was originally intended for lifelong learning of employees in the factories of the future. The expert system has been extended for an application at the university level. In this contribution we present an extension of the competence model for monitoring the sustainability-related competences at university level education, both for students and for professors. The university level has been selected because it provides the best results in the absolute level of competence improvement as the incoming students already exhibit a high level of the observed competences. These competences were acquired both from their previous formal education as well as from their other activities, such as the participation at social media and in sustainability promoting organisations. First results of the extension of the competence model and recommendations for optimisation of learning activities to achive the largest gain in sustainability-related competences will be presented.

## SDEWES2021.1001

# The ESSence of Plasma for Future Energy Storage Materials

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## Abstract

As the demands for advanced energy materials increase to meet consumer requirements, designing advanced materials at low cost is the future step towards developing next-generation energy devices. Various energy storage devices have been developed, such as lithium-ion batteries, potassium-ion batteries, lithium-metal batteries, lithium-sulphur batteries, multivalent metal ion batteries and electrochemical supercapacitors. Nevertheless, the performances of all these devices have to enhance and updated for obtaining the highest electrochemical performance for consumer applications. As the applied electrode materials highly influence the performance of energy storage devices, it is crucial to design high-performing electrode materials to improve the performance of energy storage and conversion devices. Several types of electrodes, including intercalation-type, conversion-type or alloy-type, have already been used for energy storage applications. However, all these electrodes suffer problems with delivering high capacity, rate capability, or electrochemical stability. An all-in-one packaged electrode has to be designed at a low cost to address these issues to improve the performance of the device. The most promising and widely accepted way to improve the electrochemical properties of electrode materials is their tailoring at the nanoscale. One of the potential techniques to tailor electrode structures at the nanoscale is plasma-enabled techniques. Plasma assembles the nanostructures from gaseous into solid form on a substrate material. Considering this process, direct growth of electrode material on the current collector, fast and easy dry processing, zero-waste production, cost-effective and environmental-friendly nature are the main advantages of plasma-enabled techniques over the existing wet-chemical techniques. The present paper suggests an advanced electrode fabricate technique using plasma-enabled approaches, which can design and tailor materials at nanoscale with high purity and controllability. In addition, the paper introduces the capability of plasma techniques for tuning the electrode materials specifically needed different energy storage applications such as electrode materials with tuneable interlayer distance, redox-active centres, and hybrid morphologies for the future electrochemical energy storage devices.

## SDEWES2021.1053

# Do the Technological Monopoles Endanger Democracy?

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## Abstract

Humanity is driven by exploring unexplored worlds and is about to move its borders in the next century and move to other environments like underwater or planets like Mars. This exploration is fueled by our conscious ambition to make a significant leap forward to areas beyond our reach today and futuristic visions of the future mostly established in 1975. Not only that living in extreme environments open a number of technological and scientific challenges, but also new social aspects. However, the vision of the future is today mostly dominated and presented by technological monopolies like Amazon, Google, SpaceX, Origin Blue, etc. For this reason, the foreseen future is almost invented by technological monopolies owned by technological monopolies billionaires. By accepting this future sold, there is no need for others imagination. On top of this, taking this vision of privatized future endangers our own political system and democracy. Uptalking these futuristic visions is ultimately about ownership and dictating policy. If technological monopolies control the vision of the future, then they will control the future itself. This will gradually lead to control of the infrastructure they are building and the determination of new social functions. The tech monopolies have already built massive infrastructures, which today already account for more than half of certain sectors. This is how they control large parts of the world economy and the public sphere. The privatized future taken directly from utopian proposals of the past had to be discussed in order not to leave world democracy at threat and solely in the deciding hands of technological monopolies.

## Special session: Future energy systems technologies and models fostering Green Deal targets across buildings, electricity and mobility sectors

EU Green Deal promotes an increasing commitment for the transition from fossil-based energy systems to the renewable-based ones. The application in each context calls for tailored technologies, modelling techniques and planning strategies especially with the intent of involving built environment, power grid and transportation. Changes are also pushed into the market, requiring modified or even new actors and subsequent role. Hence, this Special Session will mainly focus on:

Technologies for Future energy systems;

- Modelling and planning at different scales, technologies and connection, e.g. from Grid-connected National Wind farm to off-Grid solar thermal for rural areas' buildings;
- Smart Energy System approach coupling electricity, heating/cooling and transport sectors;
- Innovative systems layouts such as poly-generation;
- Blue energy technologies: offshore wind, floating PV, wave and tidal current converters;
- Energy analytics and techno-economic optimization for selecting the best configuration;
- Storage technologies for increasing variable RES penetration;
- Building energy systems for Sustainable Cities;

Energy policies and strategies for achieving decarbonization targets at different scales.

### Session organizers:

**Prof. Benedetto Nastasi**, Sapienza University of Rome, Rome, Italy

**Prof. Davide Astiaso Garcia**, Sapienza University of Rome, Rome, Italy

**Mr. Daniele Groppi**, Sapienza University of Rome, Rome, Italy

*Benedetto Nastasi* - Benedetto Nastasi is Assistant Professor & Senior Energy Planner at Department of Planning, Design and Technology of Architecture, Sapienza University of Rome and Guest Researcher at Department of Architectural Engineering & Technology, TU Delft University of Technology. He got the PhD title with Honors with a dissertation in Energy Systems Planning and Design. The core of his thesis was published in Energy (Elsevier) and became one of the Most Cited Paper 2016. He was rewarded for the Best Poster at 2nd SEE SDEWES Conference 2016 and Best Senior Researcher at SES4DH Conference 2018. Previous affiliations include TU/e Eindhoven University of Technology, The Netherlands, International Solar Energy Society and Guglielmo Marconi University, Italy. He is Editor at Renewable Energy (Elsevier) and Energies (MDPI), Associate Editor of Sustainable Buildings (EDP Sciences), Guest Editor at Frontiers in Energy Research, International Journal of Hydrogen Energy and Energies. His work is related to Power-to-What solutions for energy systems design with a specific focus on Built Environment. He authored more than 50 publications (H Index 26 in Scopus database).

*Davide Astiaso Garcia* - Davide Astiaso Garcia is Assistant Professor of Thermal Sciences, Energy Technology and Building Physics at Sapienza University of Rome and General Secretary at Italian Wind Energy Association (ANEV). He is currently involved as coordinator of research team in two H2020 projects (GIFT - Geographical Islands FlexibiliTy - and ODYSSEA - Operating a network of integrated observatory systems in the Mediterranean Sea), one EEA project ( YENESIS - Youth Employment Network for Energy Sustainability in ISlands) – and one Erasums+ project (SIMULWIND - Maintenance simulator for the sustainability of European wind farms). He is contracted by the European Commission Research Executive Agency (REA) as expert for the evaluation of the project proposal under H2020 calls “FET OPEN (Future Emerging Technologies)”. He is Editor at Journal of Energy Research and Reviews and Guest Editor at Applied Science and Frontiers in Energy Research. He is author of more than 70 scientific publications mainly concerning energy themes (H index 20 in Scopus database).

*Daniele Groppi* - Daniele Groppi is Ph.D. Candidate of Energy and Environment in the Department of Astronautical, Electrical and Energy Engineering at Sapienza University of Rome. Daniele Groppi graduated with Honors as Energy Engineering M.Sc with a thesis regarding the feasibility analysis of an active District Heating Network with a case study in Bologna, Italy. His research fields are energy planning, energy systems modelling and design. Within his Ph.D. project, he is studying Smart Energy Systems in order to increase the RES penetration of energy island systems by fully exploiting the synergies offered by sector coupling and demand side management solutions aiming at an optimal energy use. He has been collaborating in several EU funded projects such as the PRISMI project (https://prismi.interreg-med.eu/) where he dealt with the energy plan of Favignana island, Italy; and the GIFT project (https://www.gift-h2020.eu/) in which he will analyse the flexibility potential of the local energy community in the island of Procida, Italy, and will then investigate on the introduction of a capacity market on the island. Results of his work have been published in 20 papers in Scopus database.

Invited submissions

## SDEWES2021.0362

# Big Data Observation Analysis of Marine Service to Public End-Users Needs

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## Abstract

Abstract-

In recent times, various Earth Observation Networks (EONs) have been designed, developed and launched by in-situ, on-site and off-site collected data from fixed and moving marine sensors and Remote Sensing (RS) satellites data. Examples of such EONs include Copernicus, GOOS and EMODNet. In the context of data post-processing, these networks generate operational numerical models based on the data they have collected using different tools and measurements sensors, which is stored in a large database. This data used to process and absorb the models that are inside the database with medium- and high-resolution numerical models for global coverage using a combination of locally derived and RS data, in order to provide high quality in specific fields. This information can greatly help a wide range of public and private end-users to gain a better understanding of the medium- and high-resolution numerical models for global coverage. It can also inform decision making by universities, companies and governments in terms of (for example) the development of renewable technologies, sustainable environmental development, aquaculture, commercial and tourist shipping, oil and gas and related pollutants, tourist activities, and maritime surveillance in large and small areas. In this context, such EONs core services operational numerical data can also be seen as the result of the growing demand of developing countries and the European Union (EU) for sustainability, as well as for the creation of new job opportunities in various maritime sectors and also serves to create new job opportunities in various maritime sectors. In this case, the following five steps have been used to develop a better understanding of the essential data structure that is commensurate with the efficiency of the marine end-user's service: 1) steps and challenges of collecting data, 2) stakeholder engagement to identify, detect and assess the specific needs of end-users, 3) design, development and launching of the products offered to meet the specific needs of users, 4) achieving sustainable development in the continuous provision of these products to end-users, 5) identifying future needs and challenges related to providing these products to end-users.

## SDEWES2021.0402

# Single-Tank Storage Versus Multi-Tank Cascade System in Hydrogen Refueling Stations for Fuel Cell Buses

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## Abstract

Many countries in Europe are investing in fuel cell bus technology with the expected mobilization of more than 1 200 buses across Europe in the next years. The scaling-up will make indispensable a more effective design and management of hydrogen refueling stations, in order to improve the refueling phase, in terms of refueling time, dispensed quantity while containing the investment & operation costs. In the present study a previously developed dynamic lumped model of a hydrogen refueling process, developed in MATLAB, has been used to analyze tank-to-tank fuel cell buses (30-40 $kg_{H2}$ at 350 bar) refueling operations comparing a single-tank storage with a multi-tank cascade system. In fact, a cascading refueling approach from multiple storage tanks at different pressure levels provides the opportunity of a more optimized management of the station storage, reducing the pressure differential between the refueling and refueled tanks throughout the whole refueling process, thus reducing compression energy. The cascade refueling is evaluated in terms of refueling time, gas heating, compression energy consumption and hydrogen utilization considering the real case of the new-built Aalborg hydrogen refueling station.

## SDEWES2021.0407

# Heat Storage in Buildings to Foster Green Deal Targets. A Top-Down Energy Modelling of Heating Electrification Pathways

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## Abstract

Heating electrification through renewable energies is one of the most promising pathways towards a low carbon heating sector. However, this is a difficult task due to the intrinsic variability of renewable energy supply and the considerable increase in electricity demand. This research evaluates the heat storage potential in buildings during the next decade to foster heating electrification and decarbonisation. First, the implication of the heating sector in the European environmental targets is evaluated using the data provided by EUROSTAT, the statistical office of the European Union. Second, the potential impact of heat storage for heating electrification is evaluated using Spain as a case study. A statistical analysis using machine learning and top-down energy modelling is carried out to evaluate the impact of different load aggregation scenarios through smart demand response. The results show that 75% of the non-renewable heating sector represents 25% of the required effort to achieve the European 2030 targets. Moreover, the top-down energy modelling demonstrates that heating electrification through the combination of hourly and daily demand response strategies can reduce carbon emissions by 10-15% compared to an inefficient and uncoordinated load aggregation scenario, eliminating additional power demand. The results highlight the implications of heat storage in buildings to promote European targets, which should be considered in future building regulations to help transform the power system, accommodating more renewable energy while supporting heating decarbonisation.

## SDEWES2021.0419

# Imbalanced Federated Learning Model for Blade Icing Detection of Wind Turbines

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## Abstract

Wind farms are often located at high latitudes, which entails a high risk of icing. Traditional anti-icing methods for wind turbine blades mainly rely on manual observation, the use of special materials or external sensors/tools, but these methods are limited by human experience, additional costs and the understanding of wind turbine mechanical structure. Model-based approaches are highly dependent on prior knowledge and are prone to misinterpretation. Data-driven approaches can deliver promising solutions but require large datasets for training and might face significant challenges of privacy protection. To address these issues, this paper proposes a federated learning (FL) based model for blade icing detection. The proposed approach first creates a prototype-based model for each client, then aggregates all client models into a global weighted model. The prototype-based client modeling approach overcomes the imbalance problem of training data, while the FL-based approach preserves the privacy of using sensitive data. This paper evaluates the proposed model comprehensively by comparing with five baselines using real-world datasets, and the results show that the proposed model exhibits better performance. The results validate the effectiveness of the proposed prototype-based client modeling and weighted global modeling methods. In addition, the experiment demonstrates the superior performance of the proposed model for online detection with an accuracy of almost 100%.

## SDEWES2021.0421

# A Novel Deep Neural Network for Non-Intrusive Load Monitoring

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## Abstract

Non-intrusive load monitoring (NILM) can realize the monitoring of the user's power consumption information, which is conducive to the grid to formulate the operation plan; and for the user, the power consumption behavior can be adjusted according to the specific conditions of the electrical energy consumption of each electrical appliance. The current analysis method mainly relies on manually extracting the characteristics of the load, using traditional combination optimization (CO) and factorial hidden Markov model (FHMM) method to achieve disaggregation. With the development of artificial intelligence (AI) technology, machine learning and deep learning have also been gradually applied to NILM. This work introduces a novel deep learning model for NILM. This proposed model is based on convolutional neural network which can learn useful features from the low-sampling dataset of appliances. This work also presents a temporal pooling method, which can let the learned features to different time scales, thereby increasing the receiving field. In addition, we also present a novel attention module to enhance the feature learning of CNN. The experiment results have shown that the proposed model can achieve significant improvement than the state-of-the-art methods. The experiments also verify that the proposed model can obtain good generalization characteristics, allowing the well-trained neural network to be applied to household.

## SDEWES2021.0466

# Design and Implementation of a New Wind Speed and Power Forecasting Model Based on Hybrid Neural Network and Wpd Pre-Processing

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## Abstract

Wind speed is one of the most vital, imperative meteorological parameters, thus the prediction of which is of fundamental importance in the studies related to energy management, building construction, damages caused by strong winds, aquatic needs of power plants, the prevalence and spread of diseases, snowmelt, and air pollution. Due to the discrete and non-linear structure of wind speed, wind speed forecasting at regular intervals is a crucial problem. In this regard, a wide variety of prediction methods have been applied. So far many activities have been done in order to make optimal use of renewable energy sources such as wind, which have led to the present diverse types of wind speed and strength measuring methods in the various geographical locations. In this paper, a novel forecasting model based on hybrid neural networks (HNN) and Wavelet Packet Decomposition (WPD) processor has been proposed to predict wind speed. Considering this scenario, the accuracy of the proposed method is compared with other wind speed prediction methods to ensure performance improvement.

## SDEWES2021.0507

# Hybrid Method for the Aquaculture Energy Consumption Short Term Forecasting: Case Study of Norwegian Fish Farms

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## Abstract

The contribution of aquaculture production to global CO2 emissions has significantly increased in between 2000 and 2018. Norway is the leading producer of Atlantic salmon. Approximately 50% of the Norwegian fish farms use diesel generators to produce electricity needed. Therefore, it is important to find renewable energy resource for fish farms' operation. As hydropower is the dominate part of Norwegian grid, connecting the grid is one of potential renewable solutions to fish farms. However, most grid which is close to the fish farms has the limit of capacity. Flexibility solution is introduced to supply the extra capacity to fish farms. As such, understanding the electricity consumption behavior will be the key for the success of flexibility. However, the electricity consumption of fish farms is complex, impacted by the life cycle of fish, climate, fish farm operation strategy. To have better understanding of electricity consumption at fish farms, the hybrid model for 1-48 hours forecasting model is introduced. The hybrid method combines the fish growing and operation analysis and smart meter data of fish farms. The 12 fish farms in Polar area are used for case study. The smart meter data, operational informational, climate information of those fish farms from 2014 to 2018 are collected. The study also compares the results with traditional data driven method. The results shows that the hybrid method will increase the accuracy from 80% to 90%.

## SDEWES2021.0581

# Data-Driven Building Energy Modelling – an Analysis of the Potential for Generalization

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## Abstract

However, the debate around their effectiveness and possibility of generalization is open. In fact, the possibility to generalize findings of models that are in many cases developed for single case studies (or a limited amount of case studies) has to be critically questioned, in light of the state-of-the-art of building energy modelling. However, the debate on their effectiveness and the possibility of generalisation is open. In fact, the possibility of generalising the findings of models that have in many cases been developed for single case studies (or a limited number of case studies) must be critically questioned in the light of the state-of-the-art building of energy modelling knowledge. In this paper, we illustrate this problem through a passive case study building, which is analysed with respect to recent research findings. Valuable insights that can be found using data-driven methods are reported, highlighting limitations and constraints, as well as the potential for future research

## SDEWES2021.0619

# Technical, Economic and Environmental Issues Related to Electrolysers Capacity Targets According to the Italian Hydrogen Strategy: a Critical Analysis

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## Abstract

The recent European Hydrogen Strategy set the ambitious goal of installing a total electrolysers capacity equal to 40 GW for renewable hydrogen production, by 2030. Member States responded by developing their own strategies and setting national targets. Consequently, it will cause a sudden expansion of the electrolysers industry throughout Europe and, simultaneously, the unit cost of electrolyser production will steeply decrease. To investigate the CAPEX variation in the European market, 3 different scenarios of Learning Curve have been modelled and analysed. Applying them to 3 potential electrolysers installation pathways in Europe, 9 scenarios of annual CAPEX variation, until 2030, have been developed. In the framework of Italian Hydrogen Strategy, which set the target of 5 GW of electrolysers by 2030, 3 potential patterns for installing such a capacity have been considered. As a consequence, different 27 investment scenarios have been simulated and discussed. The LCOH (Levelized Cost of Hydrogen) trend until 2030 has been assessed and compared with the grey hydrogen (i.e. from Steam Reforming) and blue hydrogen (i.e. from Steam Reforming with Carbon Capture and Storage) ones. Therefore, a price difference can be registered throughout the decade. Assuming 3500 equivalent hours for operation, along with an average electricity cost of 40 €/MWh, in 2030 the LCOH (related to hydrogen production only) ranges between 2.42 and 2.95 €/kgH2 for water electrolysis, versus 1.61 €/kgH2 for grey hydrogen and 1.85 €/kgH2 for blue hydrogen. Additionally, a ten-year incentive scheme has been proposed. To do so, an yearly variable feed-in-tariff mechanism, able to balance the cost difference between green and grey hydrogen, has been implemented. Under the hypothesis of a fully-blended use of hydrogen in the gas grid, a potential CO2 reduction between 6 and 10 Mtons, over the time span, can be accomplished. The CO2 Avoidance Cost (CAC) is closely correlated to the gas price. For the injection into the national gas transmission network, a CAC in the range of 320-400 €/ton has been achieved. Moreover, referring to small-medium industrial hubs, as reference consumers, the CAC is reduced to 100-190 €/ton. This enhances the establishment of the so-called Hydrogen Valleys, where both the Hydrogen production and consumption coexist. In the end, a sensitivity analysis, by changing the equivalent hours, the electricity price and the gas price, has been carried out.

## SDEWES2021.0639

# Zedistrict in a Portual Area of the Mediterraneum

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## Abstract

The present research deals with an infrastructure digitisation policy aimed at optimising maintenance processes and energy efficiency, in order to transform portual areas in ZEDistrict. The Lazio Region started the process in 2020 for all its facilities (ports of anzio, Formia Terracine and Ventotene) . The port of Anzio was developed as a pilot project since it is a particularly representative sample for the Mediterranean reality due to its geomorphological conformation. In fact, the study was aimed not only at developing energy-saving procedures and strategies, but also at integrating production systems from RES for sustainable mobility. In particular micro-wind - vertical axis turbines with a nominal power of 3.0 Kw has been designed in a residual portion of the port, together with a Solar Asphalt system in all the pedestrian and driveway areas. In the article, these strategies are described in detail and an energy analysis is carried out, starting from the current state and demonstrating the potential energy self-sufficiency of the infrastructure. It also highlights the potential of the analysis carried out by means of a digital twin of the area which, combining the potential of different software such as Revit and GIS, compares future scenarios even at different scales in order to maximise the benefits of energy efficiency measures.

## SDEWES2021.0694

# Comparing Optimal Hydrogen Solutions in a Renewable Energy Community in Islands

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## Abstract

Applications of solar hydrogen are gaining more and more attention as many studies show competition with traditional electric batteries. Remote areas or weakly linked islands are an important background for the application of such a comparison, which is particularly necessary for seasonal storage due to the current sharp change in output due to solar radiation and tourism consumption. Energy and economic analysis are the instruments needed to determine the profitability of the solutions, as well as the dimensioning and functioning of the energy system. Due to the availability of reported hourly load and output datasets, a building complex of 5 buildings equipped with a total of 100 kWp of PV is being investigated here. Over the course of the year, storage facilities ranging from 500 to 2000 kWh were simulated for both hydrogen and electric battery options from an ideal dispatch perspective. In addition, the investment and operating cost value of 2020, 2030 and 2040 was inserted as an input to search for improvements to the increased Technology Readiness Level of the storage medium listed. Analysis is carried out on the basis of a Mixed Integer Linear Programming solver via the ©E-OPT platform. Finally, for both hydrogen and battery solutions, the annual dispatch is compared to shifts in economic input accounting for the incentive schemes available for setting up a Renewable Energy Community.

## SDEWES2021.0699

# Convolutional Long Short-Term Memory Neural Model for Short-Term Wind Speed Forecasting: a Case Study of North Aegean Islands

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## Abstract

Wind speed presents diverse and complex seasonal and stochastic characteristics, that addresses it a challenging process for the wind speed forecasting models. However, in order to integrate produced wind energy in large-scale grid power, an accurate prediction of short-term and long-term wind speed is needed.

This study proposes a Convolutional Neural Network (CNN) combined with a Bi-directional Long Short-Term Memory (Bi-LSTM) recurrent network to forecast the wind speed.

CCN is used to evoke more effective features from the stochastic sub-signals of wind speed.

The proposed forecasting model is trained on data collected from a Greek island located in the North Aegean Sea.

The forecasting range is one hour ahead (short-term) in this study.

Our experimental outcomes confirm that:

(1) the proposed hybrid forecasting model outperforms the other four models considerably in terms of precision and stability; (2) using Convolutional Neural Network (CNN) could be developed the performance of the proposed model;

(3) Bi-LSTM used in the proposed model performs better than the LSTM model in forecasting wind speed.

## SDEWES2021.0737

# Analyzing Solutions for Energy Independency of Small Islands - the Case Study of the Favignana Island

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## Abstract

Energy costs and carbon dioxide emissions are common challenges in small islands all over the world. The European Union identified islands as ideal location to implement innovative solutions and boost the energy transition towards an independent, sustainable, secure and low carbon energy system.

In this framework, energy planning and energy modelling are indispensable tools to optimally design the future energy system selecting between a broad range of technologies for power generation as well as the optimal flexibility providers. Energy modelling represents one of the most used solutions for energy planning; indeed, energy models enable to simulate the real energy system functioning as well as its operation costs. Particularly, optimization models have gained an ever-growing attention and are being used incrementally more in this field. In this research, a Marginal Abatement Cost (MAC) curve method is applied to optimally select the energy mix of the energy system of the island of Favignana, Italy. Particularly, the EPLANoptMAC software will be used. It is based on the widely used EnergyPLAN software and the already tested EPLANopt model. Indeed, EPLANoptMAC represents an addition of EPLANopt that has been improved to produce model-based MAC curves.

The objective function will be the carbon avoidance cost so as to consider both economic and environmental aspects in a single indicator. The technologies that will be taken into consideration are Photovoltaic, energy storage and demand response strategies including the maritime transport and heating sectors. The decarbonisation of the maritime transport sector is of utmost importance since it contributes to almost 50% of the energy consumption and greenhouse gas emissions of the whole island. This is considered a novelty since very few researches dealing with energy modelling and/or planning at island level optimise maritime transport while some more analyse it by means of simulation.

## SDEWES2021.0739

# Techno-Economic Analysis of Renewable Energy System Flexibility: a Case Study for Sicily Island

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## Abstract

Geographical Islands have been considered a challenge environment to test renewable energy integration strategies as well as cutting-edge technologies due to the alternation between actual grid-connected and island mode. This is due to the weak connection to the mainland and, subsequently, the Power Grid as well as the strong changes in seasonal energy demand leading to congestion and stability issues. Energy system flexibility is foreseen as a strategy to both integrate higher renewable share and reduce negative events to the Power Grid. The stability of this latter is ensured in current energy systems by fossil-fuel power generation while the storage options for supporting high RES share remain still just an option in many Countries. This study provides a set of Key Performance Indicators (KPI) to allow a higher renewable share in the electricity system in isolated or weak-connected contexts. This research uses HOMER software to simulate economic and technical use of photovoltaic panels/wind turbine/fuel cell/electrolyzer and hydrogen tank to meet the demand of 2 MW energy. The results of this simulation show that in order to meet the needs of 2 MW of the region, capital cost of 4.85 million Euros should be spent, which 2.59 million Euros can be returned in the estimated 25-year life of the project.

## SDEWES2021.0858

# A Review on Reversible Solid Oxide Cells Applications to the Building Sector

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## Abstract

Hydrogen is getting more and more attention as energy vectors to efficiently manage intermittent Renewable Energy Sources (RES) in systems with high RES share. Most of the studied systems are based on the binomial installation of an EleCtrolyzer (EC) and a Fuel Cell (FC) while this transition calls for mature, low cost, low space solutions bringing the light on unitized items such as the reversible Solid Oxide Cell (rSOC). This appliance includes in a single device its EC part called Solid Oxide EleCtrolyzer (SOEC) and its FC one called Solid Oxide Fuel Cell (SOFC). The scope of the review is to identify and classify the rSOC applications in the building sector as an effective operational solution and to show how much this technology is near to its commercial deployment. Research & Development projects were analyzed in this paper for a comprehensive overview.

## Special session: Harnessing the resource potential of our seas in a sustainable manner

The sea represents a huge resource for renewable energy (Blue Energy - BE). BE is the energy which can be harnessed from the ocean or the marine wind and it is comprised of five main types according to the origin of the extracted power, namely marine (offshore) wind, surface waves, tides/currents, and thermal and salinity gradients. Although the growth of offshore renewable energy technologies has so far been relatively slow compared to those onshore, it is anticipated that in the future BE will substantially contribute to the energy demands of coastal and insular areas, at the same time protecting and conserving the marine environment.

The Blue Growth Strategy proposed by the Commission in 2014 emphasized that harnessing the economic potential of BE in a sustainable manner represents a key policy area for the EU, which requires the involvement of the widest possible range of stakeholders in order to optimize capacity building and to achieve the necessary critical mass. The BE sector was, in fact, indicated as one of five developing areas in the 'blue economy' that could drive the creation high-quality jobs and pave the way for a new breed of science-trained professionals, enhancing eco-efficient value creation all along the value and supply chain. Moreover, exploiting this indigenous resource would help reduce the EU dependence on fossil fuels for electricity generation, and enhance energy security. In particular, islands and remote coastal regions can especially benefit from BE development, as it would provide a viable alternative to expensive and heavily polluting <em>fossil</em> fuelled plants, and contribute to their energy self-sufficiency.

The exploitation of Blue Energy clearly opens new frontiers in the maritime sector, by creating synergies with long established traditional activities, yet opening the door to knowledge-driven <em>innovation</em>. It offers the opportunity to pool costs and boost several connected economic sectors. Some examples of synergic activities that are welcome in this Special Session include: BE Studies and technology design; Estimation of BE exploitable resources; Marine environment assessments for BE exploitation; Evaluation of synergies with aquaculture and/or fisheries; BE exploitation in the naval sector; Energy production from Algae; Design and management of multipurpose offshore platforms; Socio-economic assessment of BE exploitation.

### Session organizers:

**Dr. Hrvoje Mikulčić**, University of Zagreb, Zagreb, Croatia

*Hrvoje Mikulčić* - HRVOJE MIKULČIĆ defended his PhD thesis in 2015 at the Department of Power Engineering, Energy and Environment, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb. His main research area includes: Numerical modelling of fluid flow; Solid fuel combustion; Endothermic calcination reaction; Pollutant formation, Greenhouse gasses emissions analysis and accounting; Energy intensive industry; Energy system analysis; Renewable energy; Multiphase flows; Waste-to-Energy, Carbon capture and utilization; Pollution reduction; Green ammonia. From 2009 till 2018 he worked on the research project "Numerical modelling of multiphase flow and combustion processes" financed by the Austrian Institute for internal combustion engines AVL List GmbH. He has also been working on the national scientific project: Smart energy storage for sustainable development of energy systems, financed by the Ministry of Science, Education and Sport of the Republic of Croatia. From 2016 till 2019 he was a project manager of a European INTERREG MED project PELAGOS - Promoting innovative networks and clusters for marine renewable energy synergies in Mediterranean coasts and islands. From 2019 he is a project manager of a European INTERREG MED project BLUE DEAL - Blue Energy Deployment Alliance, responsible for the Croatian part of the project. He is an author of 72 scientific papers, in scientific journals (SCI). His current Scopus h-index is 25. He is the Associate Editor of the Journal of Cleaner Production (IF2019= 7.246). From 2014 he serves as a SDEWES Special Issue Guest Editor in the Journal of Cleaner Production (IF2019= 7.246), in the Journal of Environmental Management (IF2019= 5.647), in Optimization and Engineering (IF2019= 1.829), and from 2020 in the international journal Fuel (IF2019= 5.578).

Invited submissions

## SDEWES2021.0002

# Analysis of Offshore Wind Power Generation in the Brazilian Electricity System

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## Abstract

In energy planning, renewable sources stand out due to their contribution to avoid greenhouse gases emission and energy security (matrix diversification). Brazil has continental dimensions and a coastline rich in natural resources, such as oil and natural gas. There are many other opportunities considering, for example, the great offshore wind power potential associated with the country's experience with onshore wind resources use and offshore structure of oil exploration. The objective is to analyze offshore wind power feasibility in the Brazilian electrical system, considering environmental issues, synergy with the oil industry, costs, and complementarity with other energy sources, allowing to establish the most appropriate locations for wind farms deployment. The methodology is based on an optimization model that minimizes the production mix costs considering the local time series of renewable energy subject to constraints. The complementarity between offshore wind and other power production sources was investigated through Pearson's correlation coefficient. Currently, there are no offshore wind farms in the Brazilian power sector, but we built scenarios to analyze the conditions offshore wind power could be competitive, considering the complementarity with other energy sources. The share of each source in the Brazilian power system was analyzed and with the offshore wind expansion, the participation of thermoelectric generation of the matrix is shifted. Wind offshore and hydro complementarity replaces the thermoelectric. Results indicate that coastal areas in the Northeast and Southeast have more favorable points for the deployment of offshore wind farms. There is a greater complementarity between offshore wind generation in the Northeast and Southeast and hydropower in the Southeast/Midwest, Northeast, and North regions. In addition, there is synergy with the oil and gas industry in those two regions and the Southeast is the nearest region with the highest energy consumption. With those results, it is possible to minimize decision-makers strategies uncertainties in investment allocation. Brazil's offshore winds can diversify the electricity matrix, stabilize water fluctuations, and reduce thermal plants use that increases the cost of production and the emission of polluting gases.

## SDEWES2021.0013

# Assessment of the Wind Power Dynamics in the North Sea Under Climate Change Conditions

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## Abstract

The objective of the present work is to analyse the expected dynamics of the wind power in the North Sea until the end of the twenty-first century. From this perspective, the proposed study is focused on the assessment of the average and extreme conditions, considering two future time windows. These are, near future represented by the 40-year time interval 2021-2060 and distant future represented by the time interval 2061-2100. The wind data provided by a Regional Climate Model (RCM) is processed and analysed in this work considering the Representative Concentration Pathway (RCP) scenarios 4.5 and 8.5 (RCP4.5 and RCP8.5). The first, denoted as the realistic scenario, considers an increase of the greenhouse gas emissions until 2040 and a stagnation and decline afterwards, while the second, denoted as the pessimistic scenario, assumes that this increase will continue along the entire 21st century and afterword. Furthermore, an analysis of the recent past wind data for the 40-year period 1980-2019 is also carried out. In this way a more comprehensive image of the wind power dynamics for both the near and distant future in the North Sea is provided. The results indicate that significant enhancements are expected in the North Sea, both in terms of mean wind power density, but also as regards the maximum wind speeds. Finally, some comparisons with the expected dynamics of some other similar marine environments, as the Baltic, Mediterranean and Black seas are also performed.

## SDEWES2021.0014

# The Near Future Expected Wave Power in the Coastal Environment of the Iberian Peninsula

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## Abstract

The main target of the proposed work is to assess the expected wave energy dynamics in the coastal environment of the Iberian Peninsula. This study is motivated by the fact that the Iberian nearshore is considered among the most promising European coastal environments for wave energy extraction with experimental wave projects already operating there since many years. The near future period considered for this analysis is the 20-year time interval 2026-2045 under the Representative Concentration Pathway scenario 4.5 (RCP4.5). In parallel, in order to have a coherent degree of comparison, the results are compared with those corresponding to the recent past 20-year time interval 2001-2020. A wave modelling system based on the third-generation spectral phase averaged model SWAN (acronym from Simulating WAves Nearshore) was implemented for the entire North Atlantic basin and focused on the Iberian nearshore. Furthermore, calibrations and extensive validations of this wave prediction system have been performed. Thus, system reliability was evaluated both against buoy and satellite data and the results were found as having good accuracy. The wave energy data corresponding to the near future (2026-2045) are compared with those from the other 20-year period from the recent past (2001-2020). In this way, a comprehensive picture of the expected wave power dynamics in the coastal environment of the Iberian Peninsula is provided. The results show that there are no significant differences between the two periods considered, especially in the transition seasons (spring and autumn), both in terms of maximum values and also as regards the general patterns of the wave power fields. However, in the near future, a decrease of the resources is expected near to the coast in the summer season, compared to the values simulated for the recent past (from 12 kW/m to 9 kW/m). A contrary tendency corresponds to the winter season when for the near future we find a maximum value higher by about 14 kW/m than in the recent past.

## SDEWES2021.0231

# Review of the Potentials for Implementation of Floating Solar Panels on Lakes and Water Reservoirs

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## Abstract

Many places are dealing with problem of water scarcity, especially in the summer months. This occurs mostly in the dry areas with hot climates that are exposed to intensive solar insolation which are the main driver for the evaporation of water. Some companies that are in charge of water service, that operate open water reservoirs developed solution to cover the water with floating balls to limit the solar insolation and to mitigate the evaporation of water. Another good approach is using the floating solar panels for the same cause, that will provide additional electric energy source. It can enhance the productivity of hydro power plants with reservoirs. Additional benefit of solution is amount of the available water surfaces for placing the solar panels, instead of potentially useful areas for other purposes (agriculture, buildings...). This paper reviews the current development of the technology, potentials and best practices. It shows that this technology is feasible and can compete with other power sources.

## SDEWES2021.0237

# Potentials for Implementation of Seawater Heat Pumps in Mediterranean

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## Abstract

Much of the Mediterranean is using fossil fuels like fuel oil for heating and relatively low efficiency air-air heat pumps for cooling. Reason for that are mild winters which lead to low demand for heat energy and lack of investments in district heating systems and larger investments for more efficient heating solutions. One of the greatest potentials for heating can be found in the sea. Blue energy sources have the potential to be the main resource for heating and cooling in Mediterranean. Currently this type of technology is not exploited enough, but many new projects are developing these solutions in last decades. This paper presents the potentials of seawater heat pumps, current best practices, and feasibility of the mentioned technology. All emissions from building sector in Cres-Lošinj Archipelago in Croatia can be reduced by 24,2% if all the heating systems in using fossil fuels are replaced by the seawater heat pumps.

## SDEWES2021.0248

# Boron Recovery from Desalination Seawater Brines by Selective Ion-Exchange Resins

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## Abstract

Seawater desalination is one of the most efficient technologies to reduce potable water scarcity. Nevertheless, seawater desalination plants (SWDP) still face environmental issues, one of which is the management of the brine produced during the desalination process. Nowadays, most of the brine is returned to the sea, which consumes energy and affects local ecosystems. However, this waste stream contains significant amounts of valuable metals that can be recovered following the circular economy schemes.

For this reason, this work aims to recover valuable metals and minerals from SWDP brines making desalination plants the third source of valuable raw materials in the European Union, as proposed in the H2020 Sea4value project. As part of this project, this study focuses on boron recovery from SWDP brines by ion-exchange resins. The commercial boron selective resins Purolite S108 and DIAION CRB03 have been tested on a batch scale, by sorption and desorption cycles, by studying the effect of different pH, initial boron concentrations and solid to liquid ratios. The best solid to liquid ratio tested was 0.003 g/mL. The boron selective resins tested efficiently removed more than 98.8% of initial boron in solution and recovered up to 95% of it after desorption using a synthetic boron solution with a concentration of 8 mg/L (expected concentration of boron in SWDP brines). Experimental data were fitted to the Langmuir isotherm ($R^2$ > 0.99) and results demonstrated that DIAION CRB03 reported the best sorption performance to recover boron from aqueous solution. Finally, the preliminary economic analysis reported a NPV of US$ 1.97 million and an IRR of 29% indicating the economic feasibility of recovering boron from SWDP brine.

## SDEWES2021.0333

# Analysis of Sea Waves Energy Resources in Baltic Sea and Technical Possibilities of Their Usage for Energy Generation in Poland

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## Abstract

The paper presents the technical, economic and environmental potential of the use of the Baltic Sea wave energy and the possibilities of converting this energy into electricity. The theoretical and technical potential of sea wave energy that could be used by Poland was estimated. The most advanced methods of converting wave energy into electricity were presented and the most promising technical solutions were selected for use in the Polish Exclusive Economic Zone and off the coast of the country. The selection of the most promising technologies - single and combined wave energy converters was based on reports on the operation of the first experimental wave power plants and wave converters operating in other waters. Obtaining energy from sea waves, in terms of technology and economics, is much more difficult than using solar or wind energy. However, along with the development of offshore wind farms and access to the infrastructure of the national power system in Poland and the need to give up traditional, emission-related energy sources, wave power plants may have a chance for development in the Polish energy sector. It is so far an untapped source of renewable energy with a high energy potential.

## SDEWES2021.0349

# Analysis of Thermal Efficiency of a Corrugated Double-Tube Heat Exchanger with Nanofluids

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## Abstract

This research experimentally investigated convective heat transfer and hydraulic resistance of smooth and corrugated double-tube heat exchangers at various flow rates from 60 L/h to 200 L/h. The inner tube with thread structure is designed with three pitches, i.e., 4 mm, 6 mm and 8 mm. Nanofluids are used as tube-side fluids to analyse the enhancement of heat transfer on the tube side. Results show the thread structure destroys the boundary layer and intensifies the shell side heat flux. The combined enhanced technology using thread structure on the shell side and nanofluids on the tube side contributes to an improvement in the overall heat transfer performance of the double-tube heat exchanger. The maximum increase in the comprehensive performance index is 59% for the case of 1.5 wt.% SiC-water nanofluid with a thread pitch of 4 mm at a flow rate of 200 L/h. Results reveal that the combined enhancement of using nanofluids and thread structure has great potential in improving the thermal performance of double tube heat exchangers.

## SDEWES2021.0545

# Machine Learning Based Long-Term Forecasting of Metocean Data for the Design of Marine Renewable Energy Systems

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## Abstract

The potential of Marine Renewable Energy (MRE) systems is evaluated based on past metocean data, assuming that the MRE resource is stationary. Yet, different studies in the literature have shown long-term resource variations and even the connection between ocean warming and wave power variations. Therefore, it is crucial to accurately characterize the future resource. To that end, this paper presents different data-driven forecasting approaches that combine the most relevant statistical features of the local resource in the Bay of Biscay, obtained via the SIMAR model ensemble. Support Vector Regression, Artificial Neural Networks and Random Forest Machine Learning (ML) models are designed and tested following the traditional exact value prediction approach. It has been observed that the long-term wave trend is irrelevant for the prediction task and that all three ML models can adequately represent the overall pattern of the dataset. However, given the challenging nature of predicting long-term wave heights, they also present difficulties with some wave height predictions. Accordingly, an alternative interval prediction approach is presented for three different wave height discretisation levels. Preliminary results obtained with the alternative predictive classification approach seem to have the same problem with the maximum peaks, although with more room for improvements.

## SDEWES2021.0547

# Blue Energy Potential Assessment and Their Impact on the Electricity System of the Republic of Croatia

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## Abstract

Nowadays, the whole world, including the European Union and Croatia, is turning to the use of renewable energy sources. From the Industrial Revolution, fossil-based technologies which contribute to CO2 emissions have been primarily used for energy production, and therefore many countries are working intensely on the energy transition. The Adriatic Sea shows the potential for future use of marine energy technologies. In this work, the potential of Blue Energy technologies in Croatia will be analysed. The observed technologies will include offshore wind farms, wave power plants and seawater heat pumps.

The introduction deals with an overview of global, European and Croatian renewable energy sources. The next section describes Blue Energy technologies with regard to available parameters and their current state, as well as future potential. After that, the input data which was put into program EnergyPLAN is shown. This data is required for obtaining results that are related to the consumption, production, CO2 emissions and others. Data for 2018 which served as the starting point was presented, and then the forecasts for 2030 and 2050 are processed. Also, the relevant parameters for BE technologies are analysed. It is important to assess the possibility of their exploitation along the Adriatic coast of Croatia because the obtained capacities are put in EnergyPLAN. An analysis of production and the impact on CO2 emissions from these technologies is shown. Finally, a techno-economic analysis is carried out according to available data and forecasts for 2030 and 2050.

## SDEWES2021.0562

# Predictability and Quality of the Tidal Energy Resource Adds Value for Renewable Energy Grids and Off-Grid Power Solutions

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## Abstract

Non-thermal renewable energy sources are variable; such as clouds and solar-PV, or gusts and wind energy. Temporal variability of renewable resource makes balancing the electricity supply to the demand difficult, with potentially costly storage needed in high penetration renewable-energy grids. For example, a single UK location showed gaps in power supply between 20 to 60 hours for the technical wind resource, whilst night length (thus impacts solar-PV) varies 7 to 16 hours in a year (ERA5 data at 53°N & 4°W in 2019). spatial distribution of renewable energy projects across the UK reduces power-intermittency to ~0.7 hours for aggregated wind power, but increases intermittency for solar-PV (29 hours largest gap in 2019) due to clouds and assumptions (data source: grid-watch). In high-penetration renewables remote island grids, large amounts of installed capacity (relative to demand) and costly systems needed to ensure supply meets demand. For example, in the Faroes Island ~50% of annual electricity demand (307GWh) is already met with renewable sources with an installed capacity twice that of peak demand and a 2.3MW battery.

Tidal energy research has often focused on reducing costs to compete with other renewable forms. It is hypothesised here that tidal electricity may be worth this additional perceived cost, due to it's predictability and quality, which requires less storage and installed capacity. The regular motion of the tide allows it's accurate prediction far into the future on broader-scales – providing cycle power four times a day (with a gap of 1-2 hours); however finer-scale variability (called turbulence) may effect the persistence and quality of tidal-stream turbine power. Fine-scale variability is a known problem in other renewable energy sources (e.g. Flicker) and requires control systems; however seawater is much denser and tidal turbine blades have more momentum (thus reducing variability).

Data from a grid-connected 1MW device and a normalised tidal-stream power curve (developed from published data on 14 devices) allowed tidal electricity supply to be explored. Variability of shore-side measured voltage was found within acceptable levels (~0.3% at 0.5 Hz), and sub 10-minute tidal power temporal variability (as a percentage of the mean signal) was observed to be low (standard deviation 10–12% of rated power). A statistical model (a "t-location" distribution) also successfully down-scale tidal predictions (30-minute temporal resolution) to sub-second power predictions using an idealised power curve (with 85% skill and 14% error in prediction of power at 0.5Hz). Therefore, the statistical downscaling method allowed accurate tidal power predictions at 2 second time-scales based only on a tidal prediction years in advance. Further, tidal-stream energy could be extremely useful in high-penetration renewables grids, or remote off-grid communities and industries, with this "added value of tidal power predictability" included.

## SDEWES2021.0716

# Assessment of the Potential of Forward Osmosis as Pretreatment of the Multi-Effect Distillation Process

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## Abstract

This paper presents a simulation tool to evaluate the performance of a multi-effect distillation unit (MED) for seawater desalination coupled with a forward osmosis (FO) based pretreatment system that reduces the concentration of divalent ions in the feedwater. This hybrid FO-MED scheme allows increasing the thermal efficiency of the MED plant by elevating the top brine temperature without the risk of scaling associated with these ions. A sensitivity analysis of the hybrid system has been carried out to assess the best boundary conditions that enhance process efficiency. This analysis includes calculating the Ryznar scale index that sets the limit of operation temperature since it predicts the possible scale formation in the tubes of the heat exchangers of the desalination unit. The analysis investigates the effect of recovery ratio, MED output brine salinity, intake seawater salinity and temperature, heating steam temperature and the number of effects on key design parameters of the MED unit such as the specific thermal energy consumption and specific heat transfer area. Results show that the use of FO pretreatment in a conventional MED plant of 8 effects and heating steam at 65 °C allows increasing the heating steam temperature up to 100 °C and the number of effects to 16 without increasing the risk of scaling. This results in a 50% reduction of the specific thermal energy consumption and 8.1% decrease of the specific heat transfer area with respect to the conventional MED plant.

## SDEWES2021.0771

# Blue Energy Spearheading the Energy Transition: the Case of Crete

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## Abstract

In the framework of the energy transition, in Europe now supported also by European green deal, energy systems are going to be transformed from fossil-fuel based, with the dispatchable generation, to variable renewable energy-based, with variable and non-dispatchable generation. This change is possible in case the abundant resource is available. Blue energy, and in particular offshore wind power, is yet to be employed in the amounts that could be relevant. In this research, offshore wind power is considered the main driver of the energy transition for the case of the island of Crete. The energy systems' development scenarios are modeled using an energy planning software EnergyPLAN, starting from a reference model developed for the year 2017. The model was validated using the data provided by EUROSTAT and IEA. The large intake of variable energy from offshore wind was shown to provide more energy than it is possible to integrate into the local system using only storage and demand response. For this reason, additional scenarios were modeled to investigate the production of electrofuels from excess electricity. Such transformations enabled system-wide decarbonisation.

## Special session: Integration of Smart Cities and Smart Industry for Circular Economy: Energy, Water and Waste to Secondary raw material for Sustainable Future

Based on the considerable success at several previous SDEWES conferences and due to the high demand, it has been decided to organise this session again in 2021, this time for the 16th SDEWES conference in Dubrovnik, Croatia. The focus of the session is in line with the most recent research developments. The topics within the interests of this special session are the integration of energy, water and waste to secondary resources towards Smart Cities, Smart Industry and Smart Agriculture which can be a powerful tool to boost the sustainability in civic, industrial, agriculture and other activities. Due to the immense importance of knowledge dissemination and transfer, presentations are also invited into the field of knowledge management and especially knowledge transfer. The research scope to be considered include smart cities, industrial processes and sites supply chain networks, municipalities and cities, regions and economies.

### 1) The main topics

- **The minimisation of energy resource use and reduction of greenhouse gas emissions**

Industry and regional economies require a considerable and continuous supply of energy delivered from natural resources – principally fossil fuels. The sectors of energy use are diverse – including industry, agriculture, transportation, residential and commercial activities. The growing human population and it's growing nutritional needs result in the continuous growth of energy demands, accompanied by equivalent pollution effects – including climatic, as well as health issues. It has become increasingly important to ensure the processing industries take advantage of recent developments in energy and resource efficiency and the use of non-traditional energy sources.

Although industry requires abundant supplies of energy to meet production targets, it is not the only sector of the world economy that is increasing its energy demands. The particular characteristics of these other sectors make optimising for energy efficiency and cost reduction more difficult than in traditional processing industries, such as oil refining, where continuous mass production concentrated in a few locations offers an obvious potential for large energy savings. In contrast, for example, agricultural production and food processing are distributed over large areas, and these activities are not continuous but structured in seasonal campaigns, limited to specific time periods, so the design of efficient energy systems to meet such demands is more problematic than in traditional, steady-state industries.

In recent years there has been increased interest in the development of renewable, non-carbon-based energy sources to counter the increasing threat of greenhouse gas emissions and subsequent climatic change. These sources are characterised by spatial distribution and variations as well as temporal variations with diverse dynamics. This imposes the logistics challenge of diminishing energy returns with increasing transportation distances. Additional dynamic effects arise from the often-significant fluctuations and in the prices of oil and gas, strengthening the interest in securing alternative resource supplies from renewables. There have been already impressive scientific results on designing combined energy systems that include both industrial and residential buildings toward the end of producing a symbiotic system.

- **Water efficiency, reuse, wastewater minimisation**

Another significant issue is water – both as raw material and effluent. Freshwater is widely used in various industries. It is also frequently used in the heating and cooling utility systems (e.g., steam production, cooling water) and as a mass separating agent for various mass transfer operations (e.g., washing, extraction). Strict requirements for product quality and associated safety issues in manufacturing contribute to large amounts of high-quality water being consumed by the industry. In addition, large amounts of aqueous waste streams are released from the industrial processes, often proportional to the freshwater intake. Stringent environmental regulations, coupled with a growing human population that seeks improved quality of life, have led to increased demand for quality water. These developments have increased the need for improved water management and wastewater minimisation. Adopting techniques to minimise water usage can effectively reduce both the demand for freshwater and the amount of effluents generated by the industry. In addition to this environmental benefit, efficient water management reduces the costs of acquiring freshwater and treating effluents.

- **Integration of residual and by-products as secondary resources for a circular economy**

The transformation needs of residual and by-products (e.g. municipal solid waste, agriculture waste, industrial non-hazardous waste, hazardous waste, e-waste even increasing with introducing the smartness, construction and demolition waste) increases with the urbanisation and population growth. It is a critical part in closing the loop to support the transition from a linear to a circular economy. The waste of a process could be a resource to another process. The utilisation of residual and by-products as resources scale down the demand for extraction of new resources and avert the impacts created along the processing chain. Integrated secondary resources management could minimise the waste generation which is a loss of resource, disposal cost and environmental cost.

Carbon capture and storage/ sequestration offer to bridge the gaps to the ideal circular economy, as mitigating alone are not sufficient. The feasibility and potential of various negative emissions technologies such as direct air capture, enhanced weathering, bioenergy with carbon capture and storage, and afforestation/deforestations are worth for research attention. This is especially the biochar, commonly viewed as a by-product of pyrolysis, which can be utilised as the energy source and soil carbon sequestration. However, the cyclical systems should have the characteristic that the environmental impacts of the circular economy are work toward sustainability.

Supply chain optimisation or management plays a significant role in utilising residual and by-products as secondary resources. Other than the cost incurs, and burdening footprints created along the transformation process, collection and transportation tend to lower the feasibility of the utilisation. The waste from the cities as well as the by-products of industry and agriculture activities have to be converted to secondary raw materials and utilised as close as possible at a resource. Supply chain optimisation could contribute to the sustainability of residual and by-products utilisation.

**2) Cross-cutting issues**

There are two crucial issues running through the mentioned topics. One is the quantification of environmental performance, and the other is knowledge management and transfer. The smart concept utilises information and communication (ICT) technologies to supply information for efficient management. ICT sector also involves in resources and energy consumption as well as waste generated, which are rising as the sector expands. Comprehensive data (real-time control, big data) will not alone lead to efficient management. It enables or facilitates improvement through data availability and transparency for optimisation. Proper planning and management as well as process integration play the primary role in achieving the smart concept, secure the utilities and resources supply, and towards low carbon emission transition. An appropriate quantification of environmental performance is vital to ensure the processes are towards sustainability and to prevent the shift of footprints.

- **Environmental performance**

The environmental performance of a process or activity can be assessed in various ways. The most prominent concepts used for this have been footprints – quantifying the impact of pollutant emissions; natural/ecological capital – measuring in a combined way the fresh resources and service capacities of a system (e.g. a region); eco-cost, eco-benefit and eco-profit – a scheme for quantification of the possible actions for improving the environmental performance of a process or activity. The emissions have to evaluated and impacts on a global basis, which gives rise to virtual footprints – accounting for these impacts from the consumer perspective as opposed to the goods producer perspective.

- **Knowledge management and transfer**

Another critical issue is knowledge management and transfer. The currently dominating societal system, or pattern, of knowledge management, is to document the research and demonstration outcomes in scientific articles and books. While the scientific articles can be viewed as "work in progress" or the current cutting edge of the knowledge development in the relevant areas, books are intended as a kind of summaries useful for learning and everyday reference. The case studies and implementation examples can be embedded within the methodology papers or be developed standalone.

## 3) Summary

This session provides a platform for the development of modern technologies for energy and water efficiency and for exchanging ideas in the field, supplemented by key contributions geared towards more efficient knowledge management. They include, besides the others, the Process Integration and optimisation methodologies and their application to improving the energy and water efficiency of mainly industrial but also nonindustrial users. An additional aim is to evaluate how these methodologies can be adapted to include the integration of waste and renewable energy sources for energy conversion and water supply/purification. The session is outlining the field of energy and water efficiency, including its scope, actors, and main features. The deals with energy and water saving techniques. An increasingly prominent issue is assessing and minimising emissions and the environmental footprints: GHG and water footprints. At previous SDEWES conferences, the session has received considerable attention. A total of 30 abstracts were submitted to the special session for the upcoming SDEWES conference in Dubrovnik, Croatia. Due to the high demand, it has been decided to organise this session again in 2021, this time for the SDEWES conference in Sarajevo - Bosnia and Herzegovina. The focus of the session is in line with the most recent research developments. The topics within the interests of this special session are the integration of energy, water and waste to secondary resources towards Smart Cities, Smart Industry and Smart Agriculture which can be a powerful tool to boost the sustainability in civic, industrial, agriculture and other activities. Due to the immense importance of knowledge dissemination and transfer, presentations are also invited into the field of knowledge management and especially knowledge transfer.

## Session organizers:

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Invited submissions

## SDEWES2021.0003

# Techno-Economic Assessment of Flexible Hydrogen and Power Production Based on Biogas Catalytic Reforming with Carbon Dioxide Capture Feature

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## Abstract

The need to develop low carbon energy conversion systems is of paramount importance in modern society to actively combat global warming by reducing greenhouse gas emissions. Hydrogen is considered one of the most promising energy carriers for the future with essential advantages in terms of increasing the energy efficiency and reducing greenhouse gas emissions. Increasing the share of renewable energy sources (e.g., wind, solar, biomass) and large-scale deployment of carbon capture, utilization and storage (CCUS) technologies are important for reducing the fossil fuel dependency with correspondent reduction of greenhouse gas emissions to actively combat climate change. Hydrogen-based energy conversion systems attract much interest in last years as they involve no $CO_2$ emission at the point of use. Also, the biogas production and utilisation got significant attention in the last decades as a promising renewable energy source and an energy-efficient way of converting various biowastes into various energy carriers (e.g., heat, power, hydrogen etc.).

This work evaluates flexible hydrogen and power production by biogas catalytic reforming processes equipped with $CO_2$ capture. The size is 50000 $Nm^3/h$ hydrogen with purity higher than 99.95% (vol.) and up to 40 MW net power. Reactive gas-liquid and gas-solid systems are used for pre-combustion $CO_2$ capture. The mass & energy balances generated by modelling and simulation were used to quantify the key plant performance indicators. As results show, the chemical / calcium looping cycles are very promising in term of increasing overall energy efficiency (up to 2.5 net percentage points), carbon capture rate (72 - 75 vs. 64%), reducing specific $CO_2$ emissions (120 - 144 kg/MWh vs. 175 kg/MWh) and improving economic parameters (e.g., lower hydrogen cost by at least 5%, $CO_2$ capture cost by at least 25%) than gas-liquid absorption (benchmark).

## SDEWES2021.0019

# Highly Efficient Diclofenac Decontamination from Water Using Green and Eco-Friendly Three-Dimensional Graphene in Packed Column Configuration

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## Abstract

The presence of pharmaceutical residues such as diclofenac in natural water resources is a major concern worldwide. Graphene oxide has demonstrated good performance in the removal of pharmaceutical contaminants from aqueous body. However, its nanometer-sized structure has limited its practical applications in wastewater treatment. In this research, a three-dimensional structured graphene adsorbent (3DGA) was developed via self-assembly assisted by lyophilisation to address the limitations of graphene oxide. The developed 3DGA exhibited characteristics such as light weight and porous structure resulted from the interconnected thin layered graphene sheets. Diclofenac adsorption was performed in fixed bed mode to evaluate the effectiveness of the 3DGA. The study revealed that breakthrough time increased with increasing bed height. The bed depth-service time (BDST) model parameters were obtained and subsequently used for generating the mathematical model to describe the column service time as a function of bed height. The relationship between the bed height and column service time exhibited a linear trend and the equation developed using the BDST model demonstrated high $R^2$ (> 0.99). As judged by the high $R^2$, the breakthrough curves were well correlated to the Thomas and Yoon-Nelson models. From the model analysis, the highest adsorption capacity predicted by the Thomas model ($q_{Th}$) was 78.19 mg/g while the time required to achieve 50% saturation ($\tau$) was 368 min. The rate-limiting steps of diclofenac adsorption onto the 3DGA were controlled by both film mass transfer and pore diffusion. In short, this research has highlighted the potential application of 3DGA as an efficient adsorbent in future wastewater treatment technology.

## SDEWES2021.0036

# Stress Analysis of Printed Circuit Heat Exchanger for Advanced Nuclear Reactor Power Generation System

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## Abstract

Intermediate heat exchanger (IHX) is a key component of advanced nuclear reactor power generation system. One of promising candidates is the printed circuit heat exchanger (PCHE). But the IHX operates at high temperature and high pressure, the operating conditions are extremely challenging for the based metals of IHX. Therefore, the design of PCHE must not only satisfy with the high thermal efficiency, but also should withstand harsh working pressures and temperatures. Numerical simulation is important to analyze the mechanical strength of PCHE under extreme working conditions, to avoid the possible damages caused by unreasonable design to the internal structure. However, the direct finite element method requires millions of finite element calculation units and large computer calculation cost due to the large number of mini-channels in the PCHE. In this study, an alternative homogenization method which requires lower computational cost is studied, and the mechanical and thermal stresses of the whole PCHE are analyzed.

## SDEWES2021.0037

# Optimization of Hydrogen Liquefaction Process Using Multi-Component Refrigerant

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## Abstract

Liquid hydrogen has good storage and transportation characteristics and will play an essential role in the future. Its high-efficiency production has attracted much attention. A hydrogen liquefaction process with propane precooled mixed refrigerant cycle, mixed refrigerant cryogenic cycle and helium-neon deep cooling cycle is proposed. Its specific energy consumption, coefficient of performance, exergy efficiency, and variation along operating parameters are analysed. The optimal pressure of feed hydrogen, the optimal pressure ratio of compressors and the optimal composition of refrigerant are identified. The specific energy consumption, coefficient of performance and exergy efficiency of the optimized process are 7.81 kWh/$kg_{LH_2}$, 0.1532 and 34.88 %, respectively. Compared with the typical hydrogen liquefaction plants, it has better energy efficiency.

## SDEWES2021.0054

# Environmental Impact Assessment of Post-Combustion CO2 Capture Applied in Cement Production Plants

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## Abstract

The cement manufacture is one of the greatest energy consumers within the industrial sectors (about 7%) being also one of the greatest source of anthropogenic $CO_2$ emissions (about 4%). This work aims to evaluate, from technical and environmental perspectives, through process modeling and simulation, thermal integration analysis as well as Life Cycle Assessment (LCA) the decarbonized cement production process. Two different reactive post - combustion $CO_2$ capture methods are assessed. The first approach consists in a reactive gas-liquid absorption system using an alkanolamine solution, Methyl-DiEthanol-Amine (MDEA), as solvent. The second one considers a reactive gas-solid adsorption method using calcium looping technology. A standard cement plant size of 1 million tonnes per year, with a carbon capture rate of 90% was evaluated. As benchmark, a conventional cement process without $CO_2$ capture was considered.

The mass and energy balances, derived from ChemCAD software, are used in the technical and environmental evaluations. A gate - to - gate approach is carried out using GaBi software. The system boundaries consider the following processes: i) up - stream processes: MDEA supply chain, oxygen generation for calcium looping, ii) main - processes: cement production with post - combustion $CO_2$ capture, iii) down - stream processes: MDEA degradation, disposal of wastes, utilisation of spent sorbent etc. Details about the most important sub-processes that significantly influence the main environmental impact categories, obtained using ReCIPe method, are extensively explained.

The outcome of the current research points to the conclusion that by integrating $CO_2$ capture technologies, a reduction of 70 - 80% in terms of global warming potential stands out, while other environmental categories are also positively influenced, thus a significantly better environmental performance is achieved.

## SDEWES2021.0063

# Solid Waste Integration Towards Efficient Use of Resources: Tomsk Region

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## Abstract

Resources recovery has an essential role in achieving sustainable development. This study aims to minimise the environmental footprint of biomass integration for energy recovery, where a wide range of biomass, including manure, residual and forest wood, are considered. The assessed case study is the Tomsk region in the Russian Federation, focusing on GHG (Greenhouse Gas) footprints. The adapted clustering-based method suggested the biomass integration, consisting of 16 districts, can be divided into three major clusters. The clusters could facilitate further resources planning, considering the land-use footprint of different energy generation. In this study, the identified biomass integration design with minimum GHG footprint (origin of biomass and transportation) of - 217 kt $CO_2$eq/y mainly contributed by the avoided methane from manure. Scenario 1, where the energy demand (3,723 TJ/y) is solely fulfilled by forest wood, contribute to 85.73 kt $CO_2$eq/y. By limit waste biomass (manure and residual) for local utilisation only (without integration), 60 % higher GHG emission (- 90.2 kt $CO_2$eq/y) is identified compared to the identified solution with a minimum GHG footprint. The environmental sustainability of bioenergy is highly subjected to the type of biomass, transporting activities, and heating value. It is crucial to evaluate case by case situation in substituting fossil-based energy or other renewable energy.

## SDEWES2021.0065

# Optimising Response Time and Cost in Energy Systems for Smart Grid Operations

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## Abstract

The 4th industrial revolution has provided interesting opportunities for the future. Among these opportunities, a notable one would be the implementation of smart grid networks. Smart grid networks contain energy systems that are flexible to cater to the user's energy demands. However, smart grid operations have some challenges. Most notably, energy systems operating within a smart grid tend to have slow response times. This is undesired as energy systems in smart grid networks are required to have quick response times toward demand-side changes. Given this, there have been several mathematical models developed to optimize and plan renewable energy smart grid networks. Unfortunately, the previously published work did not explicitly account for response times in energy systems when planning a smart grid network. Quick response time is a key aspect of the operation of smart grid networks. If response times are not factored into planning, the benefits of smart grid operations would be lost. As such, this work presents an optimization model to optimise the energy system operations in a smart grid based on response time and cost. The developed model can determine optimized load distributions based on the expected response time and cost. To demonstrate the viability of the developed mathematical model, a case study was solved in this work.

## SDEWES2021.0075

# Life Cycle Impact Assessment (LCIA) of Selected ZIF-8 Synthesis Methods

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## Abstract

Metal-organic frameworks (MOFs) are crystalline porous materials based on the coordinative interactions of metal ions and organic ligands, which are widely used for adsorption, separation, catalysis and biomedicine. As one of the most widely used is MOFs, zeolitic imidazolate framework-8 (ZIF-8) composed of $Zn^{2+}$ and 2-methylimidazolate (Hmim), is commonly used for gas separation, $CO_2$capture, gas, ion and organic sensor, crude oil spills cleanup, contaminants adsorption and degradation. As an emerging synthesised material, the synthesis and industrial applications of MOFs have been increasingly discussed. However, the environmental impacts of the synthesis process, which involves different types of toxic chemicals, have not been well investigated. This work presents a cradle-to-gate Life Cycle Impact Assessments (LCIA) to evaluate the global environmental impacts of eight different synthesis methods of ZIF-8. The environmental impact of synthesising 1 kg ZIF-8 is determined with an Input-Output method using the LCA software Simapro, with the Ecoinvent Database. Major environmental impact categories including Global Warming Potential (GWP), Aquatic Acidification (AC), Aquatic Eutrophication (AEu), Aquatic ecotoxicity (AEc), etc., are analysed.

The results showed that synthesizing 1 kg ZIF-8, Room temperature stirring method using $Zn(NO_3)_2 \cdot 6H_2O$ and Hmim method has the lowest overall environmental impact. The newly developed method such as Steam-assisted conversion method, the mechanochemical method, as well as the sonochemical method, have considerably higher environmental impacts due to the use of electricity as well as the consumption of certain types of chemicals. The major conclusions are that although the synthesis of fine chemicals in laboratory scale does not consume a large mass of chemical materials, but their environmental impacts, especially aquatic and terrestrial ecotoxicity should not be neglected. Life cycle environmental impact should be considered as a major factor for synthesis selection methods. In future studies, in order to investigate the environmental impacts of the selection of the type of reaction chemicals, the environmental impact of the synthesis process and the separation/filtration process should be determined separately.

## SDEWES2021.0085

# Numerical Study of Flow Boiling Heat Transfer Characteristics of R32 in Horizontal Straight Tube

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## Abstract

Due to the contribution to ozone depletion in the upper atmosphere, investigations of refrigerants having no ozone depletion potential (ODP) and low global warming potential (GWP) have increased. Refrigerant R32 has become one of the promising next generation refrigerants, showing excellent flow and heat transfer performance, zero ODP and low GPW. In this paper, a three-dimensional model is established, and the volume of fluid (VOF) multiphase flow model and the liquid-vapor change model are adopted to simulate the flow boiling characteristics of R32 in a horizontal straight tube. The influence of structural parameters such as tube diameter and the influence of operating parameters such as mass flux, heat flux on the heat transfer coefficient (HTC) and pressure drop are investigated. Result shows that the HTC increases when increasing the mass flux and input heat flux as exhibited in existed literatures. Furthermore, it is indicated that the application of smaller tube might show remarkable improvement on HTC. On the other hand, the pressure drop may raise pronouncedly due to the stronger turbulence compared to the flow in larger size tubes.

## SDEWES2021.0093

# Multiphysics Coupling Simulation on Temperature Rise and Mechanical Characteristics of Direct Current Biased Transformer

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## Abstract

There is a wide application prospects for the HVDC (High Voltage Direct Current Transmission) transmission system due to its large capacity and long-distance transmission characteristics. The direct current (DC) bias phenomenon occurs when the HVDC is at the mono-polar ground circuit operation mode. It endangers the safe and stable operation of transformers. In order to analyse the impact of DC bias on the winding loss and temperature rise, a transient field-circuit coupling model considering the nonlinear BH curve of core and electromagnetic-thermal-fluid model were established in this paper. The working characteristics of a 400 kVA transformer under rated conditions and DC bias were compared. The results show, (1) due to the DC bias, the current waveform for high voltage coil move downward, the higher of the DC voltage, the more obvious the movement. The current waveform for low voltage coil is slightly distorted because the core works on the nonlinear saturation zone of BH curve. (2) The instantaneous loss waveform of high voltage coil is changed by DC bias. When the DC voltage is 10000 V, the period average loss of high voltage coil increased by 33.7%. The loss of low voltage coil and core is little affected by DC bias.（3）The temperature distribution of winding is changed by DC bias. When the DC voltage is 10000 V, the hot spot temperature increases by 8.8 K, the hot spot location is transferred from the upper yoke of the core to the 82.5% height of the C-phase high voltage coil.

## SDEWES2021.0095

# Numerical Study and Optimal Design of Flow and Heat Transfer for Trench Cable

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## Abstract

The trench cables are essential basic equipment in power plants and substations. The service life and maximum electrical current (ampacity) of the cable are closely related to the temperature of the cable core. Since the trench is filled with air, the heat transfer process analysis of the trench cables is more complicated. In the present paper, the flow and heat transfer characteristics of a typical four-loop trench cables in Chongqing was numerical analyzed by COMSOL MULTIPHYSICS, with the method coupling between electromagnetic field, flow field and temperature field. The effect of concrete trench wall thermal conductivity on the heat transfer of cable under the condition of soil variable physical properties was studied. Subsequently, the effect of different loop current distribution on cable heat transfer was discussed. The results show, firstly, with the increase of thermal conductivity coefficient on concrete trench wall, the temperature of the cable core decreases and the reduction of that also decreases. When concrete thermal conductivity increased from 0.5 W/m·K to 1 W/m·K, the ampacity of the cable is increased by 9.46 %. Secondly, when the total current of overall trench cable is the constant, the loop cable current distribution will affect the air flow in the trench. When the vertical two loops are fed with higher current, the air flow forms a circulation in trench, and then the lower value of maximum temperature of the cable core can be obtained in all arrangement methods. When the total electric current of the trench cable is 2000 A, the total electric current is divided into 200 A, 400 A, 600 A and 800 A. The four types of currents with different values are fed into different loops in a permutation and combination. The difference in maximum cable core temperature value and ampacity is 4.356 K and 66 A from all arrangements, respectively.

## SDEWES2021.0097

# Advanced Approach to Cooperative Waste Treatment Cost Reduction Game

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## Abstract

Circular economy principles are accommodated worldwide to respond to current negative environmental trends. Whereas non-recyclable waste disturbs the sustainability of this concept, Waste-to-Energy technology is a promising approach to the problem. This paper studies the economic consequences of Waste-to-Energy technology implementation into waste management strategies using cooperative game theory. Assuming limited landfilling, municipalities treat produced waste using services of Waste-to-Energy plants. Cooperative reservation of some plants' capacities to waste producers with disadvantageous locations reduces their waste treatment costs in exchange for financial compensation. The paper provides a review of current applications of game theory to environmental studies and exploits apparatus of distributed dynamic coalition formation games in the Czech Republic waste management case study. Results provide a view on the impact of the Waste-to-Energy technology implementation and limited landfilling on the municipal budgets and suggest the most suitable municipal unions for handling waste management tasks.

## SDEWES2021.0099

# A Deep Learning Framework to Predict the Consumption of Petroleum Products

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## Abstract

The energy policy of the country is highly dependent on petroleum products as it is considered one of the major resources of energy. With unprecedented growth in energy demand, a well-constructed forecasting model is critical to effectively monitor energy policies by offering energy diversity and energy needs that conform to the country's diverse structure. Decision-makers, regulating authorities and energy providers will all benefit from accurate predictions of petroleum products usage. In this paper, a deep learning framework consisting of a Long Short Term Memory (LSTM) model and deep feedforward layers is developed. The proposed model is termed Deep Long Short Term Memory (DLSTM). It is used to train the monthly consumption data of main petroleum products (Bitumen, Diesel LPG, and Naphtha) along with overall petroleum consumptions from 1998 to 2019 and predicted the consumption of these products and overall petroleum consumption for the next three years.

## SDEWES2021.0100

# Anomaly Detection for Short Time-Series Data in Waste Management

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## Abstract

Anomaly detection is a very important step in every analysis of real-world data. Presence of the anomalies may strongly affect results of both tested hypotheses and created models. Data analysis is important in waste management to improve effective planning from both short- and long-term perspective. However, in the field of waste management, anomaly detection is rarely done. The goal of our paper is to propose a complex framework for anomaly detection in a big number of short time series. In such a case, it is not possible to use only an expert-based approach due to the time-consuming nature of this process and subjectivity. Proposed framework consists of two steps: 1. outlier detection via outlier test for trend adjusted data, 2. changepoints (trend changepoint, step changepoint) are identified via comparison of linear model parameters. Proposed framework is demonstrated on waste management data from the Czech Republic.

## SDEWES2021.0110

# Retrofit of Integrated Waste Gas-to-Energy Units by Conceptual Design Method

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## Abstract

Processes for thermal processing of waste gases containing combustible pollutants – shortly "waste gas-to-energy" (WGtE) units are generally very energy-intensive units with high supplemental fuel consumption. However, with improved heat recovery within the unit, a significant fuel saving can be achieved. This paper presents the latest results of development of a conceptual design method (CDM) for retrofit of WGtE units. The CDM is based on the so-called Shifting Flue Gas Line (SFGL) approach developed in our previous research as a decision-making tool for effective identification of energy retrofit targets of the WGtE units, (and presented at the conference SEE SDEWES 2020). The accuracy and reliability of the SFGL approach (as part of the CDM) were subsequently practically verified within the design of energy retrofit of a specific industrial WGtE unit. With its help, the primary fuel (i. e. natural gas) savings of over 28% were targeted with a retrofit payback period of only 6 months.

This paper presents a new graphical tool, the so-called Heat Recovery Shifting Diagram (HRSD) as the core visualization tool of the CDM, which enables to visualize the heat recovery in the existing unit, then to introduce new heat exchangers or to intensify the current ones, and finally to evaluate the influence on the rest of existing heat transfer devices.

The first part of this paper focusses on a description and calculation background of the HRSD providing an accurate technological modification assessment in terms of fuel saving evaluation and more specific design information about new heat exchangers placed in the WGtE process to save supplemental fuel (i.e., natural gas). While the second part of the paper presents case studies of WGtE unit retrofit and their results obtained for different design arrangements of integrated WGtE units to demonstrate the extended application possibilities of the CDM with HRSD. The obtained results of case studies are finally discussed in the paper in connection with the design and implementation of the so-called modern integrated equipment (MIE), which appear as a new trend of a higher level of process integration of WGtE units, mainly to further reduce investment, operational, and environmental impacts. In this sense, the presented CDM seems to be a very promising tool for the needs of identification of a suitable location and conceptual design of these MIE for WGtE units within their retrofit.

## SDEWES2021.0116

# A Hybrid Evolutionary Algorithm for Heat Exchanger Network Retrofit for Processes with Multiple Operating Cases

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## Abstract

Heat exchanger network retrofit is a useful strategy to increase energy efficiency in process industry. In Switzerland, processes often have multiple operating cases caused by environmental or multi-product production. In order to consider such variations over time, additional mixers are included in the heat exchanger network retrofit. To ensure practicability in industrial application, additional practical constraints, such as a maximal number of heat exchangers in a split, are considered. These additions increase the complexity of optimization. Therefore, in this work, a two-level hybrid evolutionary algorithm is proposed. The network topology is optimized in a top-level genetic algorithm, and the heat loads are optimized using a differential evolution at a sub-level. The algorithm was successfully applied to a chips production plant from the industry. As a result, the total annual cost was reduced by around 66%.

## SDEWES2021.0138

# Cooling Effectiveness of Li-Ion Battery Module with Multiple Phase Change Materials for Hybrid Electric Vehicle

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## Abstract

To curb the greenhouse gas and carbon emission in line with the Paris climate agreement, the road transportation needs to be electrified. The predicted electrification of the road transport can substantially reduce the greenhouse gas emission by at least 20%. The fundamental component in electric vehicles (EVs) is the power battery, in which its performance is affected by temperature. To control the temperature under desired limit and provide temperature uniformity in the battery pack, a thermal management system comprises heatsinks with fluid channels and multiple phase change materials (PCMs) was investigated in this paper. The battery module consist of eight prismatic cells with heatsinks comprises nine fluid passage and PCMs attached at each side of the cell. The height of the heatsink containing PCMs is divided into three equal sections each filled with different PCMs. The cooling effectiveness and temperature homogenization of the battery thermal management system (BTMS) were carefully explored based on the compactness of the battery stack and cooling fluids. The results indicate that increasing the PCMs thickness supressed the temperature growth by more than 2.85 K and provide better temperature uniformity compared to increasing the fluid channel width for the same volume of heatsink to volume of the battery unit ratio. Liquid cooling is more effective than air cooling in mitigating temperature especially at high ambient temperature. Choosing an appropriate ratio of volume of cooling channel to battery unit is particularly essential and can minimize the operation cost.

## SDEWES2021.0147

# Designing Solar Utility Systems

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## Abstract

The design of solar thermal utility systems to supply a fraction of the energy duty of a process plant, may lead to systems with different solar technology. This work looks at the integration of networks of solar collectors considering three different solar technologies, Flat Plate Collectors (FPC), Compound Parabolic Collectors (CPC) and Parabolic Through Collectors (PTC). The approach incorporates a collector network sizing approach and a Life Cycle Saving analysis. A case is analysed where the process heating needs are 400 kW to heat a stream from 40°C to 60°C and 700 kW to heat a second stream from 75°C to 120°C. The economic analysis reveals that the technology that suits the operating conditions is the one that in the long run gives the largest present worth life cycle saving. In the case under study, it is shown that the PTC technology gives the largest present worth in both sections.

## SDEWES2021.0150

# Cooperative Game Theory Approach for Plants' Fair Profit Allocation in Water Eco-Industrial Park

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## Abstract

Designing water symbiosis networks in an industrial site is aimed at minimising freshwater consumption or wastewater discharge to comply with the environmental discharge limit. However, it requires collaboration between individual owners of process plants on the site and extra cost compensation by the authority to facilitate the operation. This work aims to apply the Cooperative Game Theory approach to identify the distribution of stable and fair profits to the plants from the government to each stakeholder. This study considers the grand coalition of finite players (industrial plants/stakeholders) with authority to facilitate water recycling in an eco-industrial park. The first stage includes the determination of the park authority's objectives (i.e. minimum cost, resource usage or minimum pollutants discharge) if the stakeholders cooperate. In the next stage, the park authority can then compensate the cost by providing incentives or subsidies for the stakeholders that participate in the symbiosis. The subsidies or incentives have to be fair and fixed in a binding agreement between plants. The stakeholders are then allowed to decide the recycling amount that maximises their economic interests. A wastewater tax can be imposed by the authority to the stakeholders to stimulate them to take part in the symbiosis while generating the money source for subsidisation. Proper game analysis is provided to analyse the Nash Equilibrium solutions of the tax rate. An illustrative case study is used to demonstrate how fair subsidisation can be identified and the implementation of taxation policy. The framework shows the potential benefits and guidelines for each industrial plant, as well as the government, to derive a feasible cooperative policy to achieve the goal of environmental emissions reduction.

## SDEWES2021.0152

# A Circular Economy Driving Change in the Management of Plastic Waste in Hospitals During the Covid-19 Pandemic

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## Abstract

The problem of health waste management is increasingly attracting attention along with the increase in plastic waste due to the COVID-19 pandemic. Due to health and safety regulations, one of the main obstacles to recycling in the hospital environment is separating general waste from infectious waste. Applying a circular economy model for waste management will not only facilitate the transfer of waste collected from landfills to recycling plants but will also help reduce waste generation. This study highlights the need for targeted collaborative research that utilizes waste management principles and a circular economy concept, taking into account the degree of confusion in the hospital. Although this concept has been used frequently in the industry to reduce waste and energy costs, it is used less frequently in hospitals. This research investigates how the circular economy can serve as a driver for change in health care plastic waste management during the COVID-19 crisis to increase hospital value creation and profitability. A framework to describe the strategy for implementing a circular economy in hospitals that focuses on plastic waste management will be developed in this study. This study can help hospital management to contribute to reducing high levels of carbon dioxide in the environment and reducing landfill space.

## SDEWES2021.0189

# Multi-Level Stratification of Territories for Waste Composition Analysis

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## Abstract

Many articles deal with methods for estimating the composition of municipal waste, however, most details are given as to how many categories should be chosen and what technical procedure should be followed. In order to obtain a broader view and a reasonable evaluation of the results, it is necessary to effectively choose the areas where the analyses will be performed. Current approaches have insufficiently addressed this issue at the regional and national levels. This paper presents a method that uses multi-level stratification to divide municipalities into similar groups to reduce the number of observations needed to obtain an estimate of the composition of waste in a selected area (region or state level). The method combines expert knowledge with statistical considerations and makes use of cluster analysis. Socio-economic and waste-related parameters are used within the individual steps. Regarding the available financial resources and the required accuracy of the results, the municipalities in which the analyses should take place are selected. These representative municipalities represent other municipalities in the created groups and thanks to them it is possible to estimate the composition of waste in any municipality, region, or larger territory. The presented method is shown in more detail in the municipalities of the Czech Republic with the possibility to investigate a total of 10 municipalities, but any number can be set respecting the financial resources. The method is described in general and can be applied to any territory in the world, considering local conditions and possibilities.

## SDEWES2021.0190

# Improving Household Waste Segregation and Recycling in Circular Economy Transition by Analysing Resident Engagement in Social Media

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## Abstract

Waste segregation and recycling have been valued in the Circular Economy transition in the household waste management sector. With the development of digitalisation and waste management innovation, residents are becoming more active in social media related to household waste management. A few studies have demonstrated how subscription accounts on waste management-related social media platforms have increasingly favourable effects on municipal solid waste management. However, research is still lacking on the potential role of resident engagement (e.g. comments, voting and interactions) in social media played in enhancing managerial decision- and policy-making. This study develops an integrated solution to analyse resident engagement on waste management-related social media by leveraging statistical and machine-learning methods. Four interrelated components: (i) the trend and pattern of user comments, (ii) the sentiment of comments, (iii) the popularity trend of voting behaviour, and (iv) the insights extraction from user comments are incorporated. The novel solution is applied to a real-world case study with user comments and user voting on a publicity subscription account, Shanghai Green Account, related to household waste management. Observations extracted from the case study suggest promising applications to improve waste segregation and recycling.

## SDEWES2021.0193

# Applications of Game Theory in Engineering Problems: a Summary of Methods and Their Assessment

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## Abstract

Diverse branches and developed solution concepts make game theory suitable for various challenging applications asking for sustainable development. This mathematical apparatus handles such tasks as cooperation, competition, and self-regulation in the environment, where numerous agents with conflicting goals are involved. These agents might be real decision-makers or parts of an arbitrary complex system, performing different manual tasks. A behavioral model describing the ever-changing decisions of rational players is a key aspect of sustainable planning. In this article, the mathematical background of game theory is briefly summarized, and approaches used in different engineering fields are put into context. The significance of game theory in engineering is emphasized employing the performed review. Performed SWOT analyses accompanied by a decision tree provide a useful guide for applying fundamental game branches, classes, and types to the basic practical problems. Finally, identified research gaps suggest further scientific activities in more fertile fields of research.

## SDEWES2021.0203

# Multi-Period Optimization of an Organic Rankine Cycle: Utilization of Waste Heat from the Aluminium Industry and Solar Thermal

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## Abstract

This study presents the optimisation of organic Rankine cycle (ORC) which utilizes flue gas from the aluminium production process and solar thermal energy as low-temperature heat sources. Optimization of the proposed system is performed with GAMS, maximizing the power output and net present value (NPV) of the system. The ORC system model is based on a multi-period non-linear programming (NLP) formulation to account for variabilities in the solar energy supply and its effects on the ORC system. The main variables considered in the model include temperature, pressure, flowrate, mass enthalpy and energy flows of all the streams in the system. To optimize the variables in the system, correlations were developed, which were formulated as NLP models and optimized using GAMS by minimizing the sum of least squares. Results show that the proposed system is economically feasible with payback period less than 4 years.

## SDEWES2021.0205

# Structural Optimization of Printed Circuit Heat Exchanger Used for Hydrogen Cooler by Exergoeconomic Method

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## Abstract

As a clean energy carrier, hydrogen is considered as an important carrier candidate in the next generation energy and power systems. Hydrogen cooler is a key equipment of the precooling unit in hydrogen refuelling stations, which requires high thermal efficiency, high compactness and high pressure resistance. Printed circuit heat exchanger has these advantages and is an alternative competitor to be used for the hydrogen cooler. In the present paper, a hydrogen cooler with a thermal load of 72 kW was firstly designed by using the segmented design method and logarithmic mean temperature difference method. Then, a cost model of heat exchanger was developed to analyse the investment using the exergoeconomic method. The results showed that the main cost of heat exchanger is operating cost, which is related to exergy destruction and accounts for 94.2% of the total cost. The major exergy destruction is thermal exergy destruction, which occupies 97.2% of the total exergy destruction. Finally, the influence of different channel diameters on the cost of heat exchanger and exergy destruction rate was studied. The size of cold channels has more significant impact on the total cost than hot channels. Compared with the coaxial tube evaporators, the results showed that the volume and the pressure driven exergy destruction rate of printed circuit heat exchanger were reduced by 70.3% and 90.1%, which can effectively reduce the investment and save the space of hydrogen refuelling stations.

## SDEWES2021.0213

# Investigations on the Uniformity of Flow Distribution of Supercritical LNG in a Printed Circuit Heat Exchanger

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## Abstract

Printed circuit heat exchanger is considered as an ideal candidate for floating storage and regasification unit of liquefied natural gas due to its high compactness and efficiency. The flow maldistribution is an essential issue in practical applications of a printed circuit heat exchanger, which leads to the performance degradation. In this study, a printed circuit heat exchanger plate is three-dimensionally modeled to predict the flow maldistribution, and the thermal-hydraulic performance of the channels is investigated, adopting supercritical LNG as the working fluid. To save the computational cost, a simplified two-dimensional model is proposed. The comparisons of results between the two- and three-dimensional models show that the effects of backflows, vortex, interaction between properties and flow distribution can be the reasons that result in the differences between the two- and three-dimensional models. The findings suggest that the proposed simplified two-dimensional model is capable for engineering demands with the satisfaction of computational accuracy and efficiency.

## SDEWES2021.0215

# Influence of Separately Collected Waste on Mixed Municipal Waste Quantity

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## Abstract

Waste management strategies must be planned in the long term for individual countries to meet the EU targets included in the Circular Economy Package. Meaningful and targeted waste management plans are usually based on current state evaluation and waste production forecasts. Recycling goals and restrictions on the landfilling of municipal solid waste are the crucial drivers. In developed countries, the long-term trend is increasing separation efficiency. However, other conditions like waste prevention or rising living standards influence total waste generation as well. The rate of waste transfers between mixed municipal waste and separately collected wastes should be quantified to reveal hidden links in the system. The known relation between waste streams will allow a more accurate estimate of future state and target new interventions to increase the separation efficiency. Standard statistical methods work only for certain waste fractions, so a more general approach needs to be developed. This paper approaches the reconstruction of waste transfers by optimization model and several logical steps. The transfer differs for various waste fractions and territorial units (e.g., municipalities), and it can change even in time (trend might be presumed). Czech waste production data are used to present the model. The result interprets what part of the newly separated waste comes from mixed municipal waste. At the state level, this value is the lowest of the monitored fractions for paper, 0.78. On the contrary, the highest part of the shift from mixed municipal waste is for textile, 0.93. The results for the Czech Republic showed a significant difference in this value at the regional level.

## SDEWES2021.0256

# Can Photofixation of Nitrogen Compete with Traditional Nitrogen Fertilizers Production?

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## Abstract

Ammonia gained substantial interest nowadays since it is a significant chemical being considered a hydrogen vector and carbon-free fuel. The global need for food and land reclamation creates a high demand for ammonia since it is the core of nitrogen-based fertilizer production. Photocatalysis can be considered one of the most environmentally benign routes to produce fuels and chemicals. Photofixation of nitrogen to produce nitrogen-based fertilizers lies in the lower tiers of technology readiness levels in which current fundamental development stages are in early progress. This work explores the feasibility of the solar-based nitrogen fixation process from an economic perspective and compares it with the traditional process at different production scales. One of this research's main objectives is to set a performance target for efficiency, production rates, and scale to achieve economic feasibility. The levelized cost of nitrogen content is used as a metric to compare the photocatalytic process to other production routes from an economic perspective. The photocatalysis-based process is established by introducing four main subsystems: photocatalytic reactor, air separation unit, water demineralization unit, and ammonium cation recovery by ion-exchange column. Following the nitrogen fixation process, separation of ammonia product is necessary, and the ion-exchange scheme is used where ammonia is recovered in an ammonium sulfate solution. The results show that to make this process economically feasible, considering 50 years of operations and 40% capacity factor, the current ammonia yield should increase to six-folds of the current experimental laboratory conversion. Further analysis on factors that impact the cost, variations in reactor hollow tube diameter, and catalyst loading suggest the potential to decrease the required conversion almost to double the current achieved experimental conversion (6.5 mmol/g·h).

## SDEWES2021.0257

# Waste Management Forecasting for EU Member States Considering Demographic Development

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## Abstract

The Circular Economy Package approved by the EU sets targets for waste treatment. Sub-targets need to be met at the level of each EU state. The level of waste management varies significantly from one state to another and therefore has different starting position. The forecast of waste production and treatment is essential information for the expected future EU targets fulfilment. If waste treatment does not meet the targets under the current conditions, it is necessary to change waste management strategies. This contribution presents a universal approach for forecasting waste production and treatment using freely available data. The approach is based on the trend analysis with the subsequent data reconciliation. Expected demographic development of is taken into account. The results show that most states will not meet EU targets with current trend of waste management in time. Presented methodology is suitable basis for strategic planning at the national and transnational level.

## SDEWES2021.0258

# Mass Integration with Headers of Intermediate Purity and Multiple Fresh Resources

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## Abstract

Intermediate headers can be considered setting up to simplify the configuration and enhance the expandability and flexibility of mass exchange network. This paper proposes an extended Pinch Analysis method for Mass Integration with intermediate headers and multiple fresh resources. In order to reduce the consumption of an expensive, higher-quality fresh resource, fresh resources with various purity levels (multiple fresh resources) are considered. All the sources and sinks are indirectly matched with each other by headers. The effects of the location and purity of intermediate headers on the mass exchange network are also investigated. The number, connection, and purity of intermediate headers are optimised with the target of minimum fresh resources consumption and waste discharge. The proposed method is demonstrated by an industrial case of a hydrogen network. The case study shows that the total cost of fresh hydrogen consumption (utility) is reduced by 17.5 % by considering two different qualities fresh hydrogen resource. The optimal number of intermediate headers is simplified to 4 after setting up the intermediate headers. The proposed method can simplify the network configuration, and improve the controllability of mass exchange network, with the target of minimising fresh resource consumption and waste discharge.

Acknowledgments

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## SDEWES2021.0280

# Industrial and Urban Symbiosis: Closing the Circle

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## Abstract

The efficient use of material and energy resources is of utmost importance for achieving process sustainability by simultaneously minimising the use of fresh resources and pollution reduction. One of the ways of achieving this is to unite industrial and urban actors of a given market in a symbiotic network, implementing the principles of Circular Economy. This builds on the ideas for Locally-Integrated Energy Sectors for energy recovery and Industrial Symbiosis for the recovery and reuse of material streams among industrial actors.

However, the resource recovery and reuse from waste streams is not free of resource use and pollution effects. Any process in the delivery of products and services – from cradle to grave, requires the use of fresh resources and exhibits pollution effects. Invariably, part of those resources is energy to drive the processes. On the other hand, products and services, based on waste streams, replace their analogues generated from the use of only fresh resources. This creates a trade-off between the processes closing the resource cycle and the processes using only fresh resources. Since the energy is converted between different forms, mainly delivered as heating, cooling and power, the exergy concept is selected as the unifying indicator for representing the intrinsic linkage between material and energy resources, as it considers the resource quality – temperature, pressure and chemical compositions. This work aims to propose a method for targeting the maximum recycle/reuse of waste/secondary resources considering the quality constraints of the streams. The expected results could determine the maximum feasible internal resources recovery, considering the constraints of exergy supply and environmental footprints. The obtained targets and clusters of streams to be recycled can be used in follow-up work for formulating the symbiosis network synthesis problem that provides detailed network and units' size optimisation using Mathematical Programming or Stochastic Programming. The criteria to use in the optimal network design include the economical (cost) and environmental footprints, exploiting the circularity as a degree of freedom.

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## SDEWES2021.0286

# Regional Transmissions of Embodied Energy-Carbon-Water System: Case Study of Coastal Area China

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## Abstract

This study seeks to exploring the Energy-Carbon-Water nexus of China, identifying the regional transmissions of embodied energy consumption, $CO_2$ emissions and water consumption in the coastal area China. Nice provinces are taken into consideration and the Multi-Region Input-Output model is employed. The critical transmissions of embodied Energy-Carbon-Water among different provinces have been analysed. Results show that: 1) Hebei export the most embodied energy and Zhejiang import the most embodied energy; 2) The structure of embodied $CO_2$ emissions transmissions is similar with that of embodied energy consumption; 3) Guangdong benefits the most from the regional embodied water transmissions system, and Jiangsu contributes the most. This study contributes to a better understanding of the regional embodied Energy-Carbon-Water nexus system, providing a reference for future studies of other regions in the world.

## SDEWES2021.0301

# Numerical Investigation of Two-Phase Thermosyphon Heat Pipe with Different Orientations

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## Abstract

Two-phase closed thermosyphon heat pipe are widely used for energy savings in many industrial applications. In this paper, the flow pattern and heat transfer mechanism inside a Cu-water CTHP is numerically investigated at heat fluxes of 150 W. The volume of fluid (VOF) method is applied, and the effects of the inclination angle with 90°,60° and 30° and filling ratio ranging from 0.25 to 1.25 on the temperature distribution and overall thermal resistance are studied. The model was benchmarked with experimental data in existed literatures. Noted that present model shows less deviation on the wall temperature distribution compared to that reported in the literature when assuming the condensation time relaxation coefficient as 100. Result also showed that the inclination angle indicates significant influence on the flow pattern, temperature distribution and thermal resistance, especially for cases with low filling ratios. With the decrease of inclination angle, a higher filling ratio of working fluid is preferred to meet the goal of thermal performance of a thermosyphon.

## SDEWES2021.0306

# Experimental Investigation of Thermal-Hydraulic Performance of Supercritical CO2 in Asymmetric Airfoil Printed Circuit Heat Exchanger

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## Abstract

The printed circuit heat exchanger acts as a promising candidate in some energy conversion systems due to its high efficiency, high compactness, and the ability of enduring extreme conditions. The heat exchanger with discontinuous airfoil fins exhibits excellent overall performance, including high efficiency and low resistance. In this work, a printed circuit heat exchanger with asymmetric airfoil fins was analyzed. A test loop of water and supercritical carbon dioxide was applied to obtain the thermal-hydraulic performance. This work focused on the effects of the inlet temperature and the mass flow rate of supercritical carbon dioxide on the overall heat transfer performance of the printed circuit heat exchanger. Meanwhile, the effects of the forward and reverse flow on the thermal-hydraulic performance of asymmetric airfoil fins were analyzed. The results show that the comprehensive heat transfer performance of forward flow is about 64% higher than that of reverse flow. Finally, the unified Nusselt number correlations of the forward and reverse flow on supercritical carbon dioxide side is proposed with ±20% maximum deviation.

## SDEWES2021.0311

# Machine Learning Driven Waste-to-Energy Valorisation for Low-Carbon Dimethyl Ether Production

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## Abstract

The high amount of waste generation calls for effective techniques that can offer reliable disposal and recycling pathways instead of the commonly used landfilling and incineration. The Power-to-Gas and Waste-to-Energy methods have the potential to enhance energy transition and intensify waste neutralisation. Based on the combination of sustainable bioenergy and circular economy concepts, the valorisation of bio-waste sources is investigated via hydrothermal-, and atmospheric gasification processes. The modelling of thermochemical conversions and the determination of process performance indicators were carried out with the use of machine learning techniques for the production of high-quality synthesis gas intermediate. Recent advances in the field of artificial intelligence enable fast and accurate modelling of complex tasks, e.g., describing high number of simultaneous reactions, even in low available training data environment. The correlation between the composition of waste feedstocks, operational parameters and target variables (fuel gas yield, gas mixture composition, carbon conversion ratio) were established using neural networks (NNs). Levenberg-Marquardt and Bayesian Regularisation training algorithms were applied to determine the ideal topology of NNs. The produced synthesis gas is transformed into dimethyl ether via the synthesis of methanol. The process flowsheeting and life cycle environmental impacts confirm that the valorisation of bio-waste sources via thermochemical conversions is an advantageous process for the production of low-carbon (<100 g $CO_{2,eq}$ (kg DME)$^{-1}$) synthetic fuels and materials.

## SDEWES2021.0348

# Thermal Performance of Flat-Plate Heat Pipes with Various Working Fluids Under Different Inclination Angles

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## Abstract

As one promising high-efficiency equipment, flat-plate heat pipes show many advantages in the heat management of energy systems. This research investigates experimentally effects of three working fluids (acetone, ethanol, and 1.0 wt.% $Al_2O_3$ water-based nanofluid), liquid filling ratios (30%, 45%, 60%, and 80%), and inclination angles (0°, 30°, 60°, and 90°) on thermal resistance and equivalent heat transfer coefficient of flat-plate heat pipes. Results show that the flat-plate heat pipe with filling ratio of 60% has the lowest thermal resistance of 2.50 °C/W. Compared with filling ratios of 30%, 45% and 80%, thermal resistance of 60% filling ratio decreases by 42.8%, 27.8% and 50.7%. The heat transfer coefficient of the flat-plate heat pipe increases by 90.8% when the inclination angle increases from 0° to 60° due to an effect of gravity, but the heat transfer coefficient of the flat-plate heat pipe decreases by 7.2% when the inclination angle increases from 60° to 90°.

## SDEWES2021.0399

# Numerical Investigation on Melting Process of Phase Change Materials with Metal Foam and Fins in a Rectangular Container with Varying Inclination Angles

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## Abstract

Phase change material (PCM) has been widely used to solve the contradiction of energy supply and demand mismatch in thermal energy storage system. In this paper, the melting process of paraffin/copper foam composite phase change material (CPCM) without and with fins in a rectangular container in the inclination angles of 0°, 30°, 60° and 90° was numerically simulated by FLUENT. Moreover, the effects of PCM heat transfer improvement methods included using copper foam, different numbers and positions of fins in different inclination angles were scrutinized and compared with each other. The relationship of melting rate enhancement $\varphi$ and thermal energy storage efficiency $\eta$ was analyzed. The results showed that with the increased number of fins and the changed positions of fins, the melting rate had been improved, but the thermal energy storage efficiency had a first increasing and then constant trend due to the expanding heat transfer area and the decreasing capacity of PCM. With the increased inclination angles, the higher inclination angles had a more prominent effect on the melting rate than that of the lower inclination angles, contributing to the thermal accumulation caused by natural convection in the melting process. Comprehensively considering the relationship between the melting rate enhancement and the thermal energy storage efficiency, even though using copper foam and fins has an adverse effect on the total amount of energy and thermal energy storage efficiency, it has shown an ideal performance to improve the melting rate, which is beneficial to store thermal energy rapidly in a thermal energy storage system.

## SDEWES2021.0400

# Experimental Study on Heat Transfer of Granular Flow in Moving Bed: Application of Heat Resistance Theory

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## Abstract

The moving beds play vital roles in the fields of industrial heat saving and solar energy utilization. The gravity-driven granular flow moves around the wall slowly, and the indirect heat transfer happens between different mediums. The heat transfer mechanism is still worth of investigating in the granular side. In this work, the heat transfer of granular flow around a tube was studied experimentally. A modified heat resistance theory was applied to explain heat transfer coefficients (h). It was found that, the overall h is sensitive to the flow rate (u). As u varies around 0.29-1.63 mm/s, the h will locate in the range of 49.58-81.90 W/($m^2$·K). To predict h by the heat resistance theory, a probability parameter (a=0.5) is adopted to modify the penetration resistance. The maximum relative deviation is 6.3%. For the more accurate a in the future, the granular flow structure should be further quantified.

## SDEWES2021.0483

# Assessing Process Effectiveness and Specific Environmental Impact of Heat, Power & Chemicals (Hpc) Option as Future Perspective in Biogas

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## Abstract

Biogas is an important contributor to the future of bioenergy, which has been fundamental in the achievement of European energy dictates. The most used technology processes to exploit biogas are the production of heat and electricity in Combined Heat and Power plants (CHP) and Biomethane Injection Plant (BIP) with the upgrading to biomethane through the removal of $CO_2$ and impurities. Nowadays, however, with the new national and European directives lowering incentives for energy generation from biogas, these plants have the critical risk of dismissing. The chemical industry requires new innovative pathways to exploit this feedstock. The only real opportunity offering economic profitability seems to be the conversion of biogas into chemicals as bio-methanol with a new process technology called Heat, Power & Chemicals (HPC). This work introduces the HPC methanol synthesis through process simulation and series of environmental parallelism with the most consolidated processes. The scope is to enlarge and assess a future perspective in the biogas sector.

## SDEWES2021.0537

# Sensitivity Analysis of Biogas Supply Network Considering Parameter Uncertainties

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## Abstract

In recent decades, the number of biogas plants in operation has increased significantly worldwide [1]. Biogas digesters are widely used especially in rural households in developing countries. However, most primary energy from biogas is produced in the EU, where it is mainly used for electricity generation [2]. In many cases, high feed-in tariffs that support renewable electricity generation have encouraged the construction of biogas plants [3]. Due to possible loss of support measures by various governments, such biogas plants may face operational issues [4]. There are several challenges associated with the construction and operation of biogas plants such as high investment cost, low efficiency, displacement of food and feed production, loss of biodiversity and other factors [5]. Thus, there is high uncertainty regarding the sustainability of biogas production considering the combined economic, environmental and social pillars.

Fuzzy linear programming has been extensively used to account for uncertainty in process networks [6]. Fuzzy optimization involves flexible constraints and objectives whose satisfaction is characterized by a membership function [7]. Fuzzy logic deals with the concept of truth value which is between completely true and completely false (0-1). Uncertain variables include the sustainability of the system with different indicators, purposes and stakeholders [8], and could exhibit from zero to full acceptability (0-1) [9].

This work represents an extension of the mixed integer linear programming (MILP) model to optimize the biogas supply network for electricity generation with maximum economic performance [10]. The model is extended with fuzzy logic by proposing membership functions that take into account the uncertainties of the parameters. Furthermore, various sustainability criteria (economic, environmental, viability) are considered and acceptable designs are identified. The study is applied to a case study of agricultural biogas production in Slovenia.

## SDEWES2021.0579

# Optimization and Effect of Particles Distribution in Grille-Sphere Composite Packed Bed with Steam Methane Reforming

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## Abstract

Hydrogen energy is regarded as the most promising clean energy in the 21st century. Steam methane reforming with packed bed reactor is an important method to obtain industrial hydrogen production. Especially, the chemical reactor that is as the key equipment of methane reforming is given more attention. In this study, the equivalent medium method is used in the simulation which can bring the average distribution of temperature, flow and species. Through the numerical simulation, the performance of different variable diameter particles structures with steam methane reforming have been compared and the optimization method has been analyzed. It is found that the structures with smaller N (pipe-to-particle ratio) have better performance of reactions. Besides, the particles distribution can influence the performance of pack bed reactor. The results of this study can guide the design of packed beds in industrial production and improve hydrogen production as well as economic benefit.

## SDEWES2021.0642

# A Practical Approach for Synthesis of Biodiesel via Non-Edible Seeds Oils Using Trimetallic Based Montmorillonite Nano-Catalyst

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## Abstract

The potential of new trimetallic (Ce, Cu, La) loaded montmorillonite clay catalyst for synthesising biodiesel using novel non-edible Celastrus paniculatus Willd seed oil via two-step transesterification reaction has been reported along with catalyst characterisation. Transesterification reaction was optimised and maximum biodiesel yield of 89.42% achieved under optimal operating reaction states like; 1:12 oil to methanol ratio, 3.5% catalyst amount, 120°C reaction temperature for 3 h correspondingly. The predicted and experimental biodiesel yields under these reaction conditions were 89.42 and 89.4%, showing less than 0.05% variation. Additionally, optimum biodiesel yield can be predicted by drawing 3D surface plots and 2D contour plots using MINITAB 17 software. For the characterisation of the obtained biodiesel, analysis including the GC/MS, FT-IR, $^{1}$H-NMRand $^{13}$C-NMR were applied. Also, the fuel properties of obtained biodiesel agrees well with the different European Union (EU-14214), China (GB/T 20828), and American (ASTM-951, 6751) standards.

## SDEWES2021.0646

# CO2 Precooling-Assisted Refrigeration Cycle for Energy-Efficient and Cost-Effective Biomethane Liquefaction Process

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## Abstract

Biomethane is regarded as a promising renewable energy source, with great potential to satisfy the growth of energy demands and to reduce greenhouse gas emissions obtained from the biogas after upgrading it. Liquefaction is one of the most promising approaches for long distances and overseas transportation of biomethane. However, biomethane liquefaction processes are energy-intensive due to their cryogenic working conditions. The major challenge is to design a high energy efficiency liquefaction process with a minimal total annualised cost. This study presents an innovative biomethane liquefaction process that utilises $CO_2$ as a pre-cooling refrigerant. This $CO_2$ pre-cooling could provide dual benefit; one is to overcome load on primary refrigeration cycle, and other is its utilisation in a close loop that would contribute to managing $CO_2$ safely and economically. The initial design of the proposed process is simulated and analysed by simulator Aspen Hysys® v11. The vortex search pattern is applied to get the final optimised design of the proposed liquefaction process. The detailed energy, exergy, economic, and environmental footprints analysis are performed to evaluate the proposed design's early-stage feasibility. In terms of process configuration, energy consumption, exergy efficiency, and process economics, the proposed process is advantageous to available biomethane liquefaction processes. This study should be beneficial for the process engineers in solving the issues relating to energy and environmental efficiency of biomethane liquefaction processes, which should facilitate the long-distance and emission reduction transportation of biogas.

Acknowledgement

The funding from the project 'Sustainable Process Integration Laboratory – SPIL funded by EU' CZ Operational Programme Research and Development, Education, Priority1: Strengthening capacity for quality research (Grant No. CZ.02.1.01/0.0/0.0/15_003/000045) has been gratefully acknowledged.

## SDEWES2021.0734

# Secondary Separation of Fine Particles Emitted by Biomass Boilers: Controlled Particles Growth and Particles Impaction

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## Abstract

This paper deals with the experimental separation of fine combustion particles emitted by domestic biomass combusting boilers. The research focuses on the particle size ranging from 20 to 450 nm representing significant health risk. Particular steps focus on lowering the flue gas temperature and quantifying its influence on fine particle growth and subsequent separation. In the first step, controlled cooling of the flue gas is performed using a heated hose with a controlled temperature. Decreasing the flue gas temperature contributes to an increase in the concentration of particles and their size. In the second step, contact of the flue gas with a water surface is studied. A significant decrease in the concentration of particles of over 200 nm has been observed. A much less sensitive response to the presence of a water surface has been observed in particles of 50 – 150 nm.

## SDEWES2021.1082

# SPIL-HX: a Software Suite for Heat Recovery Networks and Equipment Design

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## Abstract

Shell and tube heat exchangers (STHE) are the most common types of heat exchangers used in many industrial fields. Heat Integration (HI) with heat exchangers requires intimate knowledge and intensive calculation to set energy-saving targets to achieve the goal of efficient energy utilisation. The Shell and Tube Heat Exchanger Design Software Module developed by the SPIL team, or SPIL-HX, offers features that support engineers to design and rate original STHEs, STHEs with segmented baffles and with spiral baffles. This software module determines a custom solution to meet the specific specification. Engineers can design and rate an exchanger to meet the Tubular Exchanger Manufacturers Association (TEMA) standards and user requirements considering flexible shell elements and other specific requirements. SPIL-HX is also capable of Heat Exchanger Network (HEN) synthesis and retrofit. With the built-in algorithm, the software can provide the optimal solution for Heat Integration, which significantly reduces operating, capital, and design costs. A user-friendly interface and easy data input function facilitate the use of the developed software.

## Special session: Plant Assisted Bioremediation of Contaminated Areas: A Sustainable Technology for Recovering Soil Pollution and Energy Conversion in a Framework of Circularity

Plant-assisted bioremediation (PABR) technology is currently getting popular as an environmental-friendly and sustainable strategy in comparison with traditional thermal and physico-chemical approaches. It has been successfully applied to multi-contaminated soil and water ecosystems. This session will focus on PABR case studies at lab and field scales for recovering soil from various contaminants such as persistent organic pollutants (POPs), heavy metals, oil-products, emerging contaminants (<em>e.g.</em> pharmaceuticals, microplastics) alone or in chemical mixtures. Different treatments such as the use of soil amendments (<em>e.g.</em> compost, biochar, etc.), biosurfactants, nanomaterials (<em>e.g</em>. Nano-$TiO_2$, -$Fe_3O_4$, NZVI, etc.), will be assessed as useful strategies for enhancing the efficiency of PABR technology. Particular attention will be focused on the characterization of soil microbial communities in the rhizosphere and the chemical dialogue between plant root and microorganisms (e.g. root exudates), in order to evaluate the new achievements and further research needs in the study of plant-microorganism's interactions, which play a key role in promoting PABR technology.

Moreover, the potential of converting PABR biomass for energy use will be also considered. Different conversion solutions can be applied on PABR biomass such as combustion, gasification, torrefaction and pyrolysis aiming at producing biofuel (liquids or gaseous) to be used in transport or in (co-)generation power plant. Specific actions should be considered for separating and possibly reusing the extracted contaminants, in an attempt to enforce complete circularity. Finally, the sustainable PABR technology capabilities in restoring contaminated areas and providing energy will be discussed in the light of the recent EU GREEN DEAL actions, which aim to transform EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy.

The session will host multidisciplinary works with both biological, microbiological and energy production aspects. Researches with holistic and circularity approaches, involved in the different steps of PABR, are welcome.

### Session organizers:

**Dr. Valeria Ancona**, Italian National Research Council, Water Research Institute (IRSA-CNR), Bari, Italy

**Prof. Domenico Borello**, Sapienza University of Rome, 00184, Italy

**Dr. Anna Barra Caracciolo**, Italian National Research Council - Water Research Institute (IRSA-CNR), Roma, Italy

*Valeria Ancona* - Valeria Ancona is Research Scientist at Water Research Institute –National research Council (IRSA-CNR), Bari – Italy. She's got her Ph.D. in Agricultural Chemistry, in 2008. She studied the decontamination processes of soils as a result of the synergistic action between plant species and soil microorganisms through the integrated use of microbial ecology techniques, aimed at assessing the structure and composition of soil microbial communities, and by means of analytical techniques for the determination of contaminants (organic and inorganic). Also, she is currently studying the effectiveness of BES techniques in promoting soil decontamination from organic toxic compounds. She has been involved in regional and national projects on plant-assisted bioremediation for recovering soil pollution and producing renewable energy from biomass. She is currently managing a research group including 2 Post Docs, 2 PhD students and 1 research fellowship. She is the Lead Researcher of "GREEN SOLUTIONS" project (funded by

Apulia Region in the framework of the INNONETWORK call) and responsible of a WP on Plant-assisted bioremediation techniques for soil depollution in the framework of “Energy for Taranto Technology And pRocesses for the Abatement of pollutaNts and the remediation of conTaminated sites with raw materials recovery and production of energy tOtally green (TARANTO)” project, funded by the Ministry of Education, University and Research, grant number ARS01_00637. Her scientific activity has produced more than 80 contributions: papers published in national and international scientific journals (ISI), conference proceedings and technical reports. Recently she is involved in the Phoenix Cost Action (CA19123 - Protection, Resilience, Rehabilitation of damaged environment). Tutor and co-tutor of students for master and PhD degree theses. Referee for various international scientific journals. Her Scopus H-Index is equal to 8.

*Domenico Borello* - Domenico Borello is Professor of Power Systems at Sapienza University of Rome. He’s got his Ph.D. in 2000 in Energy Systems. He has a specific interest in energy conversion processes with a specific focus on innovative, sustainable technologies. He is currently managing a research group including one Assistant professor, 3 Post Docs, 3 Ph.D. students. He is leading the Fuel Cells and Biomass Gasification labs at DIMA. In the first one, experiments on terrestrial microbial fuel cells are currently carried out aiming at understanding their capabilities for soil decontamination as well as for energy harvesting. He is a member of the PHOENIX Cost Action CA19123, where he is leading the Working Group 4 Point of Load. In the biomass gasification lab experiments on gasification and energy valorisation of biomass from phyto-assisted bioremediation are currently carried out aiming at understanding the syngas properties as well as the fate of the phyto-extracted contaminants. He is author of >90 peer reviewed research contributions to international papers&conferences. His Scopus H-index is equal to 19.

*Anna Barra Caracciolo* - She is an Ecologist PhD and Research Director at IRSA-CNR. Her current research field is the study of contaminant fate with particular regard to the role of the natural microbial community in removing chemicals (bioremediation) alone or in support to plants (phyto-assisted bioremediation). She teaches Bioremediation in the Ecological Master Course at Rome Sapienza University. She is member of the European Society of Environmental Toxicology and Chemistry (SETAC). She is the Coordinator of “AZeRO antibiotic Project” – funded by LAZIO INNOVA (Lazio Region) and is responsible of “innovative method design for identification of microorganisms involved in bioremediation “in the Project “Green Solutions” (FESR-FSE 2014-2020). She is author of 200 publications including research and opinion papers in peer-reviewed journals, book chapters and Meeting Proceedings. Her Scopus H-Index is equal to 26.

Invited submissions

## SDEWES2021.0101

# Microcosm Experiment for Assessing Sunflower Capability to Grow on a PCB-Contaminated Soil

V. Ancona*[1], A. Gatto[2], G. Aimola[3], I. Rascio[4], M. Tumolo[2], D. Losacco[2], V. Locaputo[1], P. Grenni[3], G.L. Garbini3[2], L. Rolando[5], A. Visca[5], V. Uricchio[2], A. Barra Caracciolo[6]

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## Abstract

Polychlorinated byphenyls (PCBs) are bicyclic aromatic compounds constituted by a biphenyl molecule variously chlorinated. Based on the position of chlorines on the biphenyl rings, 209 congeners can be identified. PCBs are persistent organic pollutants (POPs) and they can be toxic for both human and ecosystem health. Plant-assisted bioremediation (PABR) has been demonstrated as a sustainable green remediation strategy to recovery multi-contaminated soils. The interactions that occur in the root zone between the natural microbial population in the rhizosphere and root system make it possible decontamination processes. In this work, a preliminary study was performed for 6 months in microcosm experiments for evaluating the sunflower capacity to grow and to promote PCB degradation. The soil was collected from an area contaminated by PCBs, located close to Taranto city (Southern Italy). Different experimental conditions (low contamination, high contamination, compost addition) were set-up. Soil chemical analyses (pH, organic carbon, available phosphorous, etc.) and PCB analyses, in soil and plant tissues, were performed. Finally, soil microbial communities were investigated in terms of the total abundance and activity under the various experimental conditions. The structure of the main microbiological groups was also assessed. Moreover, the possible use of sunflower biomass for energy treatments was also investigated. The main chemical and microbiological results will be reported and discussed.

## SDEWES2021.0119

# Fluidized Bed Gasification of Biomass from Plant-Assisted Bioremediation: Assessment of the Effect of Different Catalytic Bed Materials on Heavy Metals Emissions

E. Paris[1], D. Borello*[2], M.V. Migliarese Caputi[3], M. Carnevale[1], V. Ancona[4], G. Aimola[5], F. Gallucci[1], G.G. Gagliardi[3]

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## Abstract

PABR (Plant-Assisted BioRemediation) is an excellent green strategy for the recovery of contaminated soils. A possible route for set up a circular approach for the valorisation of PABR biomass consists in gasification, producing valuable Syngas while sequestering hazardous materials disposed in biomass. Here, materials commonly used in Fluidized Bed Gasifier (FBG) reactors were compared during the gasification of PABR biomass (Arundo Donax, rich in metals). The tested materials were Olivine, K-Feldspar, Limestone, Kaolinite and Quartz Sand. The gasification process was carried out in lab-scales on a TGA-DTA (Thermogravimetric Analysis - Differential Thermal Analysis) interfaced with a bubbler system for sampling the heavy metals generated in emission. To assess the occurrence of metal release from bed materials, the tests were done both on single materials and on material + PABR biomass mixtures. The products obtained from the simulation in TGA-DTA were also analysed at SEM-EDS to characterize the surface composition of the tested materials. The comparison of the obtained data showed that K-Feldspar and Limestone represent the most appropriate materials, even if the second one undergoes a weight loss of over 60% at the considered operating temperatures. The work also represents a useful assessment of new bed materials for FBG, to be employed in pilot and real scale applications.

## SDEWES2021.0162

# Organic Amendments of Contaminated Soil for Improving Phyto-Assisted Bioremediation

V. Ancona[1], G. Aimola[2], G.L. Garbini3[3], P. Grenni*[2], D. Losacco[3], I. Rascio[4], I. Nogues[3], R. Terzano[5], F. Pietrini[3], M. Zacchini[3], C. Porfido[5], V.F. Uricchio[2], A. Barra Caracciolo[6]

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## Abstract

Soil is the final receptor of harmful waste materials and xenobiotics from various anthropogenic sources. Heavy metals (HMs) and polychlorinated biphenyls (PCBs) are among the most frequent soil contaminants and cause concern for their hazardous effects, due to their intrinsic toxicity. Plant-assisted bioremediation technologies are nature-based solutions for soil restoration and can promote contaminant removal, increasing both organic carbon content and the activity of autochthonous microbial communities. The synergistic interactions between soil microbial communities and plant-root system can promote soil metal detoxification, favouring their stabilization and/or translocation processes. In this research, organic amendments such as biochar (BC) or compost (CMP) were used for improving the soil quality of a high PCB-contaminated (up to 8000 ng/g) area where a previous poplar-assisted bioremediation (PABR) strategy was applied. The success of the PABR strategy was limited in some plots where the PCB concentrations were so high to be toxic for some trees planted in the contaminated area. Six high-contaminated plots were identified and amended with BC or CMP, depending on the specific PCB and HM levels found. Other three plots were not amended and used as controls. Before the treatments, soil samples were collected from each investigated plot. Six months after adding the organic fertilizers, soil samples (bulk and rhizosphere) and plant tissues (leaves, shoots and roots) were collected from each selected plot. Physico-chemical (pH, soil nutrients, etc.) and microbiological (microbial abundance, cell viability, dehydrogenase activity) analyses were performed in order to evaluate possible soil-quality improvement. Moreover, PCBs and HMs were analysed in both soil and plant tissues by using mass spectrometric techniques. The physiological status of each poplar target plant was assessed in terms of leaf chlorophyll content and fluorescence. Also, phenolics and the ascorbate content were analysed as indicators of plant stress status. In addition, micro-X ray fluorescence (µXRF) analyses on biomass samples (leaves, roots), made it possible to visualize the HM distribution and mineral nutrients in plant materials. Preliminary results evidenced different effects of the CMP or BC on promoting PCB and HM removal, depending on the initial pollutants concentrations.

## SDEWES2021.0230

# Chemical Valorization of Poplar Biomasses Grown on a Contaminated Area: Effect of One-Step Pre-Treatment with Performic Acid to Enhance Enzymatic Digestibility

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## Abstract

Plant assisted bioremediation (PABR) technology for recovering contaminated areas is the next frontier of the “Circular Economy”. In fact, biomasses obtained from green remediation strategies can represent a new valuable feedstock for obtaining fine chemicals and/or liquid fuels of new generation.

In this work, a sustainable technology chain for recovering chemicals from poplar grown on a multi-contaminated area, is presented. Poplar pruning residues were collected from a PABR-treated area located close to the city of Taranto, in the South of Italy. Polychlorinated biphenyls (PCBs) and heavy metals (e.g. Zn, V, Pb) occurred in soils of the survey site before starting PABR strategy. A detailed chemical characterization of poplar biomass samples was performed. Cellulose (44%), hemicellulose (15%), lignin (28%) and minerals were the main components determined in therein. With the aim of valorising the cellulosic component of such a biomass, a one-step pre-treatment based on the use of performic acid was designed and tested. Performic acid was generated in situ through the use of formic acid and hydrogen peroxide under very mild conditions (80°C). The effect of this pre-treatment was measured in terms of delignification, enhancement in enzymatic digestability of the residual cellulose and final fate of the mineral components initially present into poplar biomass.

Different concentrations (3.5, 7 and 14 M) of performic acid were tested. Biomasses recovered after pre-treatment resulted significantly subjected to delignification: 28.5, 92.8 and 100% of initial lignin were respectively removed and dissolved. Enzymatic digestibility was then proven to be effective already on samples pre-treated with 3.5 M performic acid: cellulose was completely dissolved after a test run with a commercial cellulase.

In the same pre-treatment, most of minerals were dissolved into the generated aqueous phase allowing the containment of the removal of heavy metals from soil to be achieved.

Hydrolysed cellulose obtained from enzymatic digestibility test, after a preliminary removal of the enzyme through an ultrafiltration, which allow the reuse of the enzyme, was finally reacted in presence of $AlCl_3 \cdot 6H_2O$ and sulphuric acid at 180°C for 2 h. A final yield of 75% of levulinic acid was eventually obtained.

Through this process, not only the bioremediation resulted confined in a proper solution, but also value was generated from the residual poplar biomasses by generating a platform molecule which could find application in production of fine-chemicals.

## Special session: Renewable energies, innovative HVAC systems and envelope technologies for the energy efficiency of buildings

The need to increase the sustainability and energy efficiency of buildings has led to the development and implementation of innovative buildings design criteria and standards with special attention to the integration of renewable energies, use of innovative HVAC systems and implementation of new building envelope technologies, together with the use of integrated approaches for the sustainable design of buildings and communities toward the decarbonization of our economies.

The goal of this special session is to present new research results, case studies and practices aimed at reducing the energy demand of residential, commercial, public, and industrial buildings, by also decreasing the related environmental impact and improving the occupants' comfort and well-being. The special session is dedicated to the following topics:

Automation and innovative control for HVAC systems in buildings

- Building Information Modelling and integrated design approaches
- Building integrated renewable energy systems
- District heating and cooling
- Electrical storage systems
- Energy sustainability, resilience and climate adaptability of buildings
- Heat recovery systems in buildings
- Geothermal heat pumps systems
- Innovative HVAC&R systems
- Life cycle energy efficiency of buildings and embodied energy
- Natural, mechanical and hybrid ventilation
- Passive envelope technologies and new materials
- Renewable energy systems
- Smart buildings and districts
- Solar heating and cooling
- Thermal energy storage technologies
- Thermally active building systems

Vehicle-to-building.

### Session organizers:

**Prof. Annamaria Buonomano**, University of Naples Federico II, Napoli, Italy

**Prof. Soteris Kalogirou**, Cyprus University of Technology, Limassol, Cyprus

**Prof. Adolfo Palombo**, University of Naples Federico II, Naples, Italy

*Annamaria Buonomano* - Annamaria Buonomano obtained a B.Sc. and a M.Sc. in Engineering Management summa cum laude in 2004 and 2006 from University of Naples Federico II and a Ph.D. in Energetics from University of Palermo in 2010. She was visiting scholar at the Energy Performance of Buildings Group of the Lawrence Berkeley National Laboratory (Berkeley, USA) in 2009, researcher at the Ben Gurion National Solar Energy Center of the Jacob Blaustein Institutes for Desert Research of University of Ben-Gurion (Sde Boqer, Israel) in 2011, and several times visiting scientist at Concordia University (Montreal, Canada), where she was appointed as Affiliate Assistant Professor in the Department of Building, Civil and Environmental Engineering in 2017. She is actively involved in research topics regarding building energy efficiency, with a particular focus on the development of performance simulation models and investigation of innovative building-plant solutions, based on integrated construction techniques, innovative HVAC systems and novel renewable energy technologies including solar heating and cooling systems, concentrating photovoltaic solar thermal systems, polygeneration, vehicle-to-grid, vehicle-to-buildig and related advances concepts (B2V2B or V2B2). She is also involved in collaborative research activities relative to the design of net zero energy buildings and communities through the integration of passive solar thermal systems in buildings and the use of electric vehicles to add flexibility to buildings.

*Soteris Kalogirou* - Professor Soteris Kalogirou is at the Department of Mechanical Engineering and Materials Sciences and Engineering of the Cyprus University of Technology, Limassol, Cyprus. He is currently the Dean of the School of Engineering and Technology. In addition to his Ph.D., he holds the title of D.Sc. He is a Fellow of the European Academy of Sciences and Founding Member of the Cyprus Academy of Sciences, Letters and Arts. For more than 35 years, he is actively involved in research in the area of solar energy and particularly in flat plate and concentrating collectors, solar water heating, solar steam generating systems, desalination, photovoltaics, and absorption cooling. He has a large number of publications as books, book chapters, international scientific journals and refereed conference proceedings. He is Editor-in-Chief of Renewable Energy and Deputy Editor-in-Chief of Energy, and Editorial Board Member of another seventeen journals. He is the editor of the book Artificial Intelligence in Energy and Renewable Energy Systems, published by Nova Science Inc., co-editor of the book Soft Computing in Green and Renewable Energy Systems, published by Springer, editor of the book McEvoy's Handbook of Photovoltaics, published by Academic Press of Elsevier and author of the books Solar Energy Engineering: Processes and Systems, and Thermal Solar Desalination: Methods and Systems, published by Academic Press of Elsevier. He is a member of World Renewable Energy Network (WREN), American Society of Heating Refrigeration and Air-conditioning Engineers (ASHRAE), Institute of Refrigeration (IoR) and International Solar Energy Society (ISES).

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Invited submissions

## SDEWES2021.0051

# Effect of Climate Changes on the Energy Performance of Nzebs in Mediterranean Climate: Discussion About the Renewable Integration

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## Abstract

The paper is focused on the evaluation of how the climate changes can influence the performance of buildings designed to be nearly zero energy. The case study is named BNZEB and it is a single-storey dwelling built in Benevento (South Italy, Mediterranean climate). With five-years monitored meteorological data, the typical meteorological year is defined. This scenario represents the reference to evaluate the changes in the performance of the case study both with the climate files built to account for extreme weather events and with the files containing the future medium and long term climate projections generated using the CCWorldWeatherGen tool.

From these comparisons, the achievement of the nearly zero energy goal is evaluated as well as the effects on heating and cooling energy demand. Moreover, the energy balance between energy consumption and PV generation, is discussed considering the building resilience.

## SDEWES2021.0052

# Large-Scale Hydrogen Production Using a Grid-Connected Renewable-Based Water Electrolysis System in Different World Climates

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## Abstract

Green hydrogen can be produced via water electrolysis using various renewable energy sources. In this work, the performance of a grid-connected wind turbine (WT)- photovoltaic (PV) water electrolysis system for large-scale hydrogen production is investigated. A large dataset covering a 50 MW-50 MW WT-PV hybrid renewable hydrogen production system in six localities characterized by different climatic conditions was created performing dynamic simulations by means of TRNSYS software.

Various dimensionless indicators are discussed in detail for the standardization of performance indicators for renewable-based hydrogen production systems, such as the PV and WT satisfied load fraction SLF, the PV, and WT utilization factor UF and the grid energy interaction factor GEIF. These indicators define, respectively, the electrolyzer load portion satisfied by the WT and PV, the generated WT and PV energy portion supplied to the electrolyzer load, and the quantity of energy exported to and imported from the grid.

## SDEWES2021.0053

# Climate Change and the Building Sector: an Integrated Building Energy Simulation Early – Design Tool

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## Abstract

The effects of climate change are clear on a global scale either from the perspective of global warming and the increase in the rate of occurrence of extreme weather events. This has impacts also for sure on the standard building performance analysis approach, since the buildings designed today are supposed to withstand for the following decades climate impacts that may be different than those they were designed for.

The paper proposes a simple, easy to use and freely available building simulation utility which performs morphing of existing weather data files and by connecting to the Energy Plus simulation routine allows to perform future climate building simulation analyses. Users are required to select one of the ASHRAE buildings models or provide one of their own choosing and to input the original weather data file. The tool will generate a future weather data file with the assumptions preferred (e.g. RCP scenarios, time frame) and elaborate results in terms of heating and cooling required for air conditioning.

The paper proposes also an implementation of the tool to a case-study aimed at showing the potential of the application proposed. A typical office building model from the ASHRAE library was simulated in two different locations under different climate change assumptions up to the year 2090. The analysis of the results in the two locations of Palermo (Italy) and Copenhagen (Denmark) highlight relevant increases in the current century of up to +20% of cooling requirements and similar reductions for heating in both case-studies, if compared to current levels.

The research targets a specific limit in the investigation of climate resilience of buildings and follows the principles described by SDSN in the definition of SDGs as well as the interest at the EU level towards climate neutral and innovative cities.

In this context, the paper may contribute to the limited availability of easy to use and free tools available for practitioners to investigate the design of climate resilience buildings.

## SDEWES2021.0062

# Experimental Study of a Solar System Based on Hybrid PVT Collectors for the Provision of Heating, Cooling and Electricity in Non-Residential Buildings

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## Abstract

This work aims to assess the real performance and validate a transient model of a solar hybrid pilot plant based on PVT collectors integrated via thermal storage tanks with an air-to-water reversible heat pump (rev-HP). The pilot plant provides space heating, cooling, domestic hot water (DHW) and electricity to an industrial building located in Zaragoza (Spain). The plant consists of eight uncovered PVT collectors (2.6 $kW_e$, 13.6 $m^2$), two water tanks and a rev-HP with a nominal thermal power of 16 kW for heating and 10.5 kW for cooling. The validation results over four weeks in winter show that the transient model fits the experimental data of the PVT collectors' performance, with an average error of 12% and 4%, for the thermal and electrical generation respectively. The estimated rev-HP performance differs more from the real data, which might be due to the rev-HP dynamics, faster than the selected simulation time step.

## SDEWES2021.0121

# Adaptive Transparent Insulation Materials for Window Application: Thermal and Optical Evaluation

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## Abstract

Thermotropic (TT) material can provide dynamic regulation of solar energy and daylight, thus achieving building energy saving and indoor environment improvement. Parallel Slats Transparent Insulation Materials (TIM) when integrated into the cavity of double-glazed windows can increase thermal resistance of window systems, thus reducing building heating energy consumption. In this paper, these two advanced technologies are combined together to form a novel window system. The optical properties of each individual slat and the entire window system have been investigated experimentally and numerically. The results shows that the TT slats can effectively reduce the visible and solar transmittance with well scattered spatial distribution when the TT material switch from clear to translucent state. The optical investigation results of this research will provide guidance for the further development of this system.

## SDEWES2021.0126

# Creating User-Building Interaction Profiles for Low-Carbon Heating in Residential Buildings in Europe

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## Abstract

This work is developed within the Horizon 2020 project SWS-HEATING, which aims at developing an innovative seasonal thermal energy storage unit for heating and investigating its exploitability. Therefore, an extensive, representative and multi-country tailored survey questionnaire eliciting social practices with heat as an energy service and perceptions of SWS-HEATING and other heating devices was submitted to a randomized sample of potential end-users in Europe. Moreover, within the project, the role of occupancy variability and use conditions in the performance of the proposed system is assessed. The present study focuses on the development of tailor-made user-building interaction models to be implemented in dynamic simulation. These models take advantage from the knowledge raised by the findings of the social survey to newly frame occupant behaviour scenarios representative of south, central, and north European countries. In this way, the influence of cultural context and demographic factors and their relation to heating preferences and practices are considered when developing the occupant behavior models.

## SDEWES2021.0146

# Demonstration of the Value of Network Topology Optimization for Advanced District Thermal Energy Systems

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## Abstract

In this paper, a network topology optimization framework was developed and applied to a prototypical district to determine the best design solutions for a district thermal energy system with respect to life cycle cost. The analysis focused on an advanced, fifth-generation district system operating at near-ambient temperatures. The framework leverages a particle swarm optimization algorithm and a minimal spanning tree heuristic to select an optimal subset of buildings and optimal network configuration. The topology optimization approach identified solutions resulting in life cycle cost savings of 14% to 72% (depending on the reference case) relative to designs based on heuristics. Analysis of the results indicates that fifth-generation district thermal energy systems have the potential to achieve significant reductions in energy use and emissions relative to building-level systems, but face obstacles to cost-competitiveness due to the prevalence of natural gas heating and low natural gas costs in the U.S.

## SDEWES2021.0154

# Influence of Input Data in Urban Building Energy Simulations: Lesson Learnt from an Italian Case Study

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## Abstract

Energy-related emissions growth in urban areas is among the causes that brought the scientific community to develop several Urban Buildings Energy Models (UBEMs), simulation platforms aiming to help public administrations and stakeholders in undertaking effective policies regarding buildings' efficiency and sustainability. The objective of the present work is to evaluate the effect of uncertainty in geometrical and operational input data on the accuracy of a lumped-parameter based Urban Building Energy Model. A sensitivity analysis has been conducted through the Monte Carlo method to quantify the effect of different sources of uncertainty, including internal setpoints, internal heat gains, thermo-physical properties of the building envelope and geometrical assumptions. This methodology has been applied to a case study consisting of 16 heterogenous buildings in the city centre of Verona, Italy, where energy measured data for the heating season were provided by the district heating network operator. Results underline the importance of the geometrical assumptions in Urban Simulations and the necessity to assess the uncertainties affecting the inputs prior to the accuracy of the UBEM itself.

## SDEWES2021.0168

# Development of Mgso4-Mesoporous Silica-Based Salt Composites for Thermal Chemical Energy Storage: the Role of Porous Structure on Water Adsorption

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## Abstract

Composites “salt in porous matrix” has been considered as a promising candidate for thermal energy storage due to their large sorption capacity and energy density and high cyclic stability. In this study, novel salt composites were prepared by using different mesoporous silica with large pore size and pore volume as the porous matrices and $MgSO_4$ as salt via impregnation method. Dynamic water adsorption experiments demonstrated that salt composites prepared by using Mesostructured cellular foam (MCF) with 3D-connected porous structure exhibited excellent adsorption capacities and fast adsorption rates. Compared to commercial silica with 2D-connected porous structure, the 3D-connected porous structure of MCF benefited the dispersion of salt and the reduced diffusion resistance of vapor flux inside the pores, which can effectively improve the hydration/dehydration rate. All the results indicated that the novel composites are expected to be a promising candidate for low temperature energy storage.

## SDEWES2021.0170

# Analysis of a New Index for the Thermal Performance of Opaque Building Components in Summer

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## Abstract

In the hot seasons, the thermal behavior of an opaque building component subjected to the cycle of solar radiation depends on the combination of its thermal insulation, thermal inertia, and capability of reflecting the incident solar energy. In order to rate the overall dynamic behavior of the component when a steady indoor temperature is ensured by an air conditioning (AC) system, a 'solar transmittance index' (STI) has been proposed. This is a component-based index calculated from a 'solar transmittance factor' (STF). The STI takes into account the radiative properties at the outer surface and the thermo-physical properties and layer structure of the materials beneath. It correlates the peak heat flux at the inner surface, relevant to energy need for AC and thermal comfort, to the peak solar irradiance. The peak heat flux is in turn correlated to the inner surface temperature, relevant to thermal comfort. Similar to the well known 'solar reflectance index' (SRI), the STI for the considered building component is determined comparing STF with two reference values, corresponding to a performance relatively low and very high, respectively. Thanks to its simplicity, the approach may allow defining easy to apply requirements to prevent building overheating, improve indoor thermal comfort, reduce cooling energy demand, and mitigate some fallouts of the urban heat island effect. In this work, focused on roofs above occupied attics, the heat flux and the peak temperature calculated by numerical simulation at the ceiling surface are compared with STF values for a wide range of roof types and layer structures, in different environmental conditions, in order to verify the existence of a significant correlation.

## SDEWES2021.0184

# Impact of Zoning HVAC Control Systems in Users Comfort and Energy Efficiency in Residential Buildings

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## Abstract

Recent developments in sensors, electronics and communications have motivated a lot of research into designing and optimizing HVAC control systems for buildings, often referred to as smart buildings. In particular, the standard EN 15232 regulates the use of HVAC control systems in buildings including thermal zoning as a fundamental condition in the energy efficiency in buildings. It means an HVAC zoning system can adapt the HVAC system working regime to meet the thermal demand in each zone using monitoring the air temperature according to users' preferences, in order to ensure thermal comfort in each zone and optimizing the HVAC system energy consumption. This is possible with a smart control system that can communicate with the HVAC system and control the equipment's indoor unit fan speed and set point temperature. However, sometimes it is difficult to evaluate new technological solutions employing conventional software because they are still not modeled and included in their libraries. In addition to this energy policy legislation, several voluntary standards and sustainability assessment methods for buildings have been developed by independent bodies, as BREEAM and LEED methodologies which have emerged as the most widely used around the world. This paper presents a thermo-economic analysis of a zoned control system comparing to the case with no zoning control. A residential building is studied in terms of the BREEAM certification scheme, in different Spanish cities. A model of the zoning system together with implemented HVAC control algorithms, developed in TRNSYS17, is presented and used for evaluating how the zoned control system guarantees a category B of thermal comfort and generates energy savings from 21-42%. The economic analysis results in payback periods from 4.2 to 5.8 years.

## SDEWES2021.0186

# Novel Pseudo 3D Design of Solar Thermal Facades with Triangle and Trapeze Solar Thermal Collectors for Increased Architectural Acceptance

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## Abstract

Novel pseudo 3D design of solar thermal facades is presented in the paper based on triangle- and trapeze- solar thermal collectors developed in the Renewable Energy Systems and Recycling R&D Centre of the Transylvania University of Brasov, Romania aiming to improve their architectural acceptance. Based on these two novel types of solar thermal collectors, all the subassemblies with two collectors of the same or different type having a common edge are identified in the paper, which become subsystems in the development of the solar thermal facades. Combined with an enlarged range of colours (green, purple, brown, red, orange, yellow etc.) the subassemblies are used to develop pseudo 3D patterns to increase the attractiveness of these solar thermal facades. These subassemblies can be also used for the stylized representation of various and complex images.

## SDEWES2021.0192

# HVAC Polyvalent Technologies to Balance Contemporary Loads in Buildings

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## Abstract

Energy efficiency improvement is recognized as an effective instrument to reduce buildings carbon footprint, giving to HVAC systems a key role for the transition of the sector. In this context, particular attention is devoted to electric solutions, among which the Polyvalent Heat Pump is recognized as a promising solution, being able to meet heating and cooling demands simultaneously and efficiently. Despite the potentialities that this technology could offer, few efforts have been reserved to it in literature. Therefore, this paper aims to fill this gap, investigating and modelling the Polyvalent Heat Pumps characteristics and operation modes through the development of a new and simplified numerical approach; moreover, attention is devoted to the development and use of appropriate Key Performance Indicators able to valorise these units and to highlight their peculiarity and potentialities, when compared to other all-electric HVAC configurations.

## SDEWES2021.0233

# Techno-Economic Comparison of Hydrogen- and Electricity-Driven Technologies for the Decarbonisation of Domestic Heating

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## Abstract

Sustainable transition pathways currently being proposed for moving away from the use of natural gas and oil in domestic heating focus on two main energy vectors: electricity and hydrogen. The former transition would most likely be implemented using electric vapour-compression heat pumps, which are currently experiencing market growth in many industrialised countries. Electric heat pumps have proven to be an efficient alternative to gas boilers under certain conditions, but their techno-economic potential is highly dependent on the local climate conditions. Hydrogen-based heating systems, which could potentially utilise existing natural gas infrastructure, are being proposed as providing an attractive opportunity to maximise the use of existing assets to facilitate the energy-system transition. In this case, hydrogen can substitute natural gas in boilers or in thermally driven absorption heat pumps. Both heating system transition pathways may involve either installing new technologies at the household level or producing heat in centralised hubs and distributing it via district-heating systems. Although the potential of hydrogen in the context of heating decarbonisation has been explored in the past, a comprehensive comparison of electricity- and hydrogen-driven domestic heating options is lacking in literature. In this paper, a thermodynamic and economic methodology is developed to assess the competitiveness of a domestic-scale ammonia-water absorption heat pump driven by heat from a hydrogen boiler compared to a standalone hydrogen boiler, a classic vapour-compression heat pump and district heating, all from a homeowner's perspective. Using a previously developed electric heat pump model, the different systems are compared for various climate conditions and fuel-price scenarios under a unified framework. The coefficient of performance of the absorption heat pump system under design conditions and the total system cost are found to be 1.4 and £5400, respectively. Comparing the annualised total costs of the options under consideration, it is shown that, assuming the future price of hydrogen for domestic end-users can be below 0.12 £/kWh, absorption heat pumps and hydrogen boilers can become competitive domestic heating technologies, and otherwise, electrification and the use of vapour-compression heat pump will be preferred.

## SDEWES2021.0246

# A Study on the Synergy Between a PV-Based Renewable Energy Community and a Low Temperature District Heating System with Distributed Heat Pumps

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## Abstract

Low temperature district heating networks with supply temperatures below 50°C efficiently supply heat for space heating and DHW production to both new and old buildings through high temperature water-to-water heat pumps installed in the users substations. This concept is particularly interesting for urban areas where waste or renewable heat can be recovered at low costs. One of these cases is Montegrotto Terme, a touristic town located in a well-known geothermal area in the North-East of Italy, where a large amount of groundwater is extracted from the ground, used by hotels and thermal spas, and then released to the environment. A past feasibility study found that the electrical energy demand of heat pump compressors would be the highest operational cost for the operator managing the groundwater-based DH network. Recently, the Renewables Energy Directive introduced a legal framework for Renewable Energy Communities (RECs), i.e. cooperative organisations for the development of local energy initiatives with non-commercial purposes.

The objective of the present work is to investigate to what extent such thermal network could benefit from a Renewable Energy Community (REC) including all the DH customers and further inhabitants that may share the electricity produced by their PV systems.

To this end, an urban building energy model (EUReCA) and a stochastic power load profile generator (FLEXMETER) were used to calculate the energy demand of the considered residential and non-residential buildings. PV production profiles were calculated using the Python library pvlib. This approach allowed to calculate the PV self-consumption in the case-study district of both individual buildings and of the Renewable Energy Community as a whole.

The computer simulations show that the increase of shared electricity linked to the district heating heat pumps is hindered by the different seasonality between consumption and PV production. In the best cases, such increase is limited to 6%. If the REC includes other users beside those connected to the DH network, the PV self-consumption of the community may reach 90% and the relative contribution of the heat pumps is reduced. The benefit brought by REC depends on the size and number of PV systems. There seems to be an optimal aggregated size of installed PV systems that maximizes the collective PV self-consumption. This occurs because the energy shared among REC members is incentivised. How to share this benefit between users and investors remains an open question for business models developers. In the considered case, the cost savings contribute to reduce the heating tariffs for the district heating customers. On the environmental side, the waste heat-based district heating network alone abates carbon dioxide emission by 65% compared to the current heat supply based on individual gas boilers. The use of PV systems further reduces $CO_2$ emissions up to -81%.

## SDEWES2021.0252

# The Transient Hygrothermal Modelling to Assess the Thermal Transmittance Variation of Opaque Walls in the Mediterranean Climate

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## Abstract

Many physical phenomena influencing the building thermal balance are treated in simplified in common energy simulations introducing an evident source of error when thermal performance has to be evaluated. In this regard, the thermal losses due to heat transfer through the building envelope usually are determined simply defining the U-value, especially in the case of steady and quasi-steady models. Such value does not contemplate the effects of evident perturbing factors such as the water capillary conduction and water accumulated inside opaque walls. Consequently, the steady thermal transmittance is set to a constant value during the whole simulation, with an evident simplification because the moisture content, determine by local climatic conditions, in turn, is strongly variable between winter and summer. Water content in opaque walls modifies the thermal properties of materials and it depends on climatic conditions because of the wetting and drying phenomena being mainly related to rainfall, incident solar radiation, velocity and wind direction. As a consequence, opaque walls can provide different values of the thermal transmittance related to the exposition and the location, noticeably affecting the building thermal energy requirements. In this paper, by means of dynamic numerical simulations, implemented in accordance the standard EN ISO 15026, the variation of the thermal transmittance during the year due to the variation of the moisture content in opaque vertical walls, was investigated. In particular, different wall layering usually employed in the construction of buildings in the Mediterranean area were investigated, by focusing on the thermal transmittance variation supposing the walls located in different climatic zones. Results showed how the percentage variation of the steady thermal transmittance during the year cannot be neglected, leading to deviances of about 30% during the whole year, and determining noticeable difference in the thermal energy demands for both heating and cooling services

## SDEWES2021.0259

# Optimal Household PV Arrays Under Current and Voltage Limitations

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## Abstract

In photovoltaic (PV) systems, inverters impose current and voltage boundaries for the arrays they are connected to. The present study aims to present a methodology to determine, given the voltage and current limit values of an inverter, which is the optimal array structure to be implemented, this is, the number of panels and the explicit set of connections between them. The determination of the optimal panel configuration relies on the optimization of a merit function that considers the power provided per panel, the total power obtained from the PV array and its reliability, weighted through parameters that control their relative relevance. Classical parallel connections result to be the optimal structures in terms of power production per unit panel. When power production is preferred, structures with large number of panels prove to be the best even when they are asymmetrically connected and thus some panels are underperforming. Finally, parallel connections of all panels are the optimal structures when reliability is the main contributor in the merit function. A case study of the inverter SunnyBoy 2.5 has been developed to gain insight in a particular case, computing the optimal structure in terms of the three parameters.

## SDEWES2021.0263

# Optimal Design and Operation of Distributed Generation and Biomass District Heating

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## Abstract

Building-level renewable energy systems contribute to the transition towards sustainable and energy-efficient urban areas and foster the active participation of prosumers within the energy generation and distribution stages. The European Union has also stressed the need for integrating district heating networks within the built context, with a particular focus on biomass exploitation. Although highly advisable, the coupling of thermal and electrical grids is often overlooked, especially from a prosumer-centered perspective. Under these premises, this paper proposes a mathematical model aiming at (i) defining the optimal infrastructure design for both thermal and electrical distribution grids and (ii) determining the optimal operation regulating energy distribution in local energy communities. The model is tested and discussed in a real urban district in Southern Italy. Results demonstrate the effectiveness of the proposed model to increase the awareness of urban planners in developing targeted action plans for the sustainability and decarbonization of urban areas.

## SDEWES2021.0266

# Design and Characterization of an Opv-Etfe Multi-Layer Semi-Transparent Glazing

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## Abstract

Architectural glazing presents several advantages in terms of aesthetics and user well-being perspectives. However, they can have large impacts on heating and cooling demands and artificial lighting requirements. Ethylene tetrafluoroethylene cushion systems present adequate insulating and transparency characteristics, and, combined with organic photovoltaic modules, become a glazing element leading towards energy efficient buildings. The present manuscript presents a detailed optical, thermal and electrical analysis of a 3-layer ethylene tetrafluoroethylene /organic photovoltaic cushion that may support these glazing-type systems by providing a better performance understanding. Spectrophotometric optical measurements up to 50 μm offer a complete view of the individual layer behavior. These measurements feed the optical and thermal models that aim at determining the influence of the organic photovoltaic module depending on the position in the cushion. In addition, based on the organic photovoltaic spectral response, electricity production is estimated. Results reveal that the best configuration is the one placing the organic module in the inner layer, since it represents a trade-off solution between thermal control and electricity potential production.

## SDEWES2021.0270

# Optical and Thermal Performance of a Mirror-Array Concentrating Solar Collector

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## Abstract

Concentrating solar thermal systems are widely used to supply heat for industrial processes. The state-of-the-art methods for the generation of solar process heat use different concepts like tracking Fresnel mirrors or parabolic troughs. However, devices able to operate at intermediate to medium temperatures are hardly available on the market.

To address this matter, an innovative concentrating solar thermal system is studied in the frame of the Hellenic – German cooperation project "SCoSCo". The proposed device makes use of a micro-mirror array to concentrate the solar radiation to the receiver. The purpose of this paper is to present the optical simulation results obtained by different software packages. The estimated collector efficiency based on thermal simulations is discussed as well.

Fig. 1: Proposed design of the mirror-array concentrator with receiver

The optical performance of the tracked mirror array was calculated using the ray-tracing software tools COMSOL, Tonatiuh, and Solstice.

As a preliminary optimum, the system properties as listed in Table 1 were determined. Prototypes for testing are currently under construction.

The thermal performance was calculated with the Matlab/Simulink toolbox CARNOT.

The specific annual yield at Patras with 100 °C inlet and 150 °C outlet temperature in matched-flow mode is expected to be > 700 kWh/m²a with respect to the module aperture area. In addition, to optimize the receiver design, temperature distribution calculations were done using COMSOL Multiphysics. It appears that the distance between riser pipes should not exceed 40 mm at the given boundary conditions.

## SDEWES2021.0290

# Nzeb Smart Management: Some Evaluations Based on the Energy Performance Monitoring of a Case-Study

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## Abstract

The NZEB reduced energy performance is one of the objectives of Directive 2010/31/EU. In order to maintain long-term optimal results, it is necessary to plan a correct management both of thermal systems and of passive climate control. Some strategies for setting up control systems and operating procedures of thermal plants are discussed on the basis of the simulation results and the long term measurements in a NZEB (case study),. The analyses quantitatively demonstrate how the correct energy management can significantly reduce the actual consumption, compared to the estimated one. The adopted control procedures for internal environmental conditions and plant systems, aiming at maintaining indoor comfort conditions and an efficient management of energy consumption respectively, underline the importance of providing home automation management systems in the design phase. Their smart use guarantees the expected performance, and in some cases can improve it, by adapting the energy behavior of the building to the users' specific needs. An important aspect is the analysis of the monitored data that currently are not widely available. A greater number of case studies could expand the knowledge of NZEB behavior: this would allow implementing strategies and controls of technical systems to obtain the maximum long-lasting energy performance.

## SDEWES2021.0307

# Energy and Economic Performance of Solar-Assisted Cooling Systems for Southern Italy: a Critical Comparison Based on a Case Study

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## Abstract

The growing availability of low-cost electricity-driven air-conditioning systems has determined a huge increase in the electricity demand for space cooling, especially in warm and hot climates. In this framework, solar-assisted cooling systems are a very interesting alternative, since they are mainly fed by thermal or electric energy produced by converting the largely available solar radiation: however, their economic convenience is still questionable. For this reason, many EU states have introduced suitable subsiding schemes: in Italy, for instance, the so-called “Conto Termico” has introduced cash-back incentives proportional to the thermal energy delivered by solar-assisted thermal systems.

This study presents a case study including a solar-assisted cooling system for an office building located in Palermo (Southern Italy). After a preliminary assessment of the cooling needs and the peak cooling load of the building, a simplified sizing of the system is carried out. Then its technical-economic feasibility is assessed taking into account the incentives introduced by the Italian “Conto Termico”. The results highlight that the proposed solar-assisted cooling system can significantly reduce primary energy demand and $CO_2$ emissions if compared to a conventional electric cooling system. However, even under these benefits, investment costs are high, as proved by the relatively long payback periods. Furthermore, the incentives call for high collecting surfaces, which is not always a rational choice.

## SDEWES2021.0312

# Analyisis of the Opportunity of Demand Response (Dr) Strategies in Shopping Centres

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## Abstract

The rapid expansion of renewable non-programmable generating units in powers systems is causing an increasing need of energy resources to provide ancillary services (e.g. reserves and balancing). To address this issue, new demand response (DR) strategies are being developed in distribution networks involving residential and non-residential consumers and prosumers and leveraging their communication and energy management infrastructures. The goal of these programs is to provide users flexibility to the transmission system operator, traded under market rules. DR strategies for industrial and commercial consumers pose unique challenges, as changing the load profile could lead to the violation of plant operational constraints, degradation of the service provided, or disruption of production processes. Shopping malls have great potential to become crucial players in providing flexibility to the grid by regulating their energy demand. The heating, ventilation and air conditioning (HVAC) system constitute up to 40% of the total load, therefore it has a high potential to provide flexibility to the grid according to the required occupants' comfort.

This study is focused on a shopping centre heated and cooled through an air HVAC system.

In this first stage of research, we wants to observe the possibility of providing a flexibility service without taken into consideration of the potential benefits deriving by the use of thermal or electrical storages.

Through building energy analyses performed in TRNSYS, simulations were conducted during the cooling and heating periods, foreseeing the possibility to introduce different DR events. The analysis starts by determining the daily consumption profile assuming standard conduction for the HVAC system (Baseline). Subsequently, for introducing DR events, (i.e electric load flexibility) the possibility to change the set point temperature and to modulate (reduction) the power supplied by HVAC systems, are analysed.

The results show that shopping centres have good potential for participation in DR services, however, during the summer season, the introduction of a DR event can compromise the thermal comfort of the occupants.

## SDEWES2021.0317

# The Role of Solar Cooling for Nearly Zero Energy Multifamily Buildings: Performance Analysis Across Different Climates

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## Abstract

The building sector has great potential for contributing to the 2030 EU goals of decreasing greenhouse gas emissions and increasing production from renewable sources. This is even more important considering the increasing cooling energy needs. Among the available technologies, solar cooling (SC) represents a good alternative to traditional electric chillers. However, its use in residential buildings is still limited.

The aim of this paper is to analyse the potential of solar cooling system in multi-family buildings. A dynamic model of a complete SC system with auxiliary components was developed in TRNSYS to meet the energy demand of a representative nearly zero energy multi-family building in Italy. The performance of different system design alternatives was analyzed in eight different climates with special focus on energy storages.

The results show how solar cooling should be optimally designed and provide quantification of achievable renewable energy ratios and related costs in the different climates.

## SDEWES2021.0321

# Building Integration of Active Solar Energy Systems in the Urban Fabric: Façade Renovation Using Building Integration of Active Solar Systems and Effects on Thermal Comfort in Public Spaces

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## Abstract

In the last few years, the negative externalities brought about by climate change are becoming evident. Moreover, in 2030, 80% of the world's population will live in cities, opposed to today's 50%, which explains the fact that cities are responsible for over 70% of global carbon dioxide emissions. Additionally, given that the built environment accounts for 24% of the greenhouse gas emissions and for over 40% of the total primary energy consumption in the world, some changes need to take place in the building sector towards the building integrated renewable energy production. In addition, the building stock of the European cities is getting old, thus bringing aspects of energy renovation, and building integration of active solar systems on existing buildings to the forefront of discussions.

The research performed herein, investigates the effects on thermal comfort in public spaces caused by integrating active solar energy systems on the facades of neighbouring buildings in Naples, a coastal city in south-eastern Mediterranean region. A typical area indicating the prevailing urban organizational system for Naples is chosen, and a simulation of the integration of active solar systems on the facades of buildings framing the public spaces was carried out. The thermal conditions on the street level are then simulated, using Envi-MET.

The aim of the research is to compare the thermal conditions in the public space, before and after the integration of these solar systems, evaluated through different filters of solar urban planning / building integration of active solar systems, with a view to proposing viable combinations for the integration of these systems as part of environmental renovation strategies in the urban planning and regeneration of cities.

## SDEWES2021.0324

# Effectiveness and Constraints of Using PV/Thermal Collectors for Heat-Driven Chillers

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## Abstract

Solar Cooling plants offer a reliable and environmentally friendly alternative to conventional electrically powered chillers for satisfying the building cooling demand. Although many types of research have analysed the performances of heat-driven chillers, these systems need to further detailed studies to highlight their potential for satisfying the building cooling demand in a sustainable and efficient way. In this paper, a dynamic simulation model of a pilot adsorption chiller powered by flat photovoltaic thermal collectors (PVT-ADS) in the Mediterranean area is presented. The performances of the adsorption chiller are derived from the pilot chiller developed at the Gebze Technical University in Turkey. The cooling and the power production have been investigated as a function of the regeneration temperature and the volume of the solar tank considering of technological limit temperature for the EVA layer. The energy comparison between the studied system and a plant constituted by a vapour compressor chiller fed through conventional PV modules (PV-VCC) is presented. This comparison evidenced that the Electrical yield of the PVT is significantly lower than that one of the PV, 1.0 kWh/day for kWp installed. This is one of the main constraints, which must be taken into consideration when the performances of solar cooling plant driven by PVT collectors. During a typical day, the PV-VCC produce more cooling energy than the PVT-ADS of about 2.9 kWh per kW of nominal cooling power installed. The results of this study are useful for evaluating the effectiveness of using PVT solar collector as a potential source for solar cooling plants.

## SDEWES2021.0329

# Optimized Design and Integration of Energy Storage in Solar-Assisted Ground-Source Heat Pump Systems

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## Abstract

According to latest IEA projections, heat pump is a key clean energy technology that will drive decarbonization of the building sector in the next few years. Systems based on the integrated use of multiple renewable energy sources, such as “Solar Assisted Geothermal Heat Pumps" (SAGHPs), seem to be able to overcome limits of traditional heat pump systems while increasing efficiency. However, their performance is influenced by the dynamics of renewable sources availability that do not usually follow the dynamics of energy demand. In this context, different thermal storage components are able to optimize the integration of renewable energy sources (or recovery) and the overall operation of the energy system, which require a careful optimization of each components in relation to the others, considering climate boundaries and economic feasibility.

Starting from the initial design of a system providing energy for heating and DHW of a newly built restaurant in an Alpine ski park, this work aims at investigating the potential design optimization of a SAGHP system in a mountain site. This entails dynamically exploring different design alternatives that are able to optimize the mutual relationship between the solar field, the geothermal field and the thermal storages through a dedicated simulation-based optimization method. The constraints occurring within the different variables are carefully defined according to real market and properly entered in the automated optimization process with a special attention of design variables driving the optimal integration of thermal storages based on performance in operation.

The system performance is analyzed with both energy and cost criteria included in a multi-objective function. The search for the optimal integration of energy storage in the SAGHP optimized design is performed in order to maximize the overall system efficiency while minimizing the overall electricity demand and therefore controlling the global cost, intended as the sum of investment and operation costs over a defined time span. A sensitivity analysis is performed to identify the robustness of the resulting optimal design alternatives and their sensitivity to financial parameters.

Results show that an optimized design of thermal storage in SAGHP systems, driven by simulation-based optimization, can improve the overall system performance compared to the initial design. Also, the used method demonstrated that, among the alternatives leading to the same energy performance, it is possible to identify design alternatives with lower global cost.

## SDEWES2021.0334

# Heuristic Model-Based Predictive Control Strategies for an Institutional Net-Zero Energy Building

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## Abstract

This paper presents the development of heuristic model-based predictive control strategies for a building archetype based on the first institutional solar NZEB building in Canada, the Varennes library is selected as a case study. In the considered case study, novel technologies such as 110 kW BIPV (building-integrated photovoltaics), (part BIPV/T – with heat recovery) and geothermal heat pump are integrated with distributed high thermal mass in a radiant floor heating-cooling system and passive solar design. Effective integration of passive and active technologies in a NZEB also requires an efficient control strategy to substantially decrease energy consumption and optimize the demand – generation profile when interacting with a smart grid. Beyond systematic integration, one of the key challenges that currently remain even in the high-performance traditional buildings is that the design and operation of the building are typically not considered together. This paper addresses this challenge by developing a rule-based predictive control strategy applied to the radiant floor heating system where depending on anticipated weather scenarios heuristic optimal room temperature setpoint profiles are selected. The objective is to show on a real building archetype example, that by using a simple and rule-based control strategy and fully utilizing the active and passive solar potential of the building it is possible to achieve a significant reduction in energy consumption and shift peak demand based on grid needs while ensuring comfort conditions. Given the fact that energy balance at hourly time scale might be as important as overall energy balance, two separate strategies with an emphasis on energy consumption reduction and load shifting at peak demand period are considered. Key Performance Indicators (KPIs) are compared with a currently implemented strategy in the building. An explicit finite difference $6^{th}$ order lumped parameter thermal network model is used to describe the dynamic behavior of the building. Model parameter calibration is performed and tested using real data to confirm the validity of the model. The paper also presents an approach for generalizing the heuristic predictive control strategies. Finally, theoretical and real-time energy flexibility is estimated and presented through performance indicators. Preliminary results showed the possibility of 25% energy saving on an extremely cold sunny day (a particularly important type of day for the electric grid in Quebec), with one proposed strategy. Another strategy with an emphasis on peak load shifting displaces 100% of the morning and 28% of the evening peak once the notification from the grid is given for both periods one day ahead.

## SDEWES2021.0350

# Improvements of Simplified Hourly Models for the Energy Assessment of Buildings: the Application of En Iso 52016 in Italy

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## Abstract

The issue of improving the building energy efficiency led to the development of many calculation methods for the energy performance assessment of buildings. To overcome the low accessibility to detailed input data, the EN ISO 52016-1 technical standard introduced an hourly calculation method that is based on reference assumptions and simplifications, chosen so as to allow a sufficient accuracy in the outcomes with a low amount of input data required and an unambiguous calculation flow chart. Moreover, to enhance flexibility in modelling choices, boundary conditions and input data, EN ISO 52016-1 lets individual countries to introduce different methods or default parameter's values in the national annexes. This is the case of the Italian National Annex (NA), currently at the drafting stage, which introduces improved methods regarding different aspects of the building energy performance assessment. In particular, an improved modelling procedure that takes into account the component layer's characteristics and mass distribution has been introduced for the R-C nodes determination. Moreover, hourly variation of the sky temperature and of the total solar energy transmittance of the glazed components have been introduced. The coupling of the thermally conditioned zones has been also discussed. The present study thus attempts to investigate the increase in the model accuracy related to the introduction of improved methods and assumptions. Moreover, the opportunity to expand the Italian NA is addressed through the evaluation of other improved methods and assumptions, provided in literature. The best trade-off between the achieved accuracy and the simplicity of the assessment is sought as well. Both the EN ISO 52016-1 original model and its improved variations have been applied to a residential building sited in different Italian climatic zones. The resulting accuracy has been evaluated through the comparison with the results of a detailed dynamic simulation (performed with the EnergyPlus simulation engine) in terms of heating and cooling thermal loads, and energy needs. The analysis shows that the simplified hourly method's improvement allows for a more accurate prediction of the building thermal behaviour, while guaranteeing the simplicity of the assessment.

## SDEWES2021.0375

# Design and Control Analysis for Building Integrated Photovoltaics-Heat Pump Combinations in a House

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## Abstract

This paper considers three design configurations of air source heat pumps and building-integrated photovoltaic systems in a solar house concerning energy efficiency and energy flexibility in interacting with a smart grid. The reference case is a 5kW building integrated photovoltaic system on the roof with a separate air-source heat pump water heater. In the two more novel options we have: first, a 5kW building-integrated photovoltaic with thermal recovery roof system where the heated air from the building-integrated photovoltaic with thermal recovery system is ducted to the air source of the heat pump water heater, which also contains integrated thermal storage (the hot water); in the second case we have an attached solarium with a 5kW semi-transparent photovoltaic facade, with the solar heated air in the solarium connected to the air source of the heat pump water heater with integrated water thermal storage. The three cases are modelled with an explicit finite difference thermal network model, and energy performance is determined and compared over a typical heating season in Montreal. The energy flexibility of the options is compared for different scenarios, such as heating the thermal water storage during the daytime (e.g. using the solar heat in the novel options) and using it for space heating during the time that the grid is under stress (and may have price incentives). Results show that the second novel case utilizing the solarium air as the inlet of the heat pump had over 80% reduction in energy consumption relative to the reference. In comparison, the building-integrated photovoltaic with thermal recovery configuration had around 20% reduction compared to the reference case. The tank volume and solarium size had the highest impact on the flexibility of the system. Ideal sizes for the tank volume were typically between 300 – 600 L for the house with a floor area of 116 m$^2$.

## SDEWES2021.0413

# Building Integrated Photovoltaic Thermal/thermoelectric (Pvt/tec) Air System: Modelling and Simulation

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## Abstract

This paper presents a novel building-integrated solar system with integrated thermoelectric cooler; the proposed concept consists of Photovoltaic/thermal (PV/T) panels and Peltier thermoelectric cooler (TEC). By exploiting the cooling of PV cells – necessary for increasing their electricity efficiency – PV/T devices simultaneously generate electricity and thermal energy. TEC devices allow achieving space cooling or heating, by exploiting heat transfer through TEC plates according to the direction of the electrical current. By suitably coupling PV/T panels to Peltier devices different building integrated PVT-TEC system layouts can be obtained. By such systems, a share of building electricity, heating and cooling demands can be balanced by also increasing the self-consuming rate of the PV production.

To assess the energy performance of PVT-TEC systems, a novel 2D dynamic simulation model based on a resistive-capacitance thermal network is purposely developed. In addition, to conduct building energy performance analyses, the model is implemented in a suitable computer tool written in MatLab. By such a tool different PVT-TEC configuration can be compared from energy and economic points of view.

## SDEWES2021.0489

# Building Integrated Concentrating Photovoltaic/thermal Glazing (Copvtg) Systems: Experimental Campaign and Dynamic Simulation Tool Validation

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## Abstract

The present paper investigates the electric and thermal performance of an innovative Concentrating Photovoltaic/Thermal Glazing (CoPVTG) system, developed and experimentally evaluated at the Centre for Sustainable Technologies of the University of Ulster (Belfast, UK). The novel smart window is purposely designed to be compatible with traditional façade structures and fenestration framing arrangements, facilitating direct integration into new and retrofit building applications. The device is made of a double-glazing panel whose outside pane is shaped into a series of concentrating lenses in which optical focus several PV cell stripes are located. The glazed concentrating elements are accurately designed to allow the sunlight to enter the building and provide natural daylight when required (winter months) while redirecting it onto the photovoltaic thermal absorbers to generate electricity/heat when solar gains need to be minimised to reduce cooling demands (summer months). Also, aiming at reducing the PV cells' temperature (and thus increasing the PV electric efficiency), a heat recovery system, based on a forced air flux, is adopted. Specifically, two slots, on the lower and upper frames of the window, are made to allow the air to pass through the device. In such a way, the produced hot air can be used for different aims such as space heating or pre-heating purposes, depending on the reached temperature. As a result, the innovative window delivers solar-generated electricity and thermal energy while also reducing the building heat losses (higher U-value with respect to standard windows). Aiming at investigating the innovative device performance under diverse boundary and working conditions, a suitable dynamic simulation tool has been developed in MATLAB environment. Employing the developed dynamic simulation tool, the innovative CoPVTG device performance has been investigated. In addition, two modifications of the original device have been also studied: the CoPVG and the CoPEG. From the carried-out investigations, promising results have been obtained.

## SDEWES2021.0492

# Analysis of the Energy Consumption of the Italian Railway Building Stock

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## Abstract

Since buildings are highly energivorous systems, the energy renovation of the current building stock is an important issue to be addressed toward a more sustainable society. For such a reason, today, both the political guidelines and administrative practices are oriented to stimulate the application of energy-saving measures in the building sector, mainly to the residential stock and to public infrastructures. Indeed, public administration should act as an example for private citizens. Specifically, according to the most recent national and international policy plans, two main actions such as reducing the final energy demand of buildings and exploitation of renewable energy sources need to be immediately undertaken. This challenging goal also leads to the need of renovating the building stock of railway stations which has undergone extraordinary development in the past century when no particular attention was paid to energy saving. Compared to other buildings, railway stations are particularly penalized in terms of energy consumption due to their intrinsic features (envelope, window-to-wall ratio, usage and occupancy pattern, etc.). However, the fragmentation in terms of construction typology, size and use of the building heritage owned by railway authority, with particular reference to the Italian one, entails the difficulty of establishing executive intervention plans.

In this framework, this research aims to complement the current knowledge by a robust and reliable analysis of the energy consumption of the Italian railway stations. The analysis was conducted by identifying a number of groups of similar stations that were clustered according to real data. Moreover, by the adoption of the Building Information Modelling to Building Energy Modelling (BIM to BEM) approach, a comprehensive building stock analysis was carried out in order to evaluate the "energy footprint" of the identified station typologies. Afterward, a data-driven model was also developed in order to correlate the analysed building characteristics and the climatic conditions with the simulated energy consumption of stations.

The Italian case was found a perfect location for this study since its wide range of weather and geographic characteristics, and the large building stock owned by the railway public company. The model provides results that are in good agreement with simulation data which demonstrates the validity of the adopted methodology and its applicability at international context. Furthermore, the model resulted to be a useful tool to support decision-makers in the energy renovation planning and to provide baselines for engineers.

## SDEWES2021.0493

# Exploring the Impact of Variable Physical Parameters of Human Body on the Assessment of Energy Demands in Smart Buildings Toward a Novel Dynamic Thermal Comfort Approach

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## Abstract

Indoor thermal comfort represents a key aspect of building design. The reference standards do not consider the thermal adaptability of the human body, and HVAC system control strategies are based on a steady-state assumption that returns an incorrect estimate of occupants' thermal demand with a consequential overestimation of the building energy consumption. To overcome these issues, a physiological thermal comfort model for the human body thermal behaviour evaluation is developed in MatLab environment. In the present work, heart rate and skin temperature are considered as input for the model that can be measured with thermo-scanner and wearable devices. Thus, the developed model allows to determine the dynamic variation of the physiological aspects, such as skin temperature, and to characterize the occupants' thermal sensation. Finally, the developed physiological thermal model is implemented in a building energy simulation tool (called DETECt 2.4) to perform suitable energy analyses on thermal comfort models impact. To show the potentiality of the developed model, a suitable case study consisting of an office space is considered. Here, space heating and cooling demands obtained by applying the novel developed model are compared to those obtained through standard thermal comfort models based on Fanger's theory. By the comparison, between the proposed model - which considers the occupant in thermal evolution – and the reference ones – considering the occupant heat exchange in steady state - , interesting results are obtained. The same HVAC system control strategy is used in the investigated models however, the results in thermal energy demands are different due to the dynamic variation of occupant thermal load gain. The annual heating and cooling demand in the reference case with the assumption of steady state are respectively 18.2 and 46.4 kWh/m$^2$·y whereas, assessing an occupant dynamic thermal evolution they are respectively equal to 20.4 and 44.8 kWh/m$^2$·y (+12% in heating and –3.5% in cooling). Furthermore, the comfort analysis highlights the difference in considering the physiological parameters of the person dynamically variable and not constant.

## SDEWES2021.0494

# Covid-19 and Indoor Air Quality: Dynamic Simulation Approach to Enhance Ventilation System in Railway Sector

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## Abstract

In the last year, the Covid-19 outbreak raised great awareness concerning Indoor Air Quality (IAQ) in confined spaces. Specifically, HVAC system design and operating parameters, such as Air Change per Hours (ACH), air recirculation ratio, and vents location, play a crucial role in ensuring indoor spaces air safety and in reducing the spread of viruses, mold, bacteria, and general pollutants. Concerning the transport sector, due to the impracticability of social distancing and to the low IAQ standards, the SARS-COV-19 outbreak brought a reduction of payload (up to 50%) for different carriers. Specifically, the payload reduction has been particularly severe for the railway sector, where carriages are typically characterized by a high recirculation ratio and low air changes per hour. In this framework, this paper aims at studying the feasibility and the convenience in adopting different solutions for indoor air quality enhancement in railway carriages, such as: increasing Air Change per Hour and reducing air recirculation ratio. Specifically, to carry out the energy-based ventilation analyses, a novel dynamic simulation tool for the complete performance investigation of trains was developed in OpenStudio environment. To prove the capabilities of the proposed approach and to show the indoor air quality improvements potentially achievable with the diverse investigated solutions, a suitable case study related to an existing medium-distance train operating in South/Central Italy is presented. Numerical simulations conducted by the developed models return interesting results providing also useful design criteria.

## SDEWES2021.0530

# Thermal and Electrical Modelling of a Double-Skin Façades Integrating Bifacial Photovoltaics: Energy and Economic Performance Assessment

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## Abstract

The use of integrated solar technologies is crucial to achieve the Nearly Zero Energy Building (NZEB) goal. Among the available technologies, the use of Double Skin Facades (DSFs) integrating photovoltaics is increasing in the last years. The basic idea behind this technology is to replace the outer building element with PV panels, increasing the prospects of renewable energy systems and energy efficiency of buildings. In this framework, this paper focuses on the potentials of Bifacial PhotoVoltaics in DSF, BiPV-DSF, addressed by means of a mathematical model. This is suitably developed in a MatLab environment and allows the modelling and optimization of BiPV-DSFs energy performance. This model assesses the impact of optical reflection layers properties, cavity thickness and airflow on the electrical producibility of PV panels with the aim of reducing energy demand in building. The simulation model also integrates an HVAC control to optimize the dynamic operation of the system, focusing on the cavity air-flow rate. The potentials of BIPV panels are quantified with an innovative energy performance index which highlights the effectiveness of double-sided panels compared with the mono-facial ones. Finally, by simulating the BiPV-DSF implemented on the external façade of an office space high-rise building, encouraging preliminary results are obtained in terms of energy production.

## SDEWES2021.0532

# Application of Artificial Neural Network for Energy Management of a Smart Community

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## Abstract

Due to the rapid rise of renewable energy sources, energy management has become much more complex and crucial. For this reason, suitable energy aggregators are required for resolving electric flow dispatching. These systems manage a large number of electricity fluxes in a unique and simplified electricity demand to be presented to the district system operator (DSO). In this context, starting from the concept of building prosumer, the transition to energy sharing lays the foundations for a community energy concept (Smart Community). This work proposes an innovative energy flow management concept within a community, able to involve customers passively by exploiting their potential energy flexibility. The main innovation relies on a matrix-based control system where the hourly strategy considers individual and community priorities simultaneously. Therefore, through the individual energy flexibility and the community energy pool, the aggregated network providing is controlled and shaped. The system is modeled in a suitable tool developed in MatLab environment, and it interposes the traditional individual contract with the energy supplier, to a) rely on predictive algorithms regarding energy demand and renewable production; b) maximize the self-consumption of renewable energy within the community; c) join with immediate response Demand Response events; d) reduce daily energy cost; e) consider automotive fleet into global community management optics. The presented model is based on a pure matrix approach, and it can be universally applied to many cases (e.g. different customers typology, different customer numbers, different production sources such as traditional and renewable-based energy sources, etc.). The predictive system is conceived from an artificial neural network (ANN), which performs a real-time prediction on energy demands in buildings. Suitable energy flows optimization is also presented with different implications in economic and energy savings. Moreover, the results give valuable information about the sizing of PV field and battery energy storage systems (BESS) installed in dwellings. Finally, to show the potentiality of the developed model, a suitable case study is presented. Interesting results underline the achievement of a typical WIN-WIN feature, where both the DSO and each customer benefit from this strategy.

## SDEWES2021.0533

# Simulation and Control for Energy Management: an Energy Management Strategy Applied to a Multi-Zone Building Coupled with Solar Based and Energy Storage Technologies

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## Abstract

The present study investigates the use and implementation of energy-efficient measures and strategies for building applications, toward the Near Zero Energy Buildings (NZEB) target. Specifically, the objective of the study is to implement Building Integrated Photovoltaic Thermal (BIPVT) devices coupled with Phase Change Materials (PCM) and thermal storage building components, increasing building flexibility while still maintaining the indoor comfort level of occupants. With this aim, a multi-zone grey-box model is developed to capture the thermal dynamics of a building and for use with a control strategy for energy management. The whole simulation model, including both thermophysical building, PVT, PCM and control features, is implemented in a MatLab environment. To assess the model and application potentials toward the optimal design and operation of the proposed system for energy efficiency and flexibility goals, a suitable case study analysis is conducted. Preliminary simulation results show that the proposed management strategy achieves load shifting, peak shaving, and grid interaction reduction, by optimally exploiting building thermal inertia and solar conversion toward the increase of building flexibility.

## SDEWES2021.0593

# A Cost-Optimal Analysis of Adaptation Measures in Educational Buildings of Warm Mediterranean Region

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## Abstract

Educational buildings form a significant part of non-residential buildings in public use, and in the case of Cyprus, this building stock tends to be less energy-efficient compared with other public building typologies. To deliver the European energy and climate objectives to 2050, significant changes are essential in the building sector, especially regarding existing public building stock. The current study presents an approach to design and assess energy demand retrofitting scenarios for educational buildings in Cyprus, based on the long-term cost effectiveness. Adaptation measures refer to changes in the geometry, construction, and operation of buildings. The approach combines energy demand modelling through dynamic software simulation using Integrated Environmental Solutions (IES-VE) and retrofit option ranking with life-cycle costing analysis (LCCA). These options may have very different upfront costs, but also very different carbon implications, and they result in different life expectancy predictions. The aim is to give the stakeholders as much information as possible regarding their interventions, so that they can make informed decisions. This information will then be used to develop a framework that may be used more extensively to support decision-making in retrofitting existing educational buildings for climate change resilience.

## SDEWES2021.0798

# Towards Energy-Positive Buildings Through a Quality-Matched Energy Flow Strategy

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## Abstract

Current strategies for net-zero buildings favour building envelopes with tight insulation, shading, and glazing emissivity control, thereby severely limiting holistic strategies to maximize on-site collection, transformation and application of available solar energy. In order to optimally leverage the on-site resource, a whole-building strategy is proposed: capturing, transforming, buffering, and transferring point-of-use solar energy, by matching the broad spectrum with distributed end use applications. A mid-scale commercial building was modelled in three climates with: multifunctional, solar collecting fenestration; thermal storage and circulation at three stages; adsorption chillers, and; heat pumps. The fenestration generated high efficiency electricity and thermal energy, while transmitting diffuse light and mitigating excess gains and illuminance. The balance of systems satisfied cooling and heating demands. Relative to baselines, building electrical consumption decreased 71% in a continental climate, while hot-arid and subtropical-moderate climates reached on-site net zero. Peak grid demand decreased 6%, 28%, and 20% respectively.

## Special session: Renewable Fuels and New Technologies in Sustainable Combustion

<p class="FirstlinePhDMV">In recent years, it is more and more evident that civilization expansion, correlated with global energy consumption, is affecting climate change. Most of the energy is still being extracted by combusting fossil fuels, releasing many environmentally dangerous greenhouse gases. The most prominent approach to mid-term emission reduction is the improvement of existing technologies. Such an approach does not require a significant investment in infrastructure and can enable the desired reduction of harmful gases. In the advancement of transport and energy production sectors, there are still technical challenges to be solved, and most are related to physical and chemical phenomena accruing in the combustion chambers. Therefore, the main objective of this special session is to bring together the scientists, researchers, and experts to exchange and share their experiences, new ideas, and research results about all aspects of combustion science, sustainable combustion technologies, and multiphase flow related topics: renewable fuels, fundamental physical and chemical aspects of traditional and novel fuel sources; reaction kinetics, combustion emissions, pollutants, soot, and particulates; IC engine combustion; gas turbine combustion; furnace combustion; dual fuel, ammonia, coal, biomass, biofuel and waste combustion; multiphase flows and sprays, fuel introduction methods, fuel dispersion, droplet interactions; particle technology, gasification and pyrolysis; new combustion technologies.

### Session organizers:

**Prof. Milan Vujanović**, University of Zagreb, Zagreb, Croatia

*Milan Vujanović* - Milan Vujanović is a researcher and team leader of CFD Combustion Research Group of the Power Engineering and Energy Management Chair at Department of Energy, Power Engineering and Environment, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb. Prof. Vujanović holds PhD in "numerical modelling of multiphase flow in the combustion of fuels". His research is in the areas of modelling and simulation of turbulent combustion, pollution formation, multiphase flows and sprays, and also in the areas of sustainable energy, environmental protection and climate change. He holds lecturers within courses "Combustion and Radiation Modelling", "Numerical Methods in Continuum Mechanics" and "Energy Engines". He has over 100 publications in Scientific Journals, Books and International Conferences Proceedings to his credit. Prof. Vujanović is a consultant to many industries and several public authorities. He is a member of the Combustion Institute, member of the European Research Community on Flow, Turbulence and Combustion, and member of the Centre for Sustainable Development of Energy, Water and Environment Systems.

Invited submissions

## SDEWES2021.0071

# Review of Regenerative Cooling Technology for Scramjet Engines: Phenomena and Challenges

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## Abstract

Regenerative cooling technology, currently the most optimum energy recycling method, can efficiently share the exceedingly high thermal load suffered by hypersonic scramjet engines. However, the development of propulsion system is restricted by the inherent problems of hydrocarbon fuel and cooling processes. This paper reviews the phenomena and challenges encountered in regenerative cooling research for the past few years, including the variation of thermophysical properties, fuel pyrolysis, surface coking, and associated kinetic models. Besides, a number of relevant solutions and measures for the existing problems are provided in this article. Thereinto, coking formation is very complex, and it poses many unfavourable impacts on the regenerative cooling process. Thus, the coke inhibition should be considered from different aspects, containing coking formation, additives and fuel proportion.

## SDEWES2021.0352

# Effects of Swirlers on Outlet Temperature and Co Emission of a Gas Turbine Combustor

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## Abstract

This paper investigated effects of swirlers with blade angles of 40°, 45°, 50°, 55° and 60° on outlet temperature and CO emission of a Can - type gas turbine combustor. Results show that large blade angle of swirler is beneficial to the mixing of fuel and air, which improves uniformity distribution of outlet temperature and reduces CO emission. Pattern factor reflects uniformity of temperature distribution at the outlet of the combustion chamber, and a small value of pattern factor means a good distribution uniformity. In this paper, the minimum pattern factor is 0.45 when the blade angle of the swirler is 55°, which means the best uniformity of temperature distribution at combustor outlet. Compared with the worst results with a 40° blade angle, the pattern factor for the blade angle of 55° decreases by 66.4%. CO emission decreases with the increase of the blade angle. Compared with the maximum value of CO emission for a 40° blade angle, reductions of CO emission are 67.6%, 95.9% and 99.6% with the blade angles of 45°, 50° and 55°. It is found that CO emission decreases by 1.3% and pattern factor increases by 2.2%, when the blade angle of the swirler changes from 55° to 60°. The most uniform temperature at the outlet is obtained for the 55° blade angle of the swirler in all the cases.

## SDEWES2021.0377

# Waste Cooking Oil Biodiesel Combustion in a Novel Low Emission Swirl Burner

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## Abstract

Waste cooking oil (WCO) is available in a large volume at households and restaurants. The collection efficiency varies by region and country. WCO is a second-generation biofuel, which means that its feedstock does not require arable land, hence, it does not endanger food safety. The potential of this energy source is low compared to our current needs, however, WCO-based biofuels excellently complement the current energy mix, providing a more versatile portfolio and strategic benefits. WCO has a high viscosity and low volatility compared to conventional liquid fuels, making it unfavorable for most practical combustion systems. Since it has a high heating value and the energy demand for transesterification is low, its conversion to biodiesel is a straightforward option. The material properties and evaporation characteristics of the WCO-biodiesel approach that of diesel oil. A novel combustion concept, called Mixture Temperature-Controlled (MTC) combustion, was recently developed at Budapest University of Technology. It allows ultra-low $NO_x$ emission without increased CO or unburned hydrocarbon emission. Combustion of various WCO biodiesel and diesel oil bends are evaluated in the MTC burner at different equivalence ratios to understand the correlation between fuel volatility and distributed combustion better. The distributed combustion mode was characterized by < 50 mg/Nm$^3$ $NO_x$ and < 15 mg/Nm$^3$ CO emissions at 3% reference $O_2$ level, which fulfill the strictest European emission regulations with a significant margin. The potential applications of MTC combustion are gas turbines, boilers, furnaces, and other industrial combustion chambers where steady combustion is desired.

## SDEWES2021.0395

# Slagging Mechanism of Multiple Biomass Co-Combustion in a Full-Scale Circulating Fluidized Bed Boiler

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## Abstract

Biomass is valued and promoted all worldwide in replacing the fossil fuels because of its green and sustainable features. The co-firing of multiple biomass with coal is strongly encouraged in China, using a circulating fluidized bed (CFB) boiler. Co-firing of five biomass types, including eucalyptus bark, branches, compressed board, bamboo, and furniture waste, are studied with coal in the CFB boiler in Guangdong Province. Co-firing causes a severe slagging problem in the boiler. Therefore it is very important to analyse the slagging mechanism and the effect of each biomass on the slagging. In this study, different slagging samples from high-temperature superheaters and low-temperature superheaters in a biomass CFB are investigated. The different samples are classified according to their colour and shape concerning different areas. The results show that the outer layer and inner layer of high-temperature superheater slagging are hard materials, mainly consisting $Ca_2Al_2SiO_7$ and $Ca_2MgSi_2O_7$. The middle layer formed from two types of materials: ash and white crystalline materials. The increase in KCl is prominent in the slagging sample from low temperature superheater. This is due to the condensation of a large amount of gaseous KCl present in the flue gas. Among the biomass used, eucalyptus bark, branches and bamboo contains more chlorine, which can easily lead to slagging and contamination of biomass boilers. The furniture board contains more harmful elements, which pollutes the environment. This article would provide guidance for the normal co-firing of biomass in the CFB boiler operation.

## SDEWES2021.0396

# Transition of Coal Regions by Cultivation of Short Rotation Copies and Dedicated Energy Crops for Biomass Co-Firing – a Case Study

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## Abstract

In developing countries, which dominantly produce electricity from coal, energy transition represents a significant challenge. Short rotation coppice (SRC) and dedicated energy crops could be a promising raw material for biofuel production and further biomass co-firing for electricity and heat generation. This work assesses possibilities and elaborates on the sustainability of cultivation of willow SRC and dedicated energy crop Miscanthus on former area of seven coalmines belonging to the largest power utility in Bosnia and Herzegovina, namely JP Elektroprivreda BiH d.d. – Sarajevo (EPBiH). Huge area was mapped and, by settled criteria, dedicated to either integration of future photovoltaic power plants (PVPPs) or the cultivation of energy crops and their further use in the EPBiH's generation portfolio mix. In order to adequately assess the contribution of both PVPPs and biomass in the upcoming energy transition process, specific sustainability indicator groups have been determined and used for sustainability ratio calculations. The paper focuses on economic, environmental and social indicator groups which were used to perform the aggregated economic analysis (AEA) and the multi criteria analysis (MCA).

Performed AEA lightly favours the construction of PVPPs over the use of willow as fuel. In this analysis, mischantus is lagging far behind due to its lower yield compared to willow. MCA on the other hand valorises the social indicator adequately, while the sustainability ratio results are much closer for all considered RES types, enabling decision-makers to draw appropriate conclusions.

## SDEWES2021.0398

# Enrichment of Residual Carbon from Coal Gasification Fine Slag by Spiral Separator

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## Abstract

Coal will still occupy a dominant position in China's energy structure for quite a long time in the future. The treatment and comprehensive utilization of solid waste gasification fine slag generated in the process of coal conversion and utilization has become one of the research hotspots. At present, it is mainly through landfill treatment. A certain amount of residual carbon in coal gasification fine slag is the key factor affecting its comprehensive utilization. In this paper, the residual carbon in gasification fine slag was separated by spiral separator. The results show that the ash content of spiral concentrate (the enrichment product of residual carbon) is 43.54%, and the ash content of tailings product is 89.75%. The particle size composition of spiral separation products were analyzed, and $N_2$ adsorption, TGA and SEM analysis were used to analyze the characteristics of the particles in the spiral separation flow field, and the changeable rule of the properties of gasification fine slag particles was studied. The specific surface area of spiral concentrate is 168.96$m^2 \cdot g^{-1}$, and that of tailings is 288.05 $m^2 \cdot g^{-1}$. TGA shows that the weight loss rate of spiral concentrate is the highest and that of tailings is the lowest in air atmosphere. It can be seen from SEM that the porosity of concentrate is relatively low, while the porosity of some particles in tailings is very high. It can be seen from the product properties of spiral separation of gasification fine slag that due to the influence of porosity, the stratification effect of gasification fine slag particles in the spiral flow membrane separation process can not form light and heavy products according to the density separation theory, and then form the properties of products enriched in residual carbon and tailings

## SDEWES2021.0425

# Study on the Effect of Flow Blockage Due to Rod Deformation in Quench Experiment

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## Abstract

During a loss-of-coolant accident (LOCA) in the pressurized water reactor (PWR), there is a possibility that high temperature and internal pressure of fuel rod lead to the ballooning of fuel rod cladding, which causes a partial blockage of flow area in a subchannel. Such flow blockage would influence the core coolant flow, thus affecting the core heat transfer during a reflooding phase and subsequent severe accident. However, most of the system analysis codes simulate the accident process based on the assumed channel blockage rate, resulting in the fact that the simulation results are not consistent with the actual situation. This paper integrates the developed core Fuel Rod Thermal-Mechanical Behavior analysis (FRTMB) module into the self-developed severe accident analysis code ISAA. At the same time, the existing flow blockage model is improved to make it possible to simulate the change of flow distribution due to fuel rod deformation. Finally, the ISAA-FRTMB is used to simulate the QUENCH-LOCA-0 experiment to verify the correctness and effectiveness of the improved flow blockage model, and then the effect of clad ballooning on core heat transfer and subsequent parts of core degradation is analyzed.

## SDEWES2021.0430

# Severe Accident Analysis of the Dual-Functional Lithium-Lead Test Blanket Module (Dfll-Tbm) Using the Isaa-Dfll Code

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## Abstract

"ITER" project aims to build a tokamak fusion test reactor to verify the feasibility of fusion reactors. The test blanket module is the key component of the ITER. The Fusion Design Study team proposed the concept of the Dual-Functional Lithium-lead Test Blanket Module (DFLL-TBM). ISAA is a self-developed severe accident analysis code that models the progression of severe accidents in nuclear power plants. A broad spectrum of severe accident phenomena including fission product release and transport behavior is modeled in ISAA. In this paper, a new version of ISAA, referred to as ISAA-DFLL is introduced for the application of DFLL-TBM into the treatment of multi fluids and the modules of the new physical property and heat transfer. The modification is verified by comparing the steady-state temperature distribution of the DFLL-TBM first wall with the design parameters. And then accident analysis of In-vessel loss of helium coolant in FW and TBM pipe are conducted by using the ISAA-DFLL code. By comparing the calculation results with the general safety requirements for TBMs, it is concluded that the design of DFLL-TBM system and the modifications of the current version are reasonable and accurate.

## SDEWES2021.0455

# Research on the Effects of Local Throttling on Two-Phase Flow Instabilities in Open-Channel System

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## Abstract

Thermal-induced two-phase flow instabilities referring to the flow drift and oscillation with a certain frequency in two-phase flow and heat transfer systems (such as Boiling Water Reactor core) due to small disturbance could badly slow the runtime performance of these two-phase systems and even endanger the safe operation. Hence, many researchers have carried out numerous researches on flow instability characteristics, but few publications cover the effects of local throttling on two-phase flow instabilities in open-channel systems such as coolant rod bundle subchannel with spacer grid in the nuclear reactor core. This paper provides a numerical study on the effects of local throttling on two-phase flow instabilities in a simplified typical coolant open-channel system in nuclear reactor core by using thermal-hydraulic (TH) system analysis code. The effects of local throttling ratio, throttling position, and other throttling parameters on the flow instability boundary, onset of flow instability, flow oscillation characteristics, and distribution of void and temperature under flow instability conditions in the open channel system were carried out. The results show that usually in uniformly distributed throttling conditions, the stability of the system and high throttling ratio are positively correlated; in fixed throttle ratio conditions, the stability of the system is positively correlated with the distance from the throttling region to the entrance and local void fraction; for the throttling region uniform arranged along the heating channel with a certain value, the number of throttle regions will enhance the instability of the system. Besides, this paper proposed a criterion function $f(n,RT,\alpha)$ to study the complicated throttling effects on flow instability which could provide technical reference for the safe design and operation of two-phase systems, especially, the reactor core.

## SDEWES2021.0476

# Numerical Modelling of Flue Gas Desulfurisation by Absorption in Spray and Wall Film

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## Abstract

In modelling of spray scrubbers used for flue gas desulfurisation, absorption in liquid wall films is generally disregarded, as insufficient data and numerical models are present in literature. Furthermore, no exact data is available for determining the importance of the wall film in the overall absorbing process. Present work parametrically analyses different models for mass transfer in wetted walls and compares them to the available experimental data. Additionally, the wall film absorption model is included in a previously implemented computational fluid dynamics model for sulfur dioxide absorption. Results indicate that the degree of wall film absorption depends on operating parameters such as temperature, liquid-to-gas ratio, spray configuration, and scrubber geometry, but the wall film can contribute up to 6 % of the overall absorption. Therefore, to model the absorption in spray scrubbers as accurately as possible, wall film phenomena cannot be disregarded.

## SDEWES2021.0478

# A Transient Model of a Hybrid System Based on Biomass Gasification and PV for Combined Cooling, Heat and Power for Electric Mobility Services

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## Abstract

The present paper analyses the techno-economic performance of a hybrid system, composed by a micro-cogeneration unit (mCHP), combining a syngas-fuelled engine with a biomass gasifier, a photovoltaic field (PV) and an electric energy storage system. The overall layout is dynamically simulated to assess its ability to cover building demands for power, Domestic Heat Water (DHW), space heating and cooling and the electric loads of the electric vehicles connected to the building.

An energy management control strategy is implemented, based on the dynamic partialization of the engine according to the electrical demand. The study revealed that the electric demand is completely satisfied with a 17.2% less consumption of the renewable feedstock with respect to the case in which the engine always runs at full-load conditions. However, lower cost savings and lower values of avoided $CO_2$ emitted in the atmosphere resulted from this strategy.

## SDEWES2021.0479

# Automatized Procedure for Calculation of Laminar Flame Speed and Autoignition Data Bases in Coherent Flame Models

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## Abstract

The impact of the transport sector on climate change and carbon dioxide emissions into the atmosphere can be decreased by the utilization of biofuels and e-fuels. Numerous biofuels and e-fuels are currently available, where each fuel features different physical properties, chemistry kinetics, and combustion characteristics. The chemical kinetics for calculating their combustion process is often excessively computationally demanding for numerical simulations, leading to the development and employment of combustion models, such as coherent flame models. In this work, the coherent flame models were employed for which the ignition delay and laminar flame velocities for different operating conditions are required to be precalculated in the form of a database or correlation formula. Developed procedure scrutinize available reaction mechanisms of several fuels with the validation against existing experimental data of autoignition and laminar flame velocities, aiming for the generation of look-up databases. The autoignition of fuel/air mixtures for different conditions is pre-tabulated from 0D constant pressure reactor calculation. Simultaneously, the laminar flame speed is pre-tabulated from premixed freely propagating reactors, for which the LOGE™ software was used. The ignition delay of cold flame and primary ignition was calculated using inflection point criteria implemented in the proposed method. The developed imputations methods and correlation functions are based on the lognormal distribution for laminar flame speed in equivalence ratio direction and exponential functions for pressure, temperature, and exhaust gas recirculation directions. Additionally, the method is also applicable to dual-fuel combustion. The ignition delay and laminar flame speed values of fuel blends are described with the additional parameter of the fuel composition. Finally, the database implementation into the computational fluid dynamics software is presented, verified with the detailed chemical mechanism of e-fuel three-oxyethylene ether (OME-3) fuel.

## SDEWES2021.0499

# The Impact of Inlet Boundary Conditions on Freeboard CFD Results in a Small-Scale Wood Pellet Boiler

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## Abstract

The prediction accuracy and sensibility of a fast-solving simulation method under different formulations of boundary conditions related to the fuel bed modelling, secondary air inlet and material properties was investigated. A commercial small-scale hot water wood pellet boiler available under the commercial name "Pellson X3 CC" of the European producer Waltis Ltd. was used in this study. Two sets of parameters were considered: (1) the impact of fuel bed modelling parameters i.e., the discretization of the fuel bed, (2) the impact of SA inlet parameters i.e., the temperature, mass flow and turbulence distribution between the nozzles and various wall boundary conditions. The temperature difference between the CFD predictions and measured values is evaluated in 120 measurement points in the combustion chamber and expressed for all cases in the form of root mean square error. From the results of the fuel bed modelling, it can be concluded that: (1) the division of the fuel bed into different number of zones did not have a profound impact on the result in the secondary combustion ($\sigma$ = 6K) zone nor in the post-secondary combustion zone ($\sigma$ = 3K), but had a large impact on the prediction accuracy of the temperature field in the primary combustion ($\sigma$ = 22K), (2) the case with only one zone performed better in sense of predicting the temperature field in the primary combustion zone (66K lower prediction error) compared to a multi zonal approach. From the results of the SA air inlet modelling, it can be concluded that: (1) by adopting a simplified mesh, a uniform temperature and mass flow distribution and default turbulence settings of secondary air similar results to the fully resolved case are achieved (14K lower prediction error), (2) changing the wall boundary conditions from adiabatic to either average temperature, heat flux or convection did not improve the results significantly ($\sigma$ = 3K).

## SDEWES2021.0501

# Decomposition of Organic Contaminants from Solar Pyrolysis Tar in Oxidation Processes

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## Abstract

Tars from solar pyrolysis of three biomass substrates (waste straw - WS, wood chips - WC and dried sewage sludge - DSS) were treated in selected oxidation processes (ozonation – $O_3$, photolysis – UV and photocatalysis – UV-$TiO_2$). The decomposition of organic substances present in the tars was investigated by changing the absorbance (Abs), total organic carbon (TOC) and phenol index (PI). Tar solutions before and after treatment were also submitted to an ecotoxicological assessment. It was determined that the degree of contamination of tars by organic substances depended on the type of biomass subjected to solar pyrolysis. The highest concentration of organic pollutants was recorded in the tar from sewage sludge. The paper determined that photolysis was ineffective in removing organic substances from tars. The decomposition of organic substances took place in the process of ozonation and photocatalysis, with photocatalysis being more effective. The effectiveness of these processes also depended on the type of tar as tars from the photopyrolysis of sewage sludge were the least susceptible to oxidation. After 60 minutes of photocatalysis ($TiO_2$ dose 1500 mg/L), phenolic compounds from tars coming from the photopyrolysis of waste straw and wood chips were completely removed. In turn, the reduction in Abs and TOC was 37 and 19% for WS and 41 and 28% for WC, respectively. Abs in tars from the photopyrolysis of sewage sludge in the photocatalysis process did not change, and the reduction of TOC and PI was 8 and 86%, respectively. However, the toxicity of post-process solutions requires attention. Tar solutions from the photopyrolysis of wood chips after the photocatalysis process were non-toxic against bacteria, but tar solutions coming from the photopyrolysis of waste straw and sewage sludge were low-toxic and toxic. Additionally, tars from the photopyrolysis of sewage sludge after the photocatalysis process were highly toxic to crustaceans.

Acknowledgments

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## SDEWES2021.0520

# Spatially Selective EGR - a Novel Approach for Heat Release Control in Continuous Combustion

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## Abstract

Firmly imposed dedication to achieve a clean and non-toxic environment is, besides $CO_2$ emission mitigation, in recent years one of the most profound drivers for fast pacing developments in combustion-based technologies. Utilization of exhaust gas recirculation (EGR) significantly contributes to reduction of $NO_x$ emissions by altering local kinetics through altered concentration and temperature fields. The EGR is usually introduced either internally, by maintaining a strong internal recirculation of combustion products or externally, by partial substitution of combustion air. Both approaches can be perceived as a passive strategy, largely controlled by design parameters of the combustion system, with strong impact on flame stability and limited available measures to control the spatial distribution of the EGR. Furthermore, such systems are sensitive to variations in fuel properties and the bulk dilution of the working medium intensifies the unfavourable $NO_x$-PM trade off, limiting the emission reduction potential and practical applicability.

The present study changes the paradigm of the EGR utilisation by innovatively exploiting the dilution effect of the EGR to actively steer the combustion process with specific focus on mixture control. With the presented concept, the EGR is not introduced as a part of the main working medium, but rather as a spatially selective, targeted injection of inert gasses in the near flame regions in order to control the heat release distribution, reaction rate and hence positioning of the flame. With such an approach, it is for the first time possible to circumvent the flame stability challenges, the $NO_x$-PM trade-off and design challenges imposed by conventional EGR concepts. This is reasoned by the phasing of inert components that allow maintaining oxygen availability in the late stages of combustion which prevent CO formation and facilitate PM oxidation, while efficient dilution and temperature control can be achieved specifically in the early stages of combustion to maintain stable ignition process and low $NO_x$ formation rate.

The experimental confirmation of the novel approach is demonstrated on a prototype turbine engine by introducing a set of inert components within the fuel spray in various operational regimes, supported by analysing the effect of temperature of introduced inert components and their mass flow, directly influencing the jet momentum and advection process. The results reveal that with fine-tuning of the leading parameters, it is possible to precisely control the evolution of temperature and concentration fields in the combustion chamber, and hence significantly reduce the $NO_x$and PM emissions simultaneously while maintaining the robustness of combustion process.

## SDEWES2021.0523

# Innovative Virtual Design and Experimental Characterisation of a Small Scale Sewage Sludge Incineration System

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## Abstract

Sewage sludge quantities combined with the need for the transfer to circular economy require implementation of innovative treatment approaches. Sludge incineration in small scale plants opens possibilities for independent and locally closed treatment loop. Aside lower local emissions, it decreases energy consumption and costs of logistics and provides opportunities for novel approaches to efficient material recovery from the ash. The sludge, however, features challenging chemical and physical properties. These, combined with the spatial constraints of small-scale systems, require additional attention at the design stage. Thus, frontloading and use of virtual design tools must be applied.

An innovative surrogate combustion model respecting sludge composition and a pilot small scale sewage sludge incineration system were developed to answer the design challenges. The system includes a 15 kW furnace with a primary zone allowing for the heat recovery from the ash via the imposed counter-current movement of the fuel on the grate. A cyclone is imposed in the secondary zone with tangential secondary combustion air introduction. This zone was designed using 3D CFD simulations to ensure thorough mixing and suitable residence times of combustion products. The use of simulations, however, pointed to the lack in available combustion models for complex fuel combustion in confined volumes. This led to development of the surrogate combustion model, which respects sludge characteristics and its complex combustion kinetics. The model allows for identification of suitable surrogates for certain sludge, accurate description of their combustion and thus improved virtual design. With the recent introduction of reduced reaction mechanisms, its computational performance was considerably improved to enable practical virtual development of small scale incineration systems.

The paper presents full scale application of the surrogate combustion model and its validation based on the system measurements. These include operations at conditions imposed by different air-fuel ratios. Results thus provide developed small-scale system analysis and show the model's ability for detailed description of complex fuel combustion in such devices. The work opens novel perspectives for efficient and clean combustion of complex fuels in small scale systems. Thus, the paper supports introduction of key enablers for economically and environmentally feasible implementation of circular economy solutions.

## SDEWES2021.0529

# Mass Transfer Modelling in Spray Droplets Absorption for Wet Flue Gas Desulfurization Application

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## Abstract

The operation of fossil fuel-powered machines is always associated with emissions of harmful pollutants. The regulations regarding allowed emission levels are becoming more and more stringent, promoting the development of new technologies. Lowering the emissions of sulfur oxides is usually done by the wet flue gas desulfurization process, which is achieved in scrubbers, where absorbing liquid is dispersed onto the exhaust gasses. This approach has gained traction in the maritime sector, where large amounts of sulfur-containing fuel are burned. Additionally, the seawater can be used as an inexpensive scrubbing liquid and reduce pollutant emissions. In this paper, modeling of the absorption dynamics was presented and the influence of freshwater and seawater on desulfurization efficiency was investigated. The absorption dynamics depends on the chemical reactions and mass transfer from flue gasses to water droplets due to the concentration differences. The usual approach for mass transfer modeling is the two-film theory, which divides mass transfer into gas and liquid side coefficients, the latter being more significant for the wet scrubbing cases. In this work, a new model for the liquid side mass transfer coefficient was investigated and implemented into the computational fluid dynamics software AVL FIRE™, first only for a droplet and then also for the entire 3D water spray. The Euler-Lagrangian approach was used to couple the dynamics of the liquid and gaseous phases. The new model considers additional parameters such as surface renewal rate, Reynolds number, and droplet diameter, compared to a single parameter of contact time in the robust penetration theory. The desulfurization efficiency results were compared with the experimental data and the results by previously-used penetration theory for liquid-side mass transfer coefficient. Additionally, the influence of parameters such as water and gas flow, sulfur dioxide concentration, droplet size and distribution on the desulfurization efficiency was calculated by the newly-implemented model. The results obtained by the new model showed the expected trend of increased efficiency with the water flow increase, as well as greater sensitivity to operational conditions in different cases and more accurately replicated removal efficiencies compared to the previously-used model.

## SDEWES2021.0539

# Scaling up Extractive Deacidification of Waste Cooking Oil

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## Abstract

Waste feedstocks such as used cooking oil have to be purified from free fatty acids prior to biodiesel production. Extractive deacidification with deep eutectic solvents is a promising alternative to conventional purification methods.

To evaluate the process of extractive deacidification of waste cooking oil, a full set of physical, hydrodynamic and kinetic data were determined experimentally on a laboratory scale. Hydrodynamic and kinetic experiments were performed in three geometrically similar jacketed agitated vessels. Vessels were equipped with axial flow impeller (four pitched blade impeller). Physical properties (density, viscosity and surface tension) were determined experimentally. Preliminary hydrodynamic experiments involve several model systems without mass transfer. As a result, correlation between power number and Reynolds number as well as scale up criterion was developed. Obtained dependencies were correlated with the physical properties. Mixing intensity for achieving complete dispersion was determined. Second stage of investigation involves two sets of experiments, hydrodynamic and kinetic, with interphase mass transfer (extraction of free fatty acids from waste cooking oil with deep eutectic solvent, potassium carbonate:ethylene glycol, 1:10). Obtained results enable understanding interphase mass transfer and prediction of mass transfer coefficient from the derived dimensionless correlations. The major hypothesis was that at the same dispersion rate the same separation rate is achieved (the same purity of raffinate phase).

This research will be helpful for developing continuously operated Karr column for deacidification of waste cooking oil.

## SDEWES2021.0550

# Experimental Study on NO Heterogeneous Reduction by Char

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## Abstract

Char heterogeneous reduction reaction is an effective way to remove the NOx in the flue gas. In this paper, four categories of chars were selected and the pretreated method including water pickling and acid pickling, reaction atmospheres, and reduction temperature .etc. experimental conditions were conducted in an electricity-heated fixed-bed. The results show that temperature plays an important role in the reduction of NO by different types of char, and there is a transition temperature that makes the heterogeneous reaction change from chemical kinetic control to diffusion control. The range of transition temperature is between 600-800℃. The order of denitration efficiency is: particle board char> activated carbon> fruit tree char > carboniferous coal char. At 750℃, the maximum denitration efficiency is 58.8%, and the minimum denitration efficiency is 25.4%. The influencing factors of denitrification efficiency are, in order, specific surface area, mineral richness, and chemical reaction activity. After acid pickling and water pocking, the reduction efficiency decreased by 19.3% and 18.36%. The peak promotion of heterogeneous reaction of $O_2$ moves to low oxygen content with the increase of temperature. At 1050℃, the peak of promotion for the heterogeneous reaction is 0.25% oxygen content, and the denitrification efficiency is increased by 12.7%. At high temperature, the promotion effect of CO on the heterogeneous reaction between chars and NO is attributed to the renewal of (C) active site on the char surface, while the inhibition effect of $CH_4$ on heterogeneous reaction at high temperature is attributed to its carbon deposition on the surface of char. At 1050℃, CO increased the reduction efficiency of carboniferous coal char by 10.4%, and $CH_4$ reduced the reduction efficiency by 12.3%

## SDEWES2021.0564

# Hydrogen-Enriched Natural Gas in the Decarbonization Perspective

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## Abstract

Natural gas is a major fuel source for power generation and heating applications.

Its considerable environmental impact upon combustion, the time-limited resources and increasing world population are strongly affecting the energy future.

As agreed in the 2015 Paris COP21 agreement, the future energy system must call upon clean and renewable resources, capable of producing energy with low $CO_2$ emission, hence partly decarbonizing the energy sector. Since common renewables are of intermittent nature (wind, solar) and less predictable than fossil fuels and biomass, it is important to develop novel techniques to produce an energy carrier with environmentally friendly properties, ease of storage and use. A promising technology is the production of hydrogen, easy to be mixed into the natural gas grid, or directly used in fuel cells, steel mills (e.g. direct reduction of iron ore), or as fuel in cement or limestone kilns.

The present study examines the technical and environmental benefits of adding a significant vol% hydrogen into natural gas. Despite the limited number of practical demonstrations on mixed natural gas/hydrogen networks, there is a general consensus that further investigations are needed, especially for the distribution of natural gas to residential customers.

Several $H_2$ production methods have been studied, but the catalytic conversion of methane ($CH_4$) has been advocated as having the highest potential, and is examined in the present paper. The economic and environmental benefits are predicted. In comparison with the current refinery steam methane reforming (SMR), the developed pilot plant system will reduce $CO_2$ emissions from 9.5 (SMR) to 1.24 kg $CO_2$/kg $H_2$ whereas the $H_2$ selling price can be reduced from 1.05 to less than 0.85 €/kg $H_2$, depending on the market value of the produced carbon black.

Notwithstanding the environmental benefits of adding $H_2$, additional factors need to be considered since the lower volumetric heating value of hydrogen will affect the energy transport capacity of the distribution network. Furthermore, the risks for hydrogen embrittlement in the gas piping network are still largely unknown, and a difference between existing low pressure and high-pressure grids (>40 bars) needs to be made. Modifications to current gas engines and domestic boilers will need to be studied in view of seasonal variations in the $H_2$/natural gas mix. It is not yet proven that the target level of up to 25vol% will be possible without major changes all along the gas distribution chain.

## SDEWES2021.0793

# Comparison of Reduced Chemical Kinetics Models of Ammonia Combustion in the Experimental Burner

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## Abstract

Chemical mechanisms of ammonia combustion are important for the development of ammonia combustion systems, but also as a mean of investigation of harmful NOx emissions, so they can be minimized. Despite of large body of experimental and modelling work on the topic of ammonia combustion, there is still need for further investigation of combustion kinetics that will encompass wide range of operating conditions in terms of temperature, pressure and equivalence ratio.

Taking the above stated, the object of this work is further numerical study of ammonia combustion chemistry under practical industrial conditions. After literature review, three reduced mechanisms of ammonia combustion were used for simulation of experimental premixed swirl burner with the aim of evaluating their performance. Through the analysis of temperature field reduced Mathieu mechanism was identified to be the worst one due to the fact that it was prominently different compared to other two models. Reduced mechanism based on the chemistry from Okafor proved to be the best in terms of emissions, as it was able to capture both measured trend and quantities with satisfactory accuracy. Neither one of the models was able to capture experimentally recorded ammonia slip, with discrepancies becoming especially high after equivalence ration increased over the value of 1. It is expected that this study will contribute to enhance the current knowledge by providing new insights in ammonia burning conditions closely resembling those in industrial applications and consequently help to design real industrial burning systems.

## Special session: The transition toward a decarbonized energy system: the role of energy efficiency and renewable energy sources

The twenty-first century is facing several energy and environmental worldwide problems, such as climate change, the increasing energy demand, the depletion of fossil fuels, pollution and the urgent need to mitigate the production of greenhouse gas emission. All these issues significantly affect the economic, energy and social policies of Countries around the World. In particular, in recent decades, a significant global growth in energy demand has been recorded, mainly due to the increasing needs of developing Countries.

For these reasons, many researches aimed at maximizing the exploitation of renewable energy sources and/or providing significant savings implementing suitable energy efficiency actions.

The development and diffusion of these systems have produced a series of positive effects, such as: energy diversification, reduction of polluting emissions, development of local green economies and many others. However, among the negative sides, there is the non-programmability of the energy produced by renewable systems which poses many problems for the management of energy networks. Thus, the implementation of suitable energy planning strategies is also crucial to find a balance between supply and demand.

In this context, this Special Session aims at collecting the most significant and recent studies dealing with the following topics not limited to:

Energy Planning

- Polygeneration systems based on renewable energy sources
- Geothermal power plants
- Geothermal energy for heat production
- Advanced thermal storage
- Advanced electrical storage: novel batteries, compressed air energy storage (CAES), flying wheels, supercapacitors, etc.
- District heating and cooling systems, 4th and 5th generation
- Water pumping by renewables
- Thermally driven water desalination
- Electrically driven water desalination
- Integration of renewables in the transport sector for electrical vehicles
- Use of biofuels in transport sector
- Integration of renewables for biomethane production
- Energy efficiency in wastewater treatment plants
- System dynamic simulation

- Integration of renewable systems in buildings
- Net or Plus Zero Energy Buildings
- Energy efficiency and integration of renewables in HVAC systems
- Heat metering
- Innovative renewable energy systems (solar technologies, wind turbines, geothermal wells, biomass, wave, hydropower plants)
- Optimal integration of different renewable energy sources
- Innovative high energy efficiency systems (heating, cooling, lighting,etc.)

Economic assessment and funding policies

## Session organizers:

**Prof. Francesco Calise**, University of Naples Federico II, Naples, Italy

**Dr. Maria Vicidomini**, University of Naples Federico II, Naples, Italy

**Prof. Laura Vanoli**, Università degli Studi di Napoli Parthenope, Napoli, Italy

**Mr. Diana D'Agostino**, University of Naples Federico II, Naples, Italy

*Francesco Calise* - Francesco Calise was born in 1978 and graduated cum laude in mechanical engineering from the University of Naples Federico II, Italy in 2002. He obtained the Ph.D. degree in Mechanical and Thermal Engineering in 2006. From 2006 to 2014, he is a Researcher and Assistant Professor of applied thermodynamics at the University of Naples Federico II. In 2014 he has been entitled as Associate Professor at the University of Naples Federico II. His research activity has been mainly focused on the following topics: fuel cells, advanced optimization techniques, solar thermal systems, concentrating photovoltaic/thermal photovoltaic systems, energy saving in buildings, solar heating and cooling, Organic Rankine Cycles, geothermal energy, dynamic simulations of energy systems, renewable Polygeneration systems and many others. He was invited lecturer for some courses or Conferences (UK and Finland). He teaches several courses of energy management and applied thermodynamics at the University of Naples Federico II for BsC, MS and PhD students. He was a supervisor of several Ph.D. degree theses. He is a reviewer of about 30 international Journals. He was involved in several Research Projects funded by EU and Italian Government. He is Member of the Editorial Board of 10 International Journals. He was a Conference Chair and/or member of Scientific Committee in several session of International Conferences. He is Vice-Chair Cross Reader for the FET OPEN Projects funded by EU

*Maria Vicidomini* - Maria Vicidomini was born in 1988 and graduated cum laude in Environmental engineering at the University of Naples Federico II, Italy in 2013. From 2013 to 2014, she was a fellow researcher at the University of Naples Federico II. She obtained the Ph.D. degree in Industrial Engineering in 2018. In 2019 she has been entitled as Researcher at the University of Naples Federico II. Her research activity has been mainly focused on the development of dynamic simulation models for the energy, exergy, economic and environmental analysis and impact of innovative systems for distributed polygeneration systems, supplied by renewable energy (geothermal, solar, wind energy) and natural gas. Building Integrated Solar Thermal Systems and internal combustion engines for the production of heat, cool and power.

Solar heating and cooling systems. Solar desalination systems. Hybrid renewable system based on wind, solar and geothermal energy. Electrical storage. Electric vehicles. Her research activity is also developed in cooperation with several international institutions (Portugal, Iran, Turkey, Denmark, China, Croatia, Poland, Germany, Canada). She was a supervisor of several BsC, MS and PhD students at the University of Naples Federico II. She is a reviewer of about 15 international Journals. She was guest editor in special issues on International Journals. She is a member of the scientific committee of several international conferences and she is also involved in the organizing committee of the CEER 2020 Conferences. She was a conference chair and presenter in several sessions of International Conferences.

*Laura Vanoli* - Laura Vanoli is a full professor of Applied Thermodynamics at the Engineering Department of the University of Naples Parthenope. In 1997 she obtained her five years master degree with honours in Mechanical Engineering from the University of Cassino. In 1999 she gained her Ph.D. in Industrial Engineering at the same University. From November 1999 to October 2003 she was an assistant professor at the Department of Industrial Engineering at the University of Cassino. From November 2003 to January 2005 she worked as an assistant professor at the Department of Food Science of the University of Naples Federico II. In September 2004, she was visiting researcher at the Energy Management Institute of Virginia Polytechnic Institute and State University (USA). From January 2005 to October 2008 she has been working as an associate professor at the Department of Food Science of the University of Naples Federico II. From November 2008 to December 2016 she was an associate professor at the Engineering Department of the University of Naples Parthenope. From December 2016 to February 2019 she was a full professor at the Civil and Mechanical Engineering Department of the University of Cassino and Lazio Meridionale. Her research interests cover: thermodynamic and thermo-economic analysis of advanced energy systems, energy saving, renewable energy sources, thermo-fluid-dynamic measurement. Over the last ten years, she has been working on simulation optimization and exergy analysis of hybrid SOFC-gas turbine power systems, dynamic simulation and thermoeconomic analysis of polygeneration systems based on renewable technologies and sources. On these subjects, she has written more than 100 scientific papers, mostly published in International Journals and Proceedings of International Conferences. She has coordinated and participated in several research projects funded by the Italian Ministry for Research (MIUR), and private companies. She thought several modules at the Universities of Cassino, Napoli Federico II and Napoli Parthenope: Energetics for Master of Science degree in Mechanical Engineering, Applied thermodynamics for BA degree in Food technology, Applied thermodynamics for BA degree in Industrial Engineering, Exergy analysis for BA degree in Management Engineering, Energy Management for Master degree in Management Engineering. Since 2015 she has been an adjunct researcher at the Engines Institute of the Italian National Research Council. Currently, she is the coordinator of the Ph.D. international program in Energy Science and Engineering of the University of Naples “Parthenope”.

*Diana D'Agostino* - Diana D’Agostino (Naples, Italy, 1987) is an Engineer graduated cum laude on 2013 in "Construction Engineering" at the University of Naples Federico II (Italy), with a thesis on Net Zero Energy Buildings. From 2012 to 2014 she collaborated with an engineering firm, focusing on projects in the energy sector. From 2015 to 2017 she won three scholarships at the Department of Industrial Engineering (DII) of the same University, within the “I-TOWN” European project: her research activity focused on the optimization of building-plants system with reference to energy efficiency and performance of air conditioning systems. Since January 2018 she is a Ph.D. student in Industrial Engineering at the DII. Her main research topics are: use of low enthalpy geothermal energy source in air conditioning systems, particularly by earth-to-air heat exchangers and geothermal heat pumps; Nearly, Net or Plus Zero Energy Buildings; energy refurbishment of existing and historical buildings; systems that use solar renewable energy, such as photovoltaic, concentration photovoltaic, solar thermal and CPV/T (concentrating photovoltaic/thermal). She reviewed several articles in the field of energy and engineering on

International Journals indexed on Scopus and since April 2020 she is an editorial board member of Journal of Advanced Thermal Science Research. She was co-supervisor of more than 40 Master’s Degree theses in Engineering. Since 2020 she participates to Med-EcoSuRe (Mediterranean University as Catalyst for Eco-Sustainable Renovation), a project funded by the European Union, under the ENI CBC MED program: this program is aims to promote cross-border cooperation in the Mediterranean region in order to identify the best strategies for the energy and eco-sustainable retrofitting of buildings. She was a conference chair of the International Conference SDEWES 2020.

Invited submissions

## SDEWES2021.0046

# What are the Achievements of the European Union Member States Towards Energy-Sustainable Agriculture: a Contribution to the Structural Efficiency Approach

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## Abstract

This paper applies the ‘average contribution to structural efficiency’ index to measure the environmental performance of the European Union (EU) Member States’ agricultural sectors. The contribution index considers all the possible combinations of observations (i.e., EU countries) when assessing their environmental performance. This allows for a complete ranking of the countries under consideration. The agricultural performance of Bulgaria, Denmark, France, the Netherlands, Romania, Slovakia and Slovenia, as measured by the conventional data envelopment analysis (DEA), approached the production frontier. Therefore, these countries could not be ranked based on the conventional DEA model. The application of contribution index showed that Romania, the Netherlands, Bulgaria, Slovakia and Slovenia were ranked as the best-performing countries (in that order). In addition, France and Belgium showed positive contribution to the structural efficiency even though they were not classified as efficient countries. Therefore, cooperation with these countries would allow other countries to exploit their agricultural resources in a more productive and sustainable manner.

## SDEWES2021.0049

# PV-Powered Electric Vehicle Charging Stations

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## Abstract

Electric vehicles (EVs) have zero direct air pollution, but their contribution in reducing greenhouse gas emissions depends on the energetic mix of the public grid. On the other hand, from power availability point of view, the public grid may become vulnerable when EVs number drastically increase, as predicted in many worldwide scenarios. Considering that renewable energy sources may contribute to EVs charging, this paper presents a photovoltaic (PV)-powered EV charging station including stationary storage and public grid connection, as power source backups, and investigates the conditions under which the PV energy benefits can grow. For the passenger EVs, the results show that for an average daily urban/peri-urban trip of 20-40 km, a daily EV charging based on a slow charging terminal associated with PV-powered station may bring large advantage for the public grid as well for the environmental footprint. Therefore, the paper highlights the end-user behaviour, i.e. its conscious choice regarding the EV charging, and the required business model able to influence consumer behaviour through charging pricing.

## SDEWES2021.0055

# Dynamic Strategies of the Integration of Power and Transport Sectors for Energy Systems in Transition

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## Abstract

In the context of energy transition from the fossil-fuel based energy systems to ones based on variable renewable energy, aiming for net-zero greenhouse gas emissions from energy system, synergies between sectors of energy generation and consumption are necessary. One of the significant synergies is the one between power generation sector and electrified road transport sector. When charging the batteries of numerous electric vehicles, a significant new, distributed consumer appears in the energy system. However, such a consumer also provides the opportunity to introduce demand response technologies and technologies that can provide system balancing in the systems with the high share of variable renewable energy. In this research, different dynamic scenarios of the rate of integration of technologies such as dump charge of electric vehicles, smart charge of electric vehicles and vehicle to grid concept are investigated. The energy system of Croatia is modelled in the year 2018, as a reference, and in future years: 2025, 2030, 2035, 2040, 2045 and 2050 for the future scenarios. Future scenarios are based on the Strategy of development of the energy system until 2030 with a view towards 2050 of the Republic of Croatia (business as usual) and, alternatively, on the newly proposed scenarios that are dependant on the prioritization of integration of electrified transport with different dynamics. The EnergyPLAN software was used to simulate the energy system configuration in each of the years. Future scenarios for the system's configuration development have taken into account different learning curves of electric vehicles. The learning curves are relevant for technologies that can provide balancing of the system using electric vehicle's batteries. Results show how the dynamics of the integration of electric vehicle batteries charging technologies change depending on the learning curves and cost projections, changing the cost-effectiveness of synergy between the sectors. Using the proposed method, achieving the decarbonized integrated energy system based on variable renewable energy can be done in the more cost-effective way and with higher energy efficiency along the way.

## SDEWES2021.0068

# Techno-Economic Analysis of a Green Hydrogen Valley for an Industrial District in Sardinia

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## Abstract

A techno-economic analysis of a hydrogen valley for an industrial district in the south of Sardinia (Italy) is carried out in this paper. The hydrogen produced by a PEM electrolyser fed by the electrical energy of a wind farm is employed by four different end-users (a stationary fuel cell power system, a hydrogen refuelling station, a biomethanation process, and injection in the natural gas pipeline). The expected annual performance of the hydrogen valley is evaluated by means of specific mathematical models and by considering different electrolyser sizes and hydrogen storage capacities. A preliminary economic analysis is also carried out to estimate the levelized hydrogen production cost. The results show that the optimal hydrogen storage capacity depends on the PEM size and on the final use of the hydrogen. In case of hydrogen surplus, a biomethanation process could allow reducing the hydrogen production cost by more than 10%.

## SDEWES2021.0072

# Energy Performance of Window Components Fitted with Photochromic Glass Compared with Traditional Systems Fitted with Traditional or Low-E Coated Glass

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## Abstract

The aim of the work is to evaluate the performance of a window equipped with photochromic glass in terms of transmitted radiation and natural lighting of the environment.

In these glasses a fundamental role is played by the transmission coefficient of solar radiation, which is able to change according to the incident solar irradiance. The calculations are performed with reference to a laboratory of the Department of Mechanical, Energy and Management Engineering, University of Calabria which has been modelled on the DesignBuilder software and validated with experimental data. The energy simulation environment is used to assess the energy demands and the quality of daylight, comparing a photochromic window with the case of using clear double glass and low-emission window. The results show, for a location in southern Italy, that the photochromic window allows a slight reduction in annual energy consumption compared to both solutions analysed, but it behaves badly from the lighting point of view. The use of Low-E glass is the most suitable solution, as it also provides a better visual comfort.

## SDEWES2021.0090

# An Innovative Concept of Trombe Wall for Yearly Use in Residential Buildings

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## Abstract

In the building sector, responsible for a huge amount of primary energy demand, research is actively investigating innovative envelope configurations to limit thermal exchanges with the outdoor environment, provide thermal comfort to the occupants and exploit renewable energy sources. Passive solutions are being rediscovered since they allow rational use of solar radiation and produce energy savings. Trombe walls are an interesting solution that, although initially conceived for sole winter heating, if properly managed, can be used also in a Mediterranean climate where the is the risk of summer overheating. This study presents an innovative configuration of a modular Trombe wall for a residential application that can be easily integrated into existing buildings or new constructions providing benefits in both the winter and summer seasons. Simulations with DesignBuilder were performed for a residential building to evaluate the energy savings in a hot Mediterranean climate. Proper ventilation strategies applied in the function of climatic parameters were investigated to reduce summer overheating and enhance night ventilation. Results demonstrated the validity of the proposed solution indicating how a well-managed Trombe wall can be regarded as an interesting solution to achieve energy savings in summer and winter.

## SDEWES2021.0117

# Experimental and Simulation-Based Tests on the Calibration of a Grey-Box Model Using Pso

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## Abstract

Building Energy Managements Systems (BEMS) based on Model Predictive Control (MPC) must be calibrated periodically to accurately reproduce the dynamic thermal behaviour of buildings. The calibration process avoids that the actual indoor air temperature diverge from that predicted by the underlying building model. The present paper shows a calibration process where the parameters of a lumped capacitance model are calibrated using Particle Swarm Optimization (PSO) iteratively to reproduce the average indoor air temperature pattern. In the first part of the article, the input used for calibration are measurements logged in a recently constructed laboratory for testing management strategies for "all-electric" dwellings, with an air-to-water heat pump connected to four fan coils. Various trials were carried out to find the most appropriate length of the training period used by the PSO algorithm over one and two-days tests. In the second part of the article, a detailed model of the laboratory based on EnergyPlus was used to produce synthetic data for calibration of additional heavy-weight and light-weight building structures. This step allowed to assess the additional flexibility brought by massive structures and to generalize the results. The third part investigates the physical meaning of the calibrated thermal resistances and capacitance. Results show that the optimal length of the training period falls between two and five days, and that the proposed calibration is more accurate for increasing thermal insulation and thermal mass. The last investigation showed that the calibration performance is not hindered by inaccurate initial guess on the physical parameters, provided that they are initialized in a physically meaningful domain.

## SDEWES2021.0159

# A Solar-Assisted Low-Temperature District Heating Network Coupled with a Ground-Source Heat Pump

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## Abstract

The present paper proposes a novel technical solution for the provision of heating, cooling, domestic hot water and electricity to a small residential district in cold regions. Three reference climates have been considered: Helsinki, Berlin and Strasbourg. The core of the energy system is a low-temperature district heating network supplied by a high-efficiency ground source heat pump. The source-side of the booster heat pumps installed in the buildings is connected to the district heating network. Rooftop photovoltaic thermal panels partially meet the electrical demand of the district. Moreover, they contribute to the production of domestic hot water and, when their thermal energy production exceeds the demand, the heat is injected into the ground to reduce the thermal unbalance, which typically affects the performance of the ground source heat pump systems in cold climates. Using the network heat carrier fluid to decrease the average temperature of the PVT panels further enhances their electrical efficiency. The proposed multi-energy system reaches an electrical self-consumption of 70% in the coldest locality and efficiently combines different renewable energy sources at the district level in cold climates.

SDEWES2021.0198

# Time-Evolution of Electricity Generation System: Criticalities and Opportunities

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## Abstract

Electricity generation system has faced exceptional change lately because of several aspects: the Electricity Of Everything trend, the introduction of the open electricity market, the spread of distributed energy generation and the penetration of Renewable Energy Sources (RESs) in the electricity generation mix. All these factors have contributed to exacerbate the variability of power system operation. Thus, the aim of this work is to present a data analysis of the electricity production at the country level (Italy) by considering the evolution of average and hourly efficiency and environmental indicators from 2015 to 2019. The time-dependent and energy efficiency and environmental indicators can be evaluated thanks to a deep disaggregation of power generation data which allows to obtain the electricity produced hour by hour from each fossil fuel and RESs. The results will show a significant variability of the indicators year by year and hour by hour highlighting the need of an accurate knowledge of these operational parameters in the evaluation of energy conversion systems performance and energy planning.

## SDEWES2021.0254

# Thermo-Economic Assessment of Flexible Nuclear Power Plants in the UK's Future Low-Carbon Electricity System: Role of Thermal Energy Storage

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## Abstract

Nuclear power plants are commonly operated as baseload units due to their low variable costs, high investment costs and limited ability to modulate their output. The increasing penetration of intermittent renewable power will require additional flexibility from conventional generation units, in order to follow the fluctuating renewable output while guaranteeing security of energy supply. In this context, coupling nuclear reactors with thermal energy storage could ensure a more continuous and efficient operation of nuclear power plants, while at other times allowing their operation to become more flexible and cost-effective. This study considers options for upgrading a 1610-$MW_{el}$ nuclear power plant with the addition of a thermal energy storage system and secondary power generators. The analysed configuration allows the plant to generate up to 2130 $MW_{el}$ during peak load, representing an increase of 32% in nominal rated power. The gross whole-system benefits of operating the proposed configuration are quantified over several scenarios for the UK's low-carbon electricity system. Replacing conventional with flexible nuclear plant configuration is found to generate system cost savings that are between £24.3m/yr and £88.9m/yr, with the highest benefit achieved when stored heat is fully discharged in 0.5 hours (the default case is 1 hour). At an estimated cost of added flexibility of £42.7m/yr, the proposed flexibility upgrade to a nuclear power plant appears to be economically justified for a wide range of low-carbon scenarios, provided that the number of flexible nuclear units in the system is small.

## SDEWES2021.0255

# Evaluating Social Awareness of Energy Communities Through Semantic Network Analysis of Online News

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## Abstract

Energy communities represent a novel social phenomenon that has the potential to support the energy transition by fostering the participation of citizens across the energy system. To involve people in this process and raise their awareness on the associated benefits, an important role is played by online information sources. In this view, this work analyses online news data about energy communities to understand people awareness and media importance of this topic. To this aim, the Semantic Brand Score (SBS) index, combining social network analysis and text mining, is used as an innovative measure of semantic importance. The outcomes of the analysis show that the SBS approach is flexible and useful to investigate media importance of energy communities; it also serves the identification of other energy and sustainability themes and their connections. The results support the identification of information gaps and of possible actions that should be taken to promote a low-carbon energy transition.

## SDEWES2021.0297

# Multi-Model Assessment of Heat Decarbonisation Options in the UK Using Renewable Hydrogen

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## Abstract

Achieving the UK's long-term climate targets will require a coordinated approach to decarbonising both electricity and heat supply, which will require substituting natural gas with low-carbon energy vectors, such as electricity and hydrogen that could be produced from renewable or other forms of zero-carbon energy. The objective of this paper is to use two established energy system models, RTN and WeSIM, to assess plausible heat decarbonisation pathways for the UK, while utilising their respective strengths – a technology-rich representation of hydrogen production, storage and transport options with high spatial granularity for the former, and high temporal resolution and detailed representation of the power system for the latter. The two models are linked through passing optimised capacities of hydrogen production technologies from RTN to WeSIM, and transferring an updated set of electricity prices in the opposite direction. Initial results indicate that model integration can improve the cost-effectiveness of the hydrogen technology mix by reducing the use of inefficient electrolysers during periods of high electricity prices and increasing the capacity and output of more efficient electrolysers, gas reformers and biomass gasification plants.

## SDEWES2021.0305

# Experimental Exergy Analysis of a Ground Source Heat Pump with Combi-Thermal Storage

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## Abstract

Today heating, domestic hot water and cooling demand are highly supplied by using fuel-feed boilers, chillers and electric air-to-air heat pumps. Ground Source Heat Pumps could be an attractive technology for heating, cooling and domestic hot water supply in building sector especially in harsh and warm climates to reduce the space conditioning environmental impact. In this context, this study proposes an exergy analysis of a ground source heat pump with a combi-thermal storage by means of experiments conducted in a Hardware in the Loop test bed at laboratory of the Institute of Energy Economy and Application Technology (Technical University of Munich). Second Law analysis of Hardware in Loop system allows to investigate different operating conditions and to identify the devices of the thermal plant that exhibits the largest exergy losses, efficiency defect, and the greatest room for improvement. By considering the investigated operating conditions, GSHP represents the highest dissipative component of whole plant destroying about 36% of required exergy input. A sensitivity analysis shows that the exergy efficiency of heat pump can increase until 70% by improving the borehole thermal resistance and/or ground temperature.

## SDEWES2021.0322

# A Gis-Based Approach to Identify Potential Heat Sources for Heat Pumps and Chillers Supplying District Heating and Cooling

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## Abstract

Geographic information system (GIS) software has been essential for visualising and determining heating and cooling requirements and population density, as well as visualising and identifying sources of industrial excess heat, natural bodies of water, and municipalities. Policymakers and experts highly encourage the use of GIS software at all administrative levels. It is expected that the demand for cooling and heating will continue to increase in the future. For a reliable heat and cooling supply, we must identify heat sources that can be used to provide heat or for removing surplus heat. We propose a method for identifying possible heat sources for large heat pumps and chillers that combines geospatial data from administrative units, industrial facilities, and natural bodies of water. Temperatures, capacities, heat source availability, as well as their proximity to areas with high demand density for heating and cooling were also considered. This method was used for Estonia, Latvia and Lithuania. Excess heat from heat generation plants and industries, sewage water treatment plants, and natural heat sources such as rivers, lakes and seawater were included as well. The study's findings provide an overview of possible industrial and natural heat sources, as well as their characteristics. The potential of the heat sources was analysed, quantified, and then compared to the areas of heating and cooling demand.

## SDEWES2021.0336

# Application of Wave-to-Wire Modelling to Optimise Oscillating Water Column Wave Energy Converters for Small Installations in the Mediterranean Sea

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## Abstract

Sea waves are potentially a relevant renewable resource for their availability and the power conveyed. Oscillating water column (OWC) systems, operating with Wells or impulse turbines, are one of the most suited solutions for the effective conversion of this potential. In these devices, the chamber structure (primary converter) turns sea wave motion into an oscillating airflow driving an air turbine (secondary converter) connected with an electric generator (tertiary converter) through a control strategy. Until now, the analysis of the three converters has been mainly performed individually, while a holistic approach is required.

An analytical wave-to-wire model was developed to determine the entire energy conversion process from the sea waves to the electric wire. A rigid piston model was applied to determine the hydrodynamics, thermodynamics, and aerodynamics of the caisson. The aerodynamics and dynamics of either a monoplane isolated Wells turbine and an axial impulse turbine were modelled with two fast and reliable codes relying on the blade element momentum theory. A control algorithm was implemented to regulate the instantaneous torque and angular velocity of the rotor. The three models were jointly solved to simulate the mutual interaction of the three converters. Scatter matrices were utilised to impose the wave conditions of a selected Mediterranean site located in Tuscany (Italy) for a distinctive caisson, previously optimised with experiments. The operating maps of the system configurations were obtained to vary the geometry and functioning conditions. The maps were used to select the optimal turbines of both the typologies for the specific location. Finally, the operating curves, the performance parameters, and the energy harnessed were achieved, providing an interesting overview of the annual and seasonal functioning. The selected systems with the Wells and impulse turbines convert 14.67 and 14.00 MWh/year and operate with a global efficiency of 5.32% and 5.08%, respectively.

## SDEWES2021.0342

# A Step Towards Decarbonized District Heating Systems: Assessment of the Importance of Individual Metering on the System Level

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## Abstract

In recent decades it is considered that district heating (DH) will be one of the most viable drivers for decarbonisation of urban heating. The most important characteristic of DH is the fuel flexibility and possibility to switch from fossil fuels as a primary energy source to renewable energy sources (RES) or to show its full utilisation benefits as an advanced system for useful waste heat utilisation from various sources, i.e. industry. This indicates that DH systems could be one of the most promising heat supply options in the future in order to reach the goal of fully decarbonised energy systems, especially having in mind that heat consumption in building sector in EU makes approximately 40% overall final energy, while heating and hot water preparation alone account for almost 80% of total energy use.

The research goal of this paper is to evaluate the impact of installation of individual metering in DH systems on energy savings and emission reduction by application of machine learning algorithms in order to evaluate and predict how would this particular system upgrade measure influence the energy consumption and emissions. The research is focused on DH systems in Croatia having in mind the national energy mix and primary energy factors, but with a critical overview of the latter as they are set in the national legislative. The results showed that dominant variable is the installation rate of individual metering devices (i.e. heat cost allocators - HCAs) and, for maximum energy saving, it should strive to 100% within a building. In that case, decrease in annual specific heat consumption in average building connected to a district heating system in Croatia is expected above 40 kWh/m$^2$. Developed regression models show that apartments with installed HCAs could achieve about 30% reduction in heat consumption, compared to the apartments without HCAs. It is the belief that the development of models for assessment of influence of energy efficiency measures on heat consumption in DH systems will stimulate an increase in the integration o renewable energy sources in DH and conversion of electricity from renewable sources to thermal energy during periods of high availability of intermittent RES such as solar or wind.

## SDEWES2021.0356

# Fixed and Tracking PV System for Net Zero Energy Buildings: Comparison Between Annual and Monthly Energy Balance

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## Abstract

The energy needs of a Net Zero Energy Building (NZEB) are fully met by renewable energy sources. These strongly depend on their characteristics and on meteorological-geographical factors, but also on different kinds of energy balance.

The aim of this paper is to investigate the comparison between two different photovoltaic systems (fixed and tracking) and two kinds of energy balance (yearly and monthly), to evaluate which system better achieves the definition of NZEB for an existing residential building, so limiting exchanges with the national electricity grid. A dynamic energy simulation software (DesignBuilder) is used.

The results show that the photovoltaic surface which attains the NZEB target on yearly basis not always achieves the same objective when the energy balance is performed on monthly basis. Furthermore, considering a monthly balance, the size of the photovoltaic system with biaxial solar tracking is 45% minor compared to the fixed photovoltaic system, thanks to a steadier energy production.

## SDEWES2021.0379

# Assessing the Feasibility of an Integrated Clc-Methanation System Using Solar Dried and Torrefied Biomasses as a Feedstock

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## Abstract

This work numerically analyzes an innovative process layout considering a torrefaction processes followed by chemical looping combustion of biomass waste, solar hydrogen, and carbon methanation. System performances were evaluated by considering several agro-industrial residues (i.e., sugar beet pulp from sugar production, grape marc from winemaking and olive pits from olive oil production) as fuels, CuO supported on zirconia as oxygen carrier, and Ni supported on alumina as methanation catalyst. The torrefaction pre-treatment was proposed for upgrading the properties, namely heating values, moisture content as well as hydrophobicity, and storability, of the selected biomasses. To this aim, experimental runs were performed at 300 °C and 30 min in a lab-scale fixed bed reactor under an inert atmosphere of nitrogen. The study was complemented with an extensive investigation on fuel properties (i.e., ultimate analysis, proximate analysis, calorific values determination) of both the untreated and the torrefied samples, which provides useful input data for modelling their conversion processes. By considering that only electric energy from renewable sources is used, the capability of the proposed process to be used as an energy storage system was eventually assessed.

## SDEWES2021.0390

# Plastic Waste to Methanol: a Chemical Recycling Pathway

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## Abstract

Chemical recycling of plastic waste is a topic of high interest due to the ever-growing amounts of polymers produced each year and the currently unsustainable end of life management of the waste. Pyrolysis of municipal plastic waste was a topic of interest since the early 2000's, but it gained significantly more attention in recent years. Gasification is the next step in the evolution of the process, making it autothermal, less sensitive to contaminants, and less dependent on legislation for the end of waste certification. In this paper a gasification recycling route supported by preliminary experimental campaigns in a demonstrative scale plant will be discussed and aided by a simulation in Aspen HYSYS to predict a theoretical yield to methanol. In the first section the issue of plastic waste will be discussed. In the second section the experimental campaigns carried out in the research facility of Sotacarbo will be presented, finally in the last section the overall simulation layout will be briefly described in its operating conditions and the yield to methanol reported.

## SDEWES2021.0454

# Non-Linear Model Predictive Control for the Space Heating System of Buildings in Norway

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## Abstract

The heating system in buildings accounts for a large share of total buildings' energy use. Therefore, it is critical to increasing the energy efficiency of the existing heating system in buildings. This study aimed to increase the energy efficiency of the space heating system by optimizing the operation of the space heating system. A model predictive control strategy was proposed to realize the optimal operation of the space heating system by reducing energy use and energy cost while guaranteeing thermal comfort for the building's occupants. A non-linear grey box system model was developed to predict the thermal behaviour of the building and was embedded into the MPC controller. The proposed method was tested by simulation on a university building located in Norway, while the calibration data and the case building were real. Results showed that the proposed MPC control strategy shaved the peak load by 7.8% and saved the heat use by 3.3% during one week, compared to the current rule-based control. In addition, the MPC controller demonstrated the weekly heating cost saving of 4.1%, while providing an improved level of thermal comfort, with a reduction of 65% for the indoor temperature violations.

## SDEWES2021.0484

# Dynamic Simulation Modelling of Reversible Solid Oxide Fuel Cells for Energy Storage Purpose

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## Abstract

The need to reduce the environmental impact of human activities requires the development of green technologies for the production of energy from renewable energy resources. Fuel cells, directly converting chemical energy into electricity, offer high efficiencies and significantly lower emissions than conventional technologies. The modular arrangement of the cells makes these devices suitable for a wide range of potential applications, including the combined production of heat and energy. The medium/high temperature fuel cells based on ceramic oxides (solid oxide fuel cells) can play a fundamental role in the green electricity production. In this framework, hydrogen represents a promising energy vector able to meet the high energy demand and the reduction of environmental impacts. In fact, through reversible fuel cells or fuel cells combined with electrolysers, hydrogen has high performance if used as an electrical energy storage. The "green hydrogen", i.e. the hydrogen produced by renewable sources, is considered one of the most promising solutions for energy storage, along with novel and efficient batteries. The basic idea lies in the production of hydrogen in case of excess production of electricity by renewables. Then, this hydrogen can be converted into electricity when the user demand is lower than the renewable production. In particular, the reversible solid oxide cells allow one to perform these two processes in a single device, optimizing costs and efficiency. This arrangement allows one to overcome the main limits of renewable sources, i.e. their high unpredictability and fluctuations. The main objective of this work is the development of a specific dynamic model simulation of a reversible solid oxide fuel cell, allowing one to evaluate the system operating parameters, such as: cell temperature, cell efficiency and power, hydrogen production and consumption. The model is developed in MATLAB and it is subsequently implemented in a more complex simulation model in TRNSYS. A case study is performed for a specific user equipped with a photovoltaic field and a reversible solid oxide fuel cell and a suitable hydrogen storage system. The proposed system is analyzed from energy and economic points of view. Results showed that this system exhibits a very good storage capacity. Nevertheless, its capital cost is still too high for a good economic profitability.

## SDEWES2021.0485

# Dynamic Simulation of a CO2 Heat Pump System for Residential Space Heating: Case Study for the "Superbonus" Strategy

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## Abstract

The building sector is currently one of the main responsible for $CO_2$ emissions due to the high primary energy consumption. As a matter of fact, in the last years many innovative solutions were developed which can strongly reduce these consumptions. The vast majority of actual residential buildings in Italy are old structures so they are characterized by high thermal energy dissipation. In particular, the main point to solve in order to improve the energy efficiency of a dwelling is the upgrading of the heating system. This work presents a dynamic simulation of the yearly energy consumption of the heating system for a typical residential building based on a traditional natural gas boiler. This reference system is then compared with a proposed system powered by a transcritical $CO_2$ Heat Pump (CO2HP) which leads to an increased heating efficiency by using the same radiators as heating terminals. The concept of this work is to analyse an innovative solution to be included in the Italian economic incentive for dwelling energy renovation, the so-called "Superbonus". In this framework, the system is supported by a photovoltaic (PV) field and a lithium-ion battery storage system which are included in the financial incentive. Results from the thermoeconomic and environmental analysis show a Primary Energy Saving (PES) of 49%, a total amount of avoided $CO_2$ emissions of 7.29 tons/year and a NPV higher than 45 k€. The last result is of particular interest because sums it up the extraordinary profitability of the economic relief for the final user.

SDEWES2021.0486

# Smart Energy District Based on the Integration of Photovoltaic, Electric Vehicles and Combined Heat and Power Generation: Optimal Design

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## Abstract

This work presents the design of the optimal configuration of a smart energy grid district based on a combined heat cool and power reciprocating engine, a photovoltaic field, located in Naples (South Italy). The investigated smart grid is designed for matching the power and thermal flow rate demands of this district, including the power demand of a group of 50 residential building, populated by people who only use electric vehicles, as well as the energy for space heating and cooling.

The cogenerator simultaneously provides thermal and electrical energy. The thermal flow rate recovered by the cogenerator is exploited for meeting the thermal flow rate demand of the residential district building, while the produced power is exploited for matching the power load of the district, and for charging the electric vehicles. The cogenerator operates following the thermal load of the district.

The simulation model is developed in TRNSYS 18 environment, which is also employed for carrying out the system dynamic simulations. In addition, an optimization analysis is carried out, using Genopt software, with the aim of detecting the optimal photovoltaic area which would reduce the electric energy imported by the grid, without worsening the electric performance of cogenerator. The optimization analysis assessed that the optimal photovoltaic field consists of a 3.07 MW photovoltaic field, which reaches a payback period of 6.20 years.

## SDEWES2021.0488

# Optimal Design of a 5Th Generation District Heating and Cooling Network Based on Sea Water Heat Pumps

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## Abstract

The aim of this work is the design of the optimal layout for a 5th generation district heating cooling network meeting the thermal flow rate demand of a residential district located in the Pantelleria island. In particular, the considered 5th generation district heating and cooling is based on two bidirectional low-temperature neutral rings. Both rings are balanced by means of two groups of seawater heat pumps. A renewable power park, including wind turbines and photovoltaic panels, provides power for matching the electric energy consumption of the heat pumps of the heating and cooling district, auxiliary hydronics system and load of the residential district. The dynamic simulation model is developed in TRNSYS 17. The results of the simulations show that the proposed layout achieves significantly positive results from the energy and environmental points of view, with a primary energy saving and avoided $CO_2$ emissions equal to 133% and 134%, respectively. The obtained high payback period of about 15 years is mainly due to the considerable capital cost of heat pumps, wind turbines and piping systems.

## SDEWES2021.0497

# Anaerobic Digester Feed by Renewable for Biomethane Production

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## Abstract

This work presents a dynamic analysis of a fully renewable plant for the production of biomethane from Organic Fraction of Municipal Solid Waste (OFMSW). In particular, the plant is based on an OFMSW anaerobic digester. The plant is designed in order to provide the auxiliary thermal and electrical energy by renewables. To this scope, a solar field of evacuated tube solar collectors provides the thermal energy required to control the operating temperature of the anaerobic digestion process. Similarly, the auxiliary electrical demand, for the pumps and the upgrading unit, is provided by a photovoltaic field. The photovoltaic field is also coupled with an electric energy storage system based on lithium-ion technology, in order to mitigate solar availability fluctuations The upgrading unit electricity demand is significantly high, due to use of compressors and membranes. The produced biomethane is used for a gas station, supplying gas to a fleet of buses, in order to reduce the environmental impact of the public transport by presenting a successful alternative to diesel internal combustion engines. The plant is modelled in TRNSYS simulation environment. The anaerobic digester model is developed by MATLAB® and subsequently linked to TRNSYS environment, developing a new type integrated in the analysed layout. The photovoltaic system leads to a reduction of the electric energy withdrawn from grid by 45%. The proposed plant achieves very promising and interesting energy, economic and environmental results, with an annual primary energy saving of 192% and a reduction of $CO_2$ emissions by 3505 tons/year and a pay back period of 8 years.

## SDEWES2021.0513

# Harmonized Multi-Scale Energy Planning in Metropolitan Areas: the Economic and Environmental Impact of Conurbation Systems in the Regional Energy Plan

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## Abstract

Today, more than the 36,2 % of the Italian population lives in metropolitan areas producing most of the environmental problem related to the energy consumption. For this reason, metropolitan areas and, more in general, conurbations are strategic to address key challenges for Italian's society and economy, like the promotion of cleaner energy to mitigate the impacts of human activities on climate change. The number of commitments to guidance documents, initiatives and common goals for energy and urban planning processes provided by the European Union (EU) over the last 10 years, like the Covenant of Mayors, has shown the willingness among the municipalities to actively strive towards these goals. At the same time, the recognition of cities as key energy planning actors is relatively recent and not perceived in the same way by all the stakeholders as the implementation of energy plans for municipalities has a voluntary nature. For these reasons, centralized institutional administrations, like the regional ones, implement their own energy plans with different goals over time without paying much attention in coordination and valorisation, even in those territories where the weight of a single city has dramatic impacts on the overall region in terms of population, energy consumption and environmental pollution. With the purpose of showing the importance of coordinated multiscale energy planning, this work presents an integrated approach in terms of goals, plan implementation methodology and scenarios in urban-regional energy modelling.

To implement this, different scenarios are implemented using the city of Naples as a case study. Four main steps have been followed:(i) the baseline model provided by the energy-related data collection for the reference year 2015; (ii) the implementation of a Business As Usual future scenario for the year 2030, in which only the SEAP actions are implemented; (iii) the implementation of an alternative future scenario for the year 2030; (iv) the strategy comparison.

The authors simulate the different scenarios in EnergyPLAN environment, an energy tool that allows to consider the hourly behaviour of the energy systems analysed and, therefore, the synergies between the energy sectors.

## SDEWES2021.0518

# Development Opportunities for Energy Communities in Urban Regeneration Plans

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## Abstract

District regeneration plans introduce demographic and land use changes that influence their energy balance, modifying electricity and heating/cooling demand profiles.

Traditional approaches see urban regeneration projects as independent processes with respect to the energy planning ones, ignoring the European Union targets to move towards the energy transition. An integrated approach, instead, envisions the presence of new energy systems, namely smart energy districts, where different actors can cooperate in energy communities, with the purpose of energy generation and management, playing a crucial role in the transition.

Smart energy district and energy community approaches allow to better solutions from the thermodynamic and economic point of view, and to integrate renewable energy sources, which by their nature are 'fluctuating,' with the energy demands using a data centre to menage the energy flows.

To evaluate the benefits that a district could obtain when integrating energy planning in regeneration plans, the authors analyse the effects of a different approach to the urban design that goes beyond the traditional tasks of designing districts' spatial aspects and propose a consistent technical analysis during the decision-making process.

To do this, after defining strategic targets related to energy and resource issues, the authors implement different scenarios, evaluating the most suitable technologies that can be integrated in the area. The process of modelling and dynamically simulating the energy system enables to identify the synergies among the energy sectors. This is done by creating dynamic simulation models using different energy tools, as the ones used in this work.

The research work analyses a real case for a possible process of urban regeneration, of former industrial area in a district located in the city of Naples, through retrofit and re-use of existing buildings, the construction of new ones and the implementation of smart infrastructures.

## SDEWES2021.0548

# Data Driven Optimal Design of a Cogeneration Plant: the Case Study of a Hospital Building

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## Abstract

The widespread implementation of combined heat and power (CHP) generation plants is a valuable solution to significantly reduce primary energy consumption and carbon dioxide emissions. The accurate definition of thermal and electric loads is of utmost importance for optimizing the CHP plant design to fully deploy the primary energy saving (PES) and $CO_2$ reduction potentials of this solution. Data-driven analysis could represent a valuable contribution to this aim.

In this paper the use of a bi-level optimization approach for the design of a CHP is applied to an Italian hospital in Rome. Based on historical data of the hospital thermal and electric demand, clustering analysis is applied to identify a limited number of load patterns representative of the annual load. These selected patterns are then used as input data in the design procedure. A Mixed Integer Linear Programming coupled with a Genetic Algorithm is implemented to optimize the energy dispatch and size of the CHP plant, respectively, with the aim of maximizing the PES while minimizing total costs and carbon emissions.

Results show that the proposed approach allows a further $CO_2$ reduction in the order of 8% ensuring economic savings (up to 20%) when compared to a baseline configuration characterized by constant load operation all over the year. The further role of thermal and electrical energy storage systems on CHP layout and performance parameters is also highlighted.

## SDEWES2021.0732

# Design of Heating, Cooling and Power Networks Deriving from the Insertion of Micro-Cogeneration Units in Densely Populated Areas: an Italian Case Study

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## Abstract

The increase of the energy demands of residential neighborhoods constitutes a huge challenge to be faced. A viable option lies in the insertion of both renewable energy production systems and cogeneration units within urban territories. On-site production allows for the satisfaction of heating and electrical demands of end-users and favors the distribution of produced energy within the neighborhood. Under this framework, this paper proposes a tool aimed at modeling heating and electricity networks integrated with cogeneration units installed in urban areas. The tool accounts for the following possibilities: (i) variation of topology and sizes of both heating and electric networks, and (ii) evaluation of the electricity sharing configurations arising among end-users. To better clarify the capability of the tool in supporting energy analysts and decision-makers, a densely populated area in Southern Italy is proposed as a case study. Results in terms of energy-saving compared to the current energy systems configuration are discussed.

## Special session: Valorisation of Brines for the Recovery of Energy and Raw Materials

Concentrated brines, generated by anthropic activities or available from natural resources, have attracted the interest of scientific and industrial communities as a novel, sustainable and still unexplored source of energy and raw materials. When such brines have anthropic origins, their re-use and valorisation is even more important as it helps minimising the potential environmental impacts arising from their disposal in receiving water bodies. Several different concepts have been proposed so far for the valorisation of brines for energy production via the so-called Salinity Gradient Power technologies, which allow for the production of electrical energy from the controlled mixing of saline streams at different concentration. On the other side, brines can be a valuable source for raw materials, many of which listed among the EU critical raw materials for their economic relevance or supply risk, such as Magnesium, Lithium and other Trace Elements. Different strategies have been proposed for the "mining" of minerals from brines, which depend on the type of brine, its composition and on the features required for the recovered material. All this is strongly connected with the new frontiers of separation technologies, process intensification, energy integration and circular economy approaches.

This special session will represent a platform to share new ideas, application examples and perspective analysis of the large potential of brines valorisation processes.

Covered topics will include:

brines resources characterisation;

- environmental issues of brines disposal;
- desalination and brine management;
- integrated approaches for brine disposal minimisation;
- technologies for minerals recovery from brines;
- technologies for magnesium, lithium and other trace elements selective separation;
- Salinity Gradient Power technologies in open-loop applications;
- Salinity Gradient Power technologies and integration with desalination;
- economics of brine valorisation processes.

Progresses and results of EU-H2020 project on brines valorisation will be also presented, including (yet not limited to):

- SEArcularMINE (<a href="http://www.searcularmine.eu/">www.searcularmine.eu</a>);
- WATER MINING (<a href="http://www.watermining.eu/">www.watermining.eu</a>);
- REWAISE (<a href="http://www.rewaise.eu/">www.rewaise.eu</a>);
- ZERO BRINE (<a href="http://www.zerobrine.eu/">www.zerobrine.eu</a>);

Submit your abstract for archival papers by the 15th of December 2020 via <span lang="RU"><a href="http://registration.sdewes.org/dub2021">http://registration.sdewes.org/dub2021</a><

/span><span lang="EN-US">. S</span>ession invitation code: **<span style="text-decoration: underline;">sd21vbre</span>**

## Session organizers:

**Prof. Andrea Cipollina**, Università degli Studi di Palermo, Palermo, Italy

**Dr. Alessandro Tamburini**, Università degli Studi di Palermo, Palermo, Italy

**Prof. Giorgio Micale**, Università degli Studi di Palermo, Palermo, Italy

**Prof. Jose-Luis Cortina**, Barcelona Tech UPC, Barceñona, Spain

*Andrea Cipollina* - Prof. Andrea Cipollina is an Associate Professor of Chemical Process and Plant Design. His main research areas are: Brines valorisation; Desalination and Renewable Energy coupling; Salinity Gradient Power. In all R&D areas the activities of Prof. Cipollina ranged from computer aided process modelling and optimisation to experimental characterisation of innovative systems for the development of novel technologies, but also prototype systems design, construction and operation. He published more than 100 journal papers on these topics and 3 books on desalination and salinity gradient power technologies. In the last 12 years he has conducted and coordinated research activities in more than 10 EU projects, with the last 5 years, in particular, mainly focused on the topic of brines valorisation for energy and raw materials harvesting. He coordinates the EU-funded SEArcularMINE project (www.searcularmine.eu), aiming at the development of technologies for the recovery of magnesium, lithium and other trace elements from saltworks brines, coupled with new solutions for energy harvesting and utilization. He was awarded with the Senior Moulton Medal 2013 by the Board of Institution of Chemical Engineering (UK). He is a member of the European Desalination Society.

*Alessandro Tamburini* - Alessandro Tamburini is assistant professor in Chemical Process and Plant Design at the University of Palermo. His research is focused on the experimental and numerical analysis of complex systems including multiphase stirred tanks and membrane-based units. Research interests and activities involve the following topics: stirred tank reactors, membrane-based separation, and brine valorisation technologies, including Salinity Gradient Power (SGP) for energy recovery from brines and other applications. He has published more than 100 works on these topics in journal papers, book chapters or conference contributions. He has participated in many EU-funded and national projects on water desalination and brines valorisation technologies for energy and raw materials recovery. He is currently involved in five EU projects of the Horizon2020 program, being the UNIPA responsible for the REWAISE (Resilient Water Innovation for Smart Economy) project (www.rewaise.eu). He was awarded with the Senior Moulton Medal 2013 by the Board of Institution of Chemical Engineering (UK). He is a member of the European Desalination Society and of the Associazione Italiana di Ingegneria Chimica.

*Giorgio Micale* - Giorgio Micale is a Full Professor of Conceptual Design of Chemical Processes. Core research topics are the study of Conventional and Renewable Energy Desalination processes, Salinity Gradient Power processes, Computational Fluid Dynamics, Mixing and Multiphase Flows, Computer Aided Process Engineering. He currently leads the University of Palermo team within a number of closed and ongoing EU H2020 projects building-up significant expertise in the area of electro-membrane processes, desalination and salinity gradient power technologies and brine valorisation processes. He is currently the scientific responsible for UNIPA of the ZERO BRINE (Re-designing the value and supply chain of water and minerals: A circular economy approach for the recovery of resources from brine generated by process industries) and WATER-MINING (Next generation water-smart management systems: large scale demonstrations for a circular economy and society) projects (www.zerobrine.eu; www.watermining.eu). He was awarded with the Senior Moulton Medal 2013 by the Institution of Chemical Engineers (UK). He was a member of the Board of Directors of the European Desalination Society during the years 2012-2017

*Jose-Luis Cortina* - JDr José Luis Cortina is a Full Professor of Chemical Engineering. Main research research topics are the study of Separation Processes and their integration to develop Resource Recovery Processes from Urban, Chemical, Mining and Agro-food waste. He currently leads the Resource and Recovery and Environmental Management Research group at the Multiscale Science and Engineering Research Center of the BarcelonaTECH UPC within a number of closed and ongoing EU H2020, Life and EIT projects building-up significant expertise in the area of pressure, concentration and electro driven membrane processes and ion-exchange and sorption processes to promote valorisation of secondary sources of critical materials or added value bio-active compounds. He is currently the scientific responsible for Barcelona Tech of the Searcularmine ((www.searcularmine.eu), Sea4value ((www.sea4value.eu), Enrich (www.life-enrich.eu) and Recop projects and he is Senior Research advisor of the Water Technology Center (CEtaqua). He received the Ion Exchange Award from the Society of Chemical Industry (UK) in 2008.

Invited submissions

## SDEWES2021.0224

# Development of Innovative Technology for the Treatment and Recovery of Textile Industry Brine Waste Stream

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## Abstract

Brine is highly concentrated salt solution and its discharges may cause threat to aquatic environment. In the textile industry, brine is generated by the reverse osmosis system which treated textile wastewater mainly contains sodium chloride, magnesium and calcium salts and organic pollutants. The need for sustainable management of brine leads to development of zero liquid discharge (ZLD) technology approach which enables salt and clean water recovery. In this context, development of an innovative brine treatment and recovery system for textile industry was aimed within the study. Bench scale treatability tests were carried out on the RO retentate to develop the optimum scheme for reuse. The ultimate aim was to reuse the treated retentate in the dyeing baths of textile plant and/or utilized as feed for salt production along with the reuse of clean water in the enterprise. The developed process achieved 60-70% of recovery of salt to be utilized for the dyeing processes and 50-60% of clean treated water reusable within the enterprise for several purposes. The results showed that this innovative system provides a good example for the ZLD and circular economy approaches in the sector.

We would like to acknowledge financial support through ZERO BRINE project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730390.

## SDEWES2021.0416

# Sustainable Recovery of Lithium from Saline Streams by Flow Capacitive Deionization

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## Abstract

Lithium extraction from aqueous resources, such as saline brines and seawater, by membrane-based technologies, offers promising opportunities of an almost unlimited number of lithium sources to be explored in a sustainable and environment friendly way. However, low membranes' permselectivity for lithium ions, especially in presence of monovalent cations, and their challenging scale-up, are still constraints. In this presentation, we will discuss a new approach for the development of selective membranes by electrospinning and their integration into a flow capacitive deionization (FCDI) device. FCDI technology is usually used for brackish water desalination, but herein the aim is to use it to continuously recover lithium from brines.

So far, highly selective membranes for $Li^+/Mg^{2+}$ separation were developed by mixing hydrogen manganese oxide (HMO), polystyrene sulfonate sodium salt (PSS–Na) and lithium triflate ($LiCF_3SO_3$) into the sulfonated polyethersulfone (SPES) matrix [1]. The most promising membrane, containing 20% (w/w) of HMO, showed an almost 13 times higher $Li^+$ ionic conductivity (8.28 mS/cm) compared to the control composite membrane (without HMO) and an average ideal selectivity of 11.75 for the $Li^+/Mg^{2+}$ pair. That composite membrane had the lowest intermolecular distance between the polymer chains (according to X-ray diffraction (XRD) analysis), the most flexible structure (lowest Tg) and showed a homogeneous dispersion of HMO (SEM images), which explains its highest $Li^+/Mg^{2+}$ selectivity among the tested membranes. Overall, this study provides the basis for designing and developing composite lithium selective membranes.

Furthermore, the flow-electrodes composition in the FCDI cell is being optimised to facilitate lithium sorption and desorption. Computational fluid dynamics (CFD) simulations are being performed to design the FCDI cell (to be manufactured by 3D printing) with a channels' configuration that promotes mixing and an uniform distribution of particles composing the flow-electrode slurries.

Acknowledgments: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869467 (SEArcularMINE). This work was supported by the Associate Laboratory for Green Chemistry- LAQV, which is financed by Portuguese national funds from FCT/MCTES (UIDB/50006/2020). This work was also supported by project Se(L)ect(i)vity (PTDC/EQU-EQU/6193/2020) funded by Fundação para a Ciência e Tecnologia, I.P. H.M. Saif acknowledges Fundação para a Ciência e Tecnologia, I.P. for his PhD grant 2020.09828.BD. S. Pawlowski acknowledges Fundação para a Ciência e Tecnologia, I.P. for his researcher contract CEECIND/00340/2018.

## SDEWES2021.0542

# Techno-Economic Analysis of a Novel Hybrid System for the Valorisation of SWRO Brines in a Minor Sicilian Island

C. Morgante[1], F. Vassallo*[2], D. Xevgenos[3], M. Micari[4], A. Cipollina[2], A. Tamburini[2], G. Micale[2]

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## Abstract

In small remote islands, freshwater scarcity is an issue to which several viable solutions have already been found employing constantly evolving desalination technologies. The several RO plants in the Canary and minor Sicilian Islands are just an example [1]. However, the beneficial application of seawater desalination is accompanied by a problematic matter: the production of high salinity brines [2]. Not only do they compromise the aquatic ecosystem but their treatment in order to respect environmental regulations is costly too. Worth noting how these so-called "wastewater streams" present a high concentration of valuable raw materials, such as magnesium and calcium or sodium chloride, that are essential to many industrial sectors (food, pharmaceutical, etc.) [3]. In this work, a novel hybrid system is introduced to valorize SWRO brines produced in the minor Sicilian island of Pantelleria. The treatment chain consists in the coupling of four different separation processes, each with a specific purpose: (i) Nanofiltration (separation of bivalent from monovalent ions), (ii) MF-PFR crystallizer (selective recovery of magnesium and calcium), (iii) Multi-effect distillation (freshwater production and NaCl brine concentration) and (iv) Evaporative crystallizer (recovery of sodium chloride). The chain not only recovers valuable minerals and fresh water but contemporarily reduces the volume of the final brine that will be discharged into the Mediterranean Sea and enhance the overall process sustainability by utilizing waste or solar thermal energy for powering some of the integrated units. Process models for each technology have been developed and integrated in an advanced simulative platform, which includes tools for the estimate of economic performance indicators, allowing to perform a full techno-economic analysis. Numerous scenarios, characterized by different operating conditions and energy sources of the single technologies, are taken into examination. The purpose is to identify the set of operative conditions that best yields an economically and environmentally sustainable brine treatment process, thus implementing the concept of circular economy.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 730390 (ZERO BRINE – Industrial Desalination – Resource Recovery – Circular Economy). www.zerobrine.eu.

## SDEWES2021.0592

# Chemical, Modelling and Experimental Efforts on Selective Ca and Mg Separation from Ro Seawater Desalination Brines

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## Abstract

Brines disposal from seawater reverse osmosis (SWRO) desalination plants poses environmental concerns. The approach of the near zero liquid discharge (NZLD), by recovering water and dissolved salts, mitigates this problem. To design a brine valorisation process, a key aspect is Ca and Mg removal/recovery to avoid scaling problems in the successive treatments and for economic return by minerals recovery. Some authors precipitated Ca and Mg cations as carbonates obtaining Ca removal of 94%–96% with a Mg loss>60% at 60°C [1] and Ca removal<85.4% with a Mg loss<6.7% [2] at 85°C. In this work three precipitation reagents were tested (i.e. Na citrate ($Na_3C_6H_5O_7$), $Na_2CO_3$, $NaHCO_3$) at different pH, temperature, ionic strength and reagent molar ratio to optimize the Ca and Mg selective precipitation. Ca-Mg aqueous solutions and a synthetic brine containing all major seawater electrolytes ($Na_2SO_4$, 8.4g/l, $NaHCO_3$ 0.13g/L, NaCl 48.2g/L, KCl 1.5g/L, $MgCl_2$ 11.0g/L, $CaCl_2$ 2.4g/L, Na2$CO_3$ 0.04g/L) were used. The chemical basis of the precipitation processes and ion-ion interactions based on the effective ion surface density (e.g. Slater rule), ion hydration, Eigen association process of the precipitate formation in the complex multicomponent brine, are discussed. Furthermore, chemical speciation of Ca and Mg precipitation, by using OLI and Medusa equilibrium calculation tools, has been modelled. Experimental results were in good agreement with the predicted values by the correlation tools. Ca precipitation at controlled pH, using $NaHCO_3$, gave>90% Ca removal efficiency with a Mg loss below 7% at 60°C. These results are of potential interest to design a process for brine valorisation treatment.

1) S Casas et al, Valorisation of Ca and Mg by-products from mining and seawater desalination brines for water treatment applications, J Chem Tecnol Biotecnol, 89(2014)872-883.

2) Y Wang et al, Selective removal of calcium ions from seawater or desalination brine using a modified sodium carbonate method, Desalination and Water Treatment, 174(2020)123–135.

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## SDEWES2021.0607

# Valorization of Surface-Waters Ro Brine via Assisted-Reverse Electrodialysis for Minerals Recovery: Performance Analysis and Scale-up Perspectives

A. Filingeri[1], M. Philibert[2], E. Filloux[2], N. Moe[3], V. Pavlovic[3], A. Poli[2], A. Tamburini[4], A. Cipollina*[4]

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## Abstract

- Reverse Osmosis (RO) plays a key role in seawater and brackish water desalination to fulfill the growing demand for fresh water. In recent years, RO has also been more and more adopted for the treatment and potabilization of surface waters, leading to two main problems: (i) the depletion in minerals of the product water, making it aggressive and unsuitable for drinking purposes and (ii) the production of a concentrated brine requiring proper disposal. Permeate remineralization post-treatments include pH adjustment and addition of minerals, such as bicarbonates, calcium and magnesium, which are essential for human health and required to meet drinking water guidelines. However, such solutions are exposed to critical issues related to supply, cost as well as extraction and transportation of chemicals.

- In this work, we investigate, via modelling tools, the use of Assisted-Reverse Electrodialysis (A-RED) to remineralize a surface water RO permeate stream by recovering minerals from its corresponding brine itself. This concept (patent pending [1]) was explored at the bench scale [2] and the subsequent experimental data used to validate the multi-scale model used in this study.

- The validated model was implemented to perform a process parametric analysis aiming at the design and optimization of a pilot-scale plant. Sensitivity analysis was performed considering the use of different stacks in series and hybrid configurations, including feed & bleed loops for one or both compartments and permeate by-pass.

- Moreover, the use of simplified techno-economic analysis tools allowed to identify the most promising configurations, which reduce the main cost items relevant to the industrial scale-up of the technology. More than 150 simulations were performed to compare different scenarios on the basis of the main performance parameters characterizing electro-membrane processes such as energy consumption, apparent flux and remineralization capacity. Results have shown that energy consumption can be reduced to less than 0.1 kWh/kg of salt transported to the permeate, in the case of permeate flow rates up to 2 $m^3/h$, while apparent fluxes can rise to 170 $l/(h*m^2)$ for larger bypass flow rates, resulting in lower capital and overall costs.

- References

- Philibert M., Filloux E., Garriou C., Steinmann D., Cipollina A , Installation and process for providing mineralized drinking water, European Patent EP19306565, Dec 2019.

- Philibert M., Natalello C., Filingeri A., Moe N., Filloux E., Cipollina A., Surface water RO permeate remineralization through minerals recovery from brines, submitted for publication.

## SDEWES2021.0632

# Redesigning the Coal Mine Wastewater Treatment to Enable Transition to Circular Economy Practices: the Zero Brine and Dębieńsko Case Studies

D. Xevgenos*[1], G. Gzyl[2], K. Panteleaki Tourkodimitri[3], K. Mitko[4], G.A. Tsalidis[5], A. Skalny[2], M. Mortou[3], D. Sapoutzi[3], M. Turek[4]

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## Abstract

Poland delivers high value to the EU as it is by far the largest coal producer. However, coal production comes with a high environmental cost at regional (or even national) level. The exploitation of hard coal mines leads to the generation of vast amounts of salty wastewater effluents (brines) which have severe environmental impacts. Currently, there are 18 hard coal mines in Poland, owned and operated by 5 coal mine companies, while several abandoned mines need still to be pumped to avoid flooding risks. The total mine water discharge in the Upper Silesian Coal Basin (USCB) is around 350,000 $m^3$/day, with the amount of chlorides and sulphates discharged to the rivers being approximately 4,000 tons/day. Brines from these mines are typically discharged into tributaries of the upper Wisła (Vistula) and upper Odra (Oder) rivers causing environmental and economic impacts.

The Dębieńsko wastewater treatment plant is treating brines from two coals mines leading to Zero Liquid Discharge (ZLD) as well as salt recovery since the ‘80s. However, its main drawback is the extremely high energy consumption (approx. 720 kWh/t of salt recovered), which has a high impact on the business viability and financial outcome. The aim of this work is to re-design the value proposition of the coal mine wastewater sector towards a Sustainable Business Model based on circular economy principles. To do so, we evaluate a novel coal mine brine treatment system that was demonstrated within the EU-funded project called ZERO BRINE, targeting higher salt recovery yields, improved energy efficiency, while achieving environmental and economic benefits. For this purpose, technologies such as ultrafiltration, nanofiltration, reverse osmosis, electrodialysis, crystallization and evaporation were tested. Our results showed that improving energy efficiency and environmental performance is possible. The new plant design offers the opportunity to recover salt, pure water, gypsum and magnesium hydroxide and its energy efficiency of Dębieńsko plant is improved by approx. 30% (approx. 500 kWh/t of salt recovered). Coal mines located within the hydrogeological subregion boundary (e.g. Bolesław Śmiały, Knurów-Szczygłowice, Piast-Ziemowit, Mysłowice-Wesoła, Janina, Silesia) show good potential for replicability of the Dębieńsko circular economy approach. This will be further investigated together with the coal mine industries operating these mines. Policy tools, most importantly the Just Transition Fund and the Structural & Cohesion funds, can play a crucial role in paving the right way of the most affected regions towards energy transition and carbon neutrality.

Acknowledgements

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement no. 730390 (ZERO BRINE – Industrial Desalination – Resource Recovery – Circular Economy). www.zerobrine.eu.

## SDEWES2021.0730

# Evaluation of Saltwork Ponds Operation Through Brine Characterization and Geochemical Modelling Using PHREEQC Code Integrating the Pitzer Correction

F. Vicari[1], S. Randazzo*[2], J.L. Cortina[3], G. D'alì Staiti[4], M. Fernández De Labastida[5], J. López[3], G. Micale[2], A. Tamburini[2], V. Vallès[5], A. Cipollina[2]

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## Abstract

Seawater represents a potential resource for raw materials extraction. Overall, NaCl is the most famous and representative extracted component. However, other valuable compounds such as Mg, Li and elements at trace level (Rb, Cs, Sr, Co, Ga, Ge) are also contained in this liquid mine, many of them included in the EU Critical Raw Materials list. In solar saltworks, where table-salt is mainly manufactured; evaporation of seawater leads to fractional crystallization of Ca and Na salts and the generation of residual brines, 20-40 times more concentrated than seawater. Along the evaporation sequence, minor components fate has not been extensively studied so far. With this respect, Pitzer model can be a valuable tool by allowing a reliable description of the occurring precipitation.

In the present work, PHREEQC was used to describe the minerals deposition pathway along the different ponds of the Trapani saltworks (Italy). Model results were successfully validated by characterizing samples belonging to different evaporation stages ponds.

## SDEWES2021.0736

# Seabrine™ - the Industrial Waste Brine Solution Brine Purification Demo Plant with HPO Process for Valorization ofTOCReduction of Industrial Waste Brines

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## Abstract

KVT process technology has developed the SEABRINE technology for the treatment of contaminated industrial water. It is already successfully implemented in Epichlorohydrin and epoxy resin production plants up to a treatment capacity of 90 $m^3/h$.

The SEABRINE technology aims for maximum energy recovery and low to zero waste. The process is divided in Pre-treatment; High Pressure Oxidation (HPO), and catalyst recycling unit.

The SEABRINE technology is primarily advantageous, when very low TOC values as low as 7 ppm are required in the purified brines. Purified sodium chloride brines are recycled in C/A electrolysis plants as raw material.

Within the EU-funded WATER-MINING project, a High Pressure Oxidation (HPO) Demo Plant was developed. It can handle a mass flow up to 0.1 $m^3/h$ raw brine with different degrees of TOC and Salt content. Another aim of the HPO demo plant is to test different materials of construction for the plant equipment and a new concept of catalyst recovery to optimize operational and investment costs for industrial scale plants.

Brine Pre-treatment In the HPO Demo Plant the pH-Value of the Brine is adjusted with hydrochloric acid. Typical pre-treatment steps are filtration and AOX reduction to prevent plugging and corrosion.

HPO The oxidation reaction is a homogenous catalytical reaction. The catalyst is mixed with the brine and the oxidation agent. The brine is pressurized to above 60 barg and preheated in a recuperator up to 220 – 270 °C by recovering the heat of the purified brine downstream of the reactor. The final operating temperature of above 260°C is realized by the exothermic oxidation reaction.

The purified brine is depressurized, and the heat is recovered for preheating the raw brine. Depending on the site conditions, a further treatment of the gas phase or of the brine is implemented. In the HPO Demo Plant a NaOH Scrubber is installed to remove the HCl from the waste gas.

The oxidation rate is >99%. The brine after the oxidation unit has a TOC value of <7 mg/l, which is within the specification for C/A electrolysis.

Catalyst Recycling Unit The homogenous catalyst is separated from the brine to close the catalyst cycle. The pH-value is adjusted, and the brine is treated via sedimentation or filtration and ion exchange up to a limit of <0,1 mg/l. The catalyst from both steps is recycled to the raw brine for oxidation. In the HPO Demo Plant a new method of catalyst recycling will be tested.

## SDEWES2021.0871

# Valorization of Seawater Desalination Brines Through the Integration of Eutectic Freeze Crystallization and Electrodialysis with Bipolar Membranes Innovative Technologies

A. Culcasi[1], R. Ktori[2], A. Pellegrino[3], M. Rodriguez-Pascal[2], M. Van Loosdrecht[2], A. Tamburini[1], A. Cipollina*[1], D. Xevgenos[4], G. Micale[1]

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## Abstract

European policy encourages the adoption of sustainable systems that promote the efficient use and recovery of resources. Accordingly, this study proposes integrating two innovative technologies, including Eutectic Freeze Crystallization (EFC) and Electrodialysis with Bipolar Membranes (EDBM), for treating seawater desalination brines. Two experimental campaigns were conducted to assess the viability of this novel treatment chain. Using two lab-test rig units, the effect of various operating conditions on the outputs and general performance of both EFC and EDBM was evaluated. Firstly, results showed that EFC could manage seawater brines to (i) obtain pure sodium sulphate, and fresh water in the form of ice and (ii) provide a NaCl concentrate stream to EDBM. Secondly, regardless of the feed salt concentration, EDBM can operate with high current densities without significantly affecting the current efficiency, thus resulting in high conversion rates. Within the circular economy concept, the present study demonstrates that this integrated system is effective for minimizing seawater desalination waste streams.

## Special session: Waste derived Biomix fuels for high efficiency and low emission application

Prospects of using waste derived biofuels in the internal combustion engines are increasing day by day due to the limited fossil fuel reserves and their negative impacts on the environment and human health. Although, electric vehicles are future solutions for mobility; use of conventional engines will continue in heavy-duty vehicles, marine, power generation and in other application as electrification of these sectors are yet to be feasible. Biofuels are now important part of the energy mix. However, along with the challenges of producing high quality biofuels, finding sustainable waste resource is a challenge. The bio-mix concept helps to produce high quality biofuels from various resources and mix them together to meet the international standards (for example – biodiesel- biodiesel mixing). Another important aspects of the biomix fuels are novel combustion concepts for achieving high thermal efficiency and low exhaust emissions, examples are – variable compression ignition (VCR), homogeneous charged compression ignition (HCCI), reactivity controlled compression ignition (RCCI) concepts. This special session will draw researchers working on the biofuels and their advanced combustion in the engines. The session will stimulate the discussion around these areas and will help progress R & D aspects in sustainable biofuels and combustion areas. The motivation for proposing this session has come partly from a UK-India collaboration project we are working on this research theme.

### Session organizers:

**Dr. Abul Kalam Hossain**, Aston University, Birmingham, United Kingdom

**Dr. Ganesh Duraisamy**, College of Engineering Guindy, CHENNAI, India

*Abul Kalam Hossain* - I am working as a Lecturer of Mechanical Engineering in Aston University (Birmingham, UK). My research interests and expertise are in developing small-to-medium scale sustainable renewable energy systems for poly-generation application including electricity, cooling, heating and desalination. Specific areas of interests include renewable biofuels for mobility and co-generation/tri-generation; engine waste energy recovery; 2nd and 3rd generation biofuels production, characterisation and upgradation; new and novel low temperature combustion techniques in IC engines, combustion and emission characteristics. I have gained wide experience and skills throughout my career in industry and academic R&D activities. I collaborate with several UK and international universities and industry partners.

*Ganesh Duraisamy* - Dr. Ganesh Duraisamy is Associate Professor at Internal Combustion Engineering Division of Department of Mechanical Engineering, College of Engineering Guindy, Anna University, Chennai, India where he has been working from 2003. He obtained his Master Degree and PhD in Mechanical Engineering at Anna University. Dr Ganesh Duraisamy 's research focus is on High Efficiency Advanced combustion modes for on-road and off-road engine applications, Hybrid and Electrical vehicles. He has published 40 research publications with h-index of 10 and 1308 citations. He is also a member of combustion Institute - India and SAE. He has collaboration with industry partners and bilateral projects with international universities.

Invited submissions

## SDEWES2021.0086

# Effect of Quality of Used Oil on the Properties of Biodiesel, Engine Performance and Engine Out Emissions

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## Abstract

Cooking oil having total polar matter (TPM) content higher than 25% is generally considered as waste cooking oil (WCO). WCO is a sustainable feedstock for biodiesel production. Since WCO is a degraded raw material, it is important to know the effect of WCO degradation on the properties of the biodiesel. In this work, the effect of TPM content of the oil on the properties of biodiesel was investigated. Sunflower oil and palmolein oil were used for this study. WCOs were produced from these oils in the laboratory by frying food items. Biodiesels from WCOs were produced by transesterification. Kinematic viscosity, Cold flow property and oxidation stability of the biodiesel were affected with increase in TPM of oil. Furthermore, in this work, engine experiments were conducted to study the effect of biodiesels produced from fresh oils and WCOs on the performance and emission of Diesel engine. It is found that the biodiesels produced from WCOs resulted in slightly higher brake thermal efficiency of the engine, higher carbon monoxide emission and higher unburned hydrocarbon emission, compared to the biodiesels produced from fresh oils.

## SDEWES2021.0136

# Energy and Sustainability Based Investigation of an Off-Road Diesel Engine Fuelled with Cassia Fistula Biodiesel

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## Abstract

Diesel engines are not only used in the transportation sector, but also used in many places for stationary power generation. Hybridization/Electrification is feasible in the transportation sector but not in the stationary power generation sector due to their complexity and lower power density. Presently, the off-road diesel engine also significantly degraded the environment and contributes the global warming like diesel engines used in the transportation sector. Further, currently, off-road diesel engines consume almost 25 to 30% of total fossil fuel all around the world. Hence, finding an efficient and sustainable alternative fuel for off-road diesel engines is imperative. Accordingly, in the present investigation, the effect of Cassia fistula ester biodiesel on off-road diesel engines was investigated through energy and sustainability analysis. Experiments were performed on a stationary diesel engine at the rated power of the engine. First, cassia fistula biodiesel was prepared through an ultra-sonication assisted transesterification process using a heterogeneous base catalyst. The energy and sustainability analyses were performed with different injection strategies and compared with diesel fuel. The experimental investigation shows that using cassia fistula ester biodiesel in diesel engines enhances energy and exergy efficiency by reducing the energy and exergy destruction rate. Further, it was observed that cassia fistula ester biodiesel provides a better sustainability index which means it may be a sustainable future alternative fuel for diesel engines. Instead of using a single direct injection splitting the direct injection, enhances the exergy and exergy efficiency particularly at triple injection strategy

## SDEWES2021.0587

# Biomix Fuel Production from Waste Resources and Their Utilization in a VCR-Crdi Compression Ignition Engine

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## Abstract

The utilisation of waste material to produce energy is the need of the hour to reduce environmental pollution and hazards related to unsustainable disposal practices. Biomix is a new and effective sustainable approach to utilise waste as a bio-liquid fuel. Waste cooking oil and pig fat were used to prepare raw biomix oil and converted into biomix methyl ester (BMME) through transesterification. Biomix fuel properties were characterised and observed to be within the biodiesel standard's limits. The biomix sample was tested on a modified variable compression ratio-common rail direct injection engine at various compression ratios (CR 7.5, 20, and 22) and injection pressures (400, 500, and 600 bar), and at various proportion of exhaust gas recirculation (10%, 20%). It was observed that at CR of 22 and at injection pressure 600 bar, the BMME fuel without exhaust gas recirculation gave a minimum reduction in brake thermal efficiency by about 0.15% as compared to fossil diesel fuel. Due to the increased delay period of BMME fuels, and the start of combustion was advanced. The NO gas emissions were found to be decreased by about 50% at CR of 17.5 for all injection pressures and exhaust gas recirculation flows; but NO gas emissions were increased when the CR was increased to 20 and 22. Smoke and hydrocarbon emissions were observed to be increased with the increase of exhaust gas recirculation ratios. The engine test results of BMME fuels were observed to be comparable to the fossil diesel fuel. The biomix approach reduced the overall production cost by about 45% as compared to the conventional biodiesel produced from the single feedstock. The study concluded that biomix fuel could be a sustainable alternative fuel for stationary diesel engines widely used in utility power generation, agriculture, marine, and construction equipment.

## SDEWES2021.0669

# Biodiesel Fuel Property Enrichment and NOx Emission Mitigation Techniques

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## Abstract

Sustainable waste derived biodiesel can replace significant amount of fossil-based fuels currently used for marine propulsion, agricultural processes, small power generation, and in heavy goods vehicles. However, biodiesel fuel quality varies depending on the feedstock, production method and storage conditions. Hardly, biodiesel produced from a single feedstock would satisfy the biodiesel fuel standards. In addition, it is well known that NOx emission is likely to increase in biodiesel-fuelled engines compared to fossil diesel. This study aims to suggest fuel property enhancement by biodiesel-biodiesel blending, to review the engine test results of the existing biodiesels in the literature and to describe methods to reduce NOx emission. The waste driven and inedible plant oil feedstocks are investigated in terms of biodiesel production. Fuel properties and engine test results of various biodiesels are also reviewed from the literature. This information is summarised for the feedstock origins to understand and suggest best matching feedstocks for biodiesel-biodiesel blending. The study suggests that blends of animal fat biodiesels and vegetable oil biodiesels are likely to improve fuel properties, combustion characteristics and reduce exhaust gas emissions. This is mainly attributed to the chemical compositions of the mentioned feedstocks i.e. animal fat biodiesels are mainly composed of saturated fatty acid methyl esters, whereas vegetable oil biodiesels are unsaturated. In addition, NOx reduction techniques are categorised and investigated under three sub-groups, which are fuel treatment, engine adjustment and exhaust after-treatment. Based on the state of art review, scopes for future R&D have been presented for related industries and researchers.

## SDEWES2021.0783

# Aviation Biofuels: Progress and Challenges

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## Abstract

The significant growth of the aviation industry plays a vital role for socio-economic development, creating nearly 57 million jobs and USD 2.2 trillion worth in global GDP. Worldwide, the aviation industry produced 770 million tonnes of $CO_2$ in 2015, out of which 12% emission was produced by aviation transport. The Air Transport Action Group (ATAG) projected that by 2035, airlines are going to carry some 8.2 billion passengers per annum. The increase in freight travel will mean a drastic increase in the consumption of fossil-based fuels used in aircraft engines. The current growth rate predicts that aviation-related carbon emissions could triple by 2050, equivalent to 3.1 billion tons of GHG emissions. Electric propulsions of passenger aircraft are yet to be technologically feasible. Due to the stringent emission regulations in the aviation sector, it is a significant research challenge to find sustainable alternative solutions to reduce the airline industry's GHG emissions. The jet fuel used in aircraft engines is currently obtained from the kerosene fraction of crude oil, however, green biofuel could be the potential sustainable alternative to reduce GHG emission to meet emission targets. Recently, biofuels derived from waste resources, vegetable oils and micro-algae have attracted attention as potential replacements if biofuel properties can match aviation fuel quality specification (ASTM D7566-11). Most of the renewable jet fuels are derived from liquid biomass derived from hydro-processing technology. This paper reviews the state of the art of aviation biofuel, and covers production technology, type of liquid biomass feedstock and their sustainability and includes recent developments in algal biotechnology that are required to drive this sector forward. Energy, environment and economical ($E^3$) analysis of advanced aviation biofuel, to compare their merits and drawbacks are discussed and topics for future R & D are presented.

## SDEWES2021.0794

# Model for Energy Consumption and Costs of Bioethanol Production from Waste Paper

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## Abstract

This work investigates bioethanol production from wastepaper via acid and enzymatic hydrolysis with the aim to attain the highest possible yield, including an evaluation of energy consumption of the production processes and costs involved. A mathematical model was designed using MATLABR software, in which pre-calculated chronological stages have been specified with the parameters that significantly affect the bioethanol yield, including type and number of consumables, reaction temperature and residence time. The independent variables have been determined based on recommended values found in the literature and are provided as suggestions to the user, who is also given the choice to manually input the other values in the built computer programme based on the model. Mass and energy balance are carried out for each process stage of bioethanol production in order to calculate the energy consumption of the chemical reactions. The model also calculates the bioethanol yield per 100 g of lignocellulosic biomass and the related costs. A comparison between enzymatic and acid hydrolysis bioethanol is presented by a line chart on the MATLAB$^{R}$ APP DESIGNER interface, helping the understanding of the effects of the independent variable parameters. As a result, the most optimal conditions to produce the highest yield of bioethanol and therefore increasing the efficiency of a process is obtained. The model is expected to aid in the reduction of laboratory -based experiments being conducted, saving time, human errors and costly microorganisms and other consumables.

## SDEWES2021.0967

# Addition of the Natural Compound Squalene Reduces Oxidation in Unsaturated Oils

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## Abstract

Preventing oil oxidation is an important commercial practice and a number of synthetic antioxidants have been used to extend shelf life and reduce rancidity. However, there are health concerns around the use of many of these synthetic antioxidants and there is a shift towards the desire to use natural antioxidants. Vitamin E is a lipid soluble antioxidant, though its effects are not always predictable and in many cases addition of the compound to oils actually stimulates oxidation. Squalene is a C30 hydrocarbon triterpenoid and has proposed antioxidant activity due to the presence of double bonds in its structure. Here we report on the oxidative stability of two oils, namely cottonseed and linseed, following addition of this compound. Cottonseed is rich in linoleic acid C18:2 (delta$^{9,12}$)and linseed was chosen because of its high 18:3 (delta$^{9,12,15}$)content. Based on their high unsaturation levels, both oils are predicted to readily oxidize. Oil oxidation was followed in time-course studies at both 25 °C and at 80 °C using a range of techniques including titration-based assays (peroxide and p-anisidine values), GC-MS, $^{1}$H NMR, DSC and TGA. The results show that addition of squalene at 0.1% level significantly lowered oxidation in both oils and could prove to be an important application to improve commercial oil oxidative stability.

## SDEWES2021.0998

# Investigation on Yield, Fuel Properties, Ageing and Low-Temperature Flow of Various Fish Oil Esters

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## Abstract

In order to reduce pollution in the contemporary environment, it is necessary to use waste resources for energy production. In this study, biodiesel was produced from waste fish oil by using methanol, ethanol, and iso-propanol in the presence of heterogeneous catalyst. Prior to transesterification, esterification of the fish oil was performed to reduce the free fatty acids content. Three biodiesel samples fish oil methyl ester, fish oil ethyl ester, and fish oil propyl ester were produced. Optimization studies were carried out under various operating conditions such as alcohol-to-oil ratio (v/v) catalyst concentration, reaction time, and reaction temperature. The best conditions were achieved at 16:1 alcohol to oil ratio, 3% catalyst by (wt/wt), 90 min reaction time, and 65°C, 80°C, 85°C reaction temperatures for methanol, ethanol, and isopropanol. The qualities of biodiesel fuel were investigated, we found that ethyl ester and propyl ester gave better physiochemical properties than methyl ester. The use of ethanol and isopropanol increased low-temperature qualities such as cloud point and pour point. To determine the rate of degradation, these three biodiesel samples were kept in the dark for ten months. At every two-month intervals, the qualities of fuel samples were measured. Results showed that the degradation rate of fish oil propyle ester and fish oil methyl ester (FOME) were lower as compared to fish oil ethyl ester. The future scope of the research activity is to assess engine performance and emission characteristics using these biodiesels.

## Advanced sustainable energy conversion systems

## SDEWES2021.0408

# Thermodynamically Consistent Reduced Dimensionality Multi-Species Electrochemical Model for Solid Oxide Fuel Cell Performance Modelling, Control and Digital Twin

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## Abstract

Solid Oxide Fuel Cells (SOFCs) are a promising and emerging technology that provides several advantages over traditional energy conversion systems, which, besides high efficiency and relatively low levels of emissions, comprises also long-term stability and fuel flexibility. The simultaneous reduction in production costs and prolongation of service life while maintaining high system efficiency are considered as major challenges toward their wider market adoption. Reaching these objectives calls for the application of advanced virtual tools over the entire product lifecycle management.

This paper will, therefore, address a challenging aspect, which covers advanced system level models, which feature mechanistic basis, high accuracy and short computational times. Such models can be used in the left arm of the V-development process due to their mechanistic basis and thus high accuracy and extrapolation capability. When such models feature also real-time capability, they can be applied in the right arm of the V-development process in HiL applications, where good extrapolation capability also significantly enhances applicability and accuracy of the model, as it can be parametrized on smaller data sets. Furthermore, such models can also be applied as digital twins, thus ensuring enhanced control capabilities. Fast running mechanistic models namely enable introducing new functionalities such as advanced SoX observers further pushing boundaries of performance and service life optimizations as well as predictive maintenance and failure analysis.

To present significant progress in the aforementioned area this contribution presents, for the first time, the framework of computationally-fast thermodynamically consistent reduced dimensionality electrochemical SOFC model based on the closed form solution. In particular, the model is also capable of evaluating the anode open circuit voltage and overvoltage for two component fuel consisting of CO and $H_2$.

Multiple validation steps against polarization curves with different fuel mixtures confirm the capability of the newly developed model to replicate experimental data at extremely short computational times. Additionally, the presented work features the determination of an optimal set of calibration parameters and their sensitivity and unique identifiability based on Fisher information analysis. Furthermore, in-depth analyses of the model capabilities show that the model exhibits very good extrapolation capabilities for operation points outside the calibrated variation space of parameters. In addition, on the fly predictive analysis of the energy production in immediate future and future at rated voltage due to fluctuation in fuel quality and reactant ratio confirms State-of-Function capability of the model. These features characterize the model as a suitable candidate for crossing the system level part of the V-development process, for control applications and as a model basis of digital twins.

## SDEWES2021.0410

# Green Hydrogen Production Potential in West Africa – Case of Niger

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## Abstract

Renewable energy sources are the only energy solutions to reduce the effect of global warming induced climate change. Nevertheless, variable renewable electricity (e.g. from solar or wind energy) requires enormous energy storage capacity to supply the future energy demand. Green hydrogen, as an energy vector, has the potential to be the most suitable solutions to some of these problems. The current production of hydrogen from renewable electricity (green-hydrogen) comes at high levelized costs of hydrogen (LCOH) compared to the same produced from fossil fuels (grey-hydrogen). These high costs are the result of the relatively young technology used for such a production system (electrolyzer). However, the LCOH is expected to decrease in the future with technology maturity and economy of scale, making hydrogen as one of the most versatile energy vector.

Niger offers the possibility of producing green hydrogen due to its high solar energy potential. Due to the still growing domestic oil and coal industry, the use of green hydrogen in the country currently seems unlikely at the higher costs of hydrogen as energy vector in the coming years. However, the export of green hydrogen to industrialized countries could be a promising option. In 2020, a hydrogen partnership has been established between Germany and Niger. The potential import of green hydrogen represents a promising option for Germany and other European countries to decarbonize domestic energy supply. Currently there are no known projects for the electrolytic production of hydrogen in Niger. In this work, techno-economic potential for the production of green hydrogen in Niger has been analyzed under different scenarios of domestic consumption and export. While doing so, the possible challenges (e.g. water scarcity in arid regions, infrastructure, etc.) are also analyzed and contrasted to the above-mentioned benefits.

## SDEWES2021.0433

# Photocatalytic Activities of Visible Light Photocatalysts for Hydrogen Production by Liquid Phase Plasma Irradiation

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## Abstract

Ammonia is easy to apply as a hydrogen carrier and is a promising material as a direct source of hydrogen production. This paper was proposed a mass-production of hydrogen from liquid ammonia through photocatalytic decomposition by applying liquid phase plasma discharge with photocatalysts. In this reaction, commercial $TiO_2$ was introduced as a UV-sensitive photocatalyst, and $TiO_2$ codoped with N and Ag was prepared and applied as a visible light-sensitive photocatalyst. The bandgap of N- with Ag codoped $TiO_2$ determined from the spectrum measured by photoluminescence spectroscopy was 2.0 eV. It has been described that N atoms and Ag ions are doped to narrow the bandgap between the conduction band and valance band of $TiO_2$. In the decomposition reaction of liquid ammonia by liquid phase plasma irradiation, the highest hydrogen evolution rate was found in the N- and Ag-codoped $TiO_2$ photocatalyst.

## SDEWES2021.0440

# CFD Simulation of Ball Milling Reactor for Novel Ammonia Synthesis Under Ambient Conditions

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## Abstract

The present study simulating the alternative method of producing the Ammonia from conventional approach (Haber Boach method). Recently a mechanochemical synthesis approach using an iron powder-based catalyst was developed at lab scale. The operating parameters of the proposed method at which ammonia was successfully synthesized at competitive yields were 45°C and 1 bar which is far lower than conventional Haber Bosch process. Utilizing ball milling, high defect densities were locally generated by mechanical collisions, accelerating nitrogen dissociation, and the transferred energy produced from the dynamic relaxation during violent impacts helped the desorption of strongly adsorbed intermediates. This work takes the first steps towards a realistic scale-up of the system. Since vertical ball mill is not a common practice at industrial scale this work will utilize experimental reaction data to build and validate a vertical ball mill reactor model. To understand internal behavior inside the planetary vertical ball reactor, discrete element method was used. The impact force stress intensity, and stress frequency of iron ball on wall were simulated with an end goal of producing a global reactor model as a basis for an experimentally validated scale-up.

## SDEWES2021.0688

# Tofu Derived Electrocatalyst for Oxygen Reduction Reaction in Anion Exchange Membrane Fuel Cell

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## Abstract

The oxygen reduction reaction (ORR) at the cathode of anion exchange membrane fuel cell is a very slow reaction. Therefore, Pt-based catalyst is only applied to practical application. Since Pt-based noble metals are very expensive, research is underway to reduce the amount of noble metals or to replace Pt-based noble catalysts. To reduce the production price of fuel cells, the development of a simple fabrication process with mass-productivity and the replacement of the use of noble metals should be required. Transition metal catalysts with Metal-N-C (M-N-C) sites has been investigated as an alternative of the noble metal catalyst for the oxygen reduction reaction (ORR), which occurs on a cathode of fuel cell. In this research, to generate the M-N-C sites, protein precipitation is used through chelating metal cations with protein's functionalized groups, -COOH and $-NH_2$. For doing this, we utilize the traditional fabrication method of tofu made of soy milk to intake the proteins. To separate the dissolved protein from soy milk as a solid-state, coagulant containing the metal divalent cations (i.e., $Mg^{2+}$ and $Ca^{2+}$) is added. Accordingly, the solidified protein contains the M-N-C site for ORR, in which the coagulant components ($Mg^{2+}$, $Ca^{2+}$) replace the transition metal components (e.g., $Zn^{2+}$, $Co^{2+}$). Bimetallic Tofu (Zn and Co) was prepared and carbonized to synthesize M-N-C site. At this time, Zn was used to generate pore and prevent aggregation of Co. Prepared Co-N-C catalyst showed high ORR performance ($E_{1/2}$ = 0.86 V, $E_{onset}$=0.934) and stability.

## SDEWES2021.0715

# Synthesis of Atomically Dispersed Mn-Nc Hollow Sphere as Enhanced Electrocatalysts in Fuel Cell

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## Abstract

Metal-nitrogen-carbon (M-N-C) catalysts have been reported as a promising electrocatalyst to replace noble metal catalysts (Pt/C, Au/C, and Ru/C, etc.).

Carbonized ZIFs (Zeolite imidazole frameworks) as a precursor of metal-nitrogen-carbon (M-N-C) catalyst has been extensively studied because of their porosity and ligand that is composed of nitrogen and carbon. Most of the ZIFs precursor is prepared by hydrothermal method with metal salt and 2-methylimidazole. Although this method has the advantages of simple and low-cost synthesis, it is difficult to control the shape of the particles, and it is difficult to synthesize in large quantities. This study synthesized M-doped ZIFs particles (M=Co, Cu, Mn, and Fe) from M-doped ZnO (M=Co, Cu, Mn, and Fe) sphere by spray pyrolysis method and pseudomorphic replacement. This process makes it possible to control the morphology of MOF particles and make MOF composite particles easily. The pyrolyzed ZIFs particles were applied to an oxygen reduction reaction, $CO_2$ reduction reaction, and Hydrogen evolution reaction depending on the doped metal.

## SDEWES2021.1016

# Challenges of Heat Pipes Application for Sustainable Development of Energy Systems

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## Abstract

The heat pipe is a device of very high equivalent thermal conductivity. Because of their superior thermal conductivity, heat pipes are prime candidates for applications in energy systems involving the utilization renewable energy sources as solar and geothermal energy, the recovery of the low-grade waste heat from various industrial plants and processes and improving the performance of energy machines and equipment, i.e. the efficiency of the cycles in which they work. Due to superior heat transfer and other favorable characteristics, heat pipes are widely used in solar collectors and solar energy utilization generally. Heat pipe deicing and snow melting systems of the highway pavement, and heat pipe heating systems in the buildings and greenhouses, utilizing natural stored geothermal energy of the earth and of the underground water or from hot springs and sea have been developed and investigated. Features of those systems are no moving parts and no external power requirement, implying high reliability, i.e. maintenance free. A heat exchanger using heat pipes can efficiently be used to transfer heat between fluid streams having a small difference in temperature, such as with low-grade heat. Also, due to their particular performance characteristics, a heat pipe heat exchanger can be used where other conventional heat exchangers become inappropriate. The application of heat pipes is becoming increasingly important in the cooling of energy machines components (electric motors, turbomachines (steam and gas turbines, compressors), internal combustion engines)) and equipment (bearings, tools, etc.). Today, the heat pipes are widely used for cooling electrical and electronic components like transistors, other semiconductor devices and integrated circuits. The aim of this paper is, based on typical applications as well as conceptual ideas, to show that heat pipes contribute to the sustainable development of energy systems. For a better understanding, in the paper the physical phenomena related to the operation of the heat pipe will be also presented.

## Alternative fuels

### SDEWES2021.0282

# Prediction of the Product Yield from the Co-Pyrolysis of Biomass and Waste Plastics and the Influence of the Synergistic Effect

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## Abstract

Co-pyrolysis of biomass with different waste plastics might be a promising alternative for producing high-quality alternative fuels and dealing with the emerging problem of waste disposal. Plastics materials have properties similar to those of fossil fuels in terms of heating value and absence of oxygenated compounds; therefore, they could significantly improve biomass products properties, especially bio-oils. To scale-up the process on an industrial level, it is of great importance to ensure high-quality product yield, but even more, it is an absolute necessity to develop a method for the prediction of product yield and distribution. This could be done by observing the results from Ultimate and Proximate analysis, product yield from individual pyrolysis, and considering the influence of synergistic effect. In this work, we present the model for product yield for the co-pyrolysis of biomass sawdust with polystyrene, polypropylene, and polyurethane foam. The model is based on the calculated theoretical yield and a mathematical relationship established for the synergistic effect of the selected critical mixtures of biomass and plastic feedstock. The presented model for predicting product yield gives an excellent accuracy for investigated feedstock, even though investigation should continue to ensure reproducibility of the method for other types of biomass feedstock. Furthermore, an additional conclusion is given regarding the optimal share of plastic content in the fuel mixture, observing the bio-oil quality.

## SDEWES2021.0708

# Synthesis of Co and Fe Doped Hollow Carbon Spheres from Mof/polypyrrole Core-Shell Particles and Their Application for Oxygen Reduction Reaction

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## Abstract

The fuel cell is one of the most promising electrochemical devices, which are sustainable, clean, and environmentally sound. Oxidation-reduction reaction (ORR) is one of the key reactions for fuel cells which should be improved for higher performance. Currently, a lot of approaches have been tried to improve the efficiency of the ORR, and MOF-derived electrocatalysts are getting more attention due to their tunable pore structure and easy functionalization. Herein, we fabricate Fe and Co-codoped hollow carbon spheres, which was prepared on the hybrid PPy-Ps spheres as hard templates. PPy is used as a source for nitrogen-doping as well as a carbon source for the catalyst. Sodium sulfate is a surfactant that increases the electronegativity of PPy, which plays a pivotal role in the growth of ZnCoBZIF layer evenly on the entire sphere's surface. After a single pyrolysis step, Co and Fe species were embedded in the hollow carbon spheres. The catalysts were characterized by field emission scanning electron microscope, field emission transmission electron microscope, X-ray diffraction, Brunauer–Emmett–Teller analysis, and X-ray photoelectron spectroscopy. Morphological control combined with transition metal and high nitrogen atom concentrations from PPy and ZIFs yield excellent ORR performance.

## SDEWES2021.0753

# Design and Optimization of a Multi-Mode Hydrogen Delivery Infrastructure for Clean Mobility

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## Abstract

With the introduction of the Green Deal, the European Union has committed to strongly curb $CO_2$ emissions, aiming at a zero net balance by 2050. The transition to a fully decarbonized system requires the involved stakeholders to pursue all the available options able to mitigate emissions in all sectors. Within this framework, hydrogen has the potential to play a major role, as it provides a way to decarbonize hard-to-abate segments. However, the widespread use of hydrogen is currently hindered by the lack of a delivery infrastructure that allows a distributed access to such energy vector.

This work aims at developing a model to optimize the design and the operation of a hydrogen infrastructure, comprising production, storage, and transport up to the demand points (e.g., industrial offtakes or refuelling stations), given the demand distribution and time evolution. The developed tool combines the use of detailed spatial data through a Geographic Information System (GIS) to define the candidate networks' topologies and the resolution of an optimization model to determine the cost-optimal infrastructure, considering a year-long time horizon with daily resolution. The description of the supply chain includes multiple production technologies, namely steam methane reforming equipped with $CO_2$ capture and electrolysis systems fed by solar PV, as well as multiple transport modalities, i.e. pipelines, compressed-hydrogen trucks, and liquid-hydrogen trucks.

The analysis looks at a 2050 scenario in which hydrogen is broadly employed as a fuel for clean mobility, assuming a 25% share of fuel cell electric vehicles among passenger cars and consistent cost projections for the system components. Given the high computational complexity, the model is applied at a regional scale, considering the Italian region of Lombardy, featuring a case study with 14 production sites, 15 storage nodes, 366 demand points, and more than 5000 connecting edges. Results show that the optimal infrastructure relies on all the three transport modalities, with a predominance of pipelines and liquid-hydrogen trucks. The cost of hydrogen delivered to refuelling stations ranges between 5-8 €/kg, the greatest contribution being that of production which would mainly come from PV-based electrolysis plants. Infrastructural integration over wider areas or improved production options appear essential to approach a more competitive long-term target of 4 €/kg.

## SDEWES2021.0911

# Advanced Methods of Green Hydrogen Production and its Transportation

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## Abstract

In this work, the focus is on reducing the need for electricity per mole of hydrogen, and on the investigation of the effect of the magnetic field on green hydrogen production, i.e. hzdrogen production via water electrolysis using solar energy, and current density, depending on the different Lorentz force direction. Energy consumption analyzes will be conducted for different types of porosity of the electrode material. The new design of an electrolyzer is to be constructed without a membrane with the additional introduction of a magnetic (and optical) field, which should ensure higher hydrogen production efficiency. Along with improving the efficiency of hydrogen production processes, processes involving hydrogen transportation need to be addressed. Hydrogen transport is a crucial factor in the costs, emissions, and energy consumption associated with hydrogen routes involving the central production at the production plant. At present, transportation to existing pipelines seems to be the most economical solution for transporting large quantities of hydrogen over long distances.

All these would allow a drastic reduction in the cost of mass production of hydrogen, which, along with transportation through existing gas pipelines, would make technology in the price range with today's conventional fuels/energy sources. This would open opportunities for the industry to become involved in the production of the electrolyzers, which would enable job creation and education of experts in this specialized field of hydrogen technology, which would have a direct impact on the economy.

## SDEWES2021.0969

# A Decentralized Production of Sustainable Synthetic Kerosene: Impacts of Operation Strategies on the Energy Supply

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## Abstract

Especially for medium and long-distance flights, the supply with sustainable synthetic kerosene may play a significant role in the future defossilization of the aviation sector. In the case of Brazil, a large number of airports is situated in remote areas with a poor infrastructural connection to the current highly centralized fuel industry, which leads to an elaborate and expensive supply with kerosene. A decentralized production of sustainable synthetic kerosene with modular Power-to-Liquid (PtL) units directly on site, might therefore be a cost-competitive solution already in the near future.

To exploit the potential of synthetic fuels with regard to the sustainability, a supply with renewable electrical energy is crucial and has to be considered as part of the overall system, as in most cases of these airports, local electricity grids – if available – are supplied with electrical energy based on the combustion of fossil fuels.

This work evaluates the role of different possible plant setups of the PtL process and its impacts on the upstream supply via intermittent renewable electricity and adequate storage systems. Based on location-specific renewable energy potentials and literature-based economic assumptions, the levelized costs of electricity or hydrogen are assessed for future scenarios until 2050. A sensitivity analysis is carried out and, based on a generic approach, the cost-optimal plant setups for different scenario assumptions and selected airports are assessed, using a linear optimization model. Aside the different setups of the PtL process which affect the required feedstock – either electrical energy or hydrogen – the effects of a possible partial load operation, different storage technologies and different renewable energy technologies are taken into consideration.

The results give an economical insight on the expectable future energy supply costs of PtL units for the decentralized production of synthetic kerosene and point out the decisive role of the type of required feedstock, which is one of the key drivers concerning the supply costs, due to its significant impact on the applicable storage technologies.

## SDEWES2021.0970

# Sustainable Synthetic Kerosene: Evaluation of a Power-to-Liquid Process via Fischer-Tropsch Reaction on the Basis of an Open-Source Python Model

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## Abstract

Synthetic liquid kerosene will play a significant role as part of the defossilization of the future aviation sector. One of the currently approved process routes for Jet A-1 kerosene containing synthesized hydrocarbons describes the production of synthetic paraffinic kerosene (SPK) which derives from a syncrude produced via Fischer-Tropsch synthesis. Integrated into a Power-to-Liquid (PtL) process which includes a synthesis gas production based on renewable energy, this process enables the possibility of a sustainable production of kerosene, either in centralized plants or in decentralized modular units.

This work describes the development and evaluation of a PtL-process model in a modular open-source Python framework, which enables a complete traceability and reproducibility of the process and the results. In contrast to existing studies with a high level of detail which are based on commercial software, the entire process chain is depicted with an intermediate level of detail to enable a further generic implementation into an energy system analytical assessment with regard to the current and future role of PtL-based liquid fuels.

The modelling of the different relevant process steps for the production of high yields of a synthetic kerosene fraction is described and key operation parameters are identified.

As a result, the achievable maximal mass flows of PtL-based fuel production via Fischer-Tropsch are assessed and the corresponding operation parameter sets which aim at an optimization of the kerosene fraction yield are pointed out.

## SDEWES2021.0989

# Incentive Structures for Power-to-X Pathways in EU and Member States

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## Abstract

Power-to-X pathways attract interest as solutions for decarbonising parts of the transport sector that are not suitable for electrification. The next decade is likely to witness a significant rise in power-to-X deployment to produce liquid or gaseous fuels. Still, the implementation of these technologies is currently slowed down by the regulatory framework. Previous literature did not identify dedicated targets for power-to-fuels, and this seems to represent a neglected area.

This paper examines the updates in the legal framework in the EU from 2019 to mid-2021 related to power-to-X, from hydrogen strategies to National energy and climate plans and potential roadmaps. The analysis covers the main aspects of the regulatory framework: support schemes, specific targets, and potential barriers. The aim is to update the current regulatory framework and the ongoing trends and possible success stories.

The results show a trend for increasing interest and market entrance of electrolysis and push from the different actors and regulatory parties to establish solutions that will enable faster upscaling. Starting from mid-2020, opportunities for hydrogen energy technologies considering the National Energy & Climate Plans (NECPs) have been published for most of the Member states, where power-to-liquids are mentioned but no specific targets are set. Half of the Member states have included hydrogen in their infrastructure for alternative fuels framework, and ten have published the strategies. A similar trend as in NECPs is visible from the strategies where most of the focus is still on hydrogen as end fuel or power-to-gas.

The analysis of the barriers for power-to-fuel deployment shows that a stable and predictable regulatory framework is crucial for investors and operators. It is also visible that some Member States have shown more substantial commitment in supporting the power-to-X installations and settling the regulatory environment than others.

## Biofuels and biorefineries 1

## SDEWES2021.0206

# Lipids Extraction from Sewage Sludge Using Green Biosolvent for a Sustainable Production of Biodiesel

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## Abstract

Sewage sludge is an urban waste, generated in large quantities by wastewater treatments. This waste can be considered as a source of lipids, which can be converted into biofuels. Recovery of lipids from sludge is the key step in the overall process and the choice of the extracting solvent should satisfy efficiency, as well as sustainability criteria.

This study reports the experimental optimization of the extraction of lipids from sewage sludge using ethyl butyrate, which is a green bio-derivable solvent. Extraction conditions were optimized using the desirability function applied on the response surface methodology analysis of a Box–Behnken factorial design of 27 experiments. By carrying out the extraction at 70°C for 7 h, using an equivalent amount of solvent with respect to wet sludge and without using any acids, almost 90 % of the starting lipids were recovered. The extracted lipids were then efficiently converted into biodiesel through a direct esterification promoted by $AlCl_3 \cdot 6H_2O$ (obtaining a biodiesel yield of almost 95% of the maximum yield obtainable) and the sludge resulting from the extraction with ethyl butyrate, differently from the one obtained by using hexane, was found anaerobically digestible, without any inhibition. Finally, an economic evaluation of the extraction process was conducted: the productive chain results feasible and sustainable if performed on centrifuged primary sludge (total solids: 15-20 %wt) with a high content of esterifiable lipids (20 %wt with respect to total solids).

## SDEWES2021.0293

# Evaluation of Biogas Potential of Sewage Sludge Co-Digestion with Different by-Products from Vegetable Oils Industry

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## Abstract

This study investigated the biogas production potential of 4 different by-products from vegetable oil extraction: the pumpkin seed press cake (PSPC), grape seed press cake (GSPC), olive mill pomace (OMP) and coconut cake (CC). In addition, three other wastes from vegetable oil industry were tested in batch anaerobic digestion (AD), filtration additive (FA), spent bleaching earth (SBE), and sludge from a WWTP treating wastewaters from the vegetable oil industry (SOI). In addition to mono-digestion of these substrates, co-digestion tests with sewage sludge were also conducted. The degradation of organic matter was monitored by measuring parameters such as sCOD, TOC, fatty acids content and $NH_4^+$ content. Furthermore, the effect of co-digestion on biogas yield and composition was investigated and compared with mono-digestion tests.

The highest biogas yield in mono-digestion tests was obtained with the substrates with the highest fat content: SOI (1637 mL/gVS), followed by FA (1288 mL/gVS), PSPC (830 mL/gVS) and CC (750 mL/gVS). Co-digestion experiments gave the highest biogas yield in the case of SS co-digestion with FA (839 mL/gVS), while the combination of SS with SBE, SOI, CC and PSPC gave lower biogas yields, but the values were still promising, 749, 571, 563 and 532 mL/gVS, respectively. The methane content for these mixtures varied from 61 to 74%. The sCOD removal efficiency ranged between 42-78%. High contents of fatty acids and ammonium accumulation were observed in the reactors, which varied greatly with the type of feedstock.

## SDEWES2021.0298

# Valorization of Organic Waste to Aromatics via Catalytic Pyrolysis with Methane

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## Abstract

Here, BTEX (benzene, toluene, ethylbenzene, and xylenes) production from various organic wastes such as rice husk, waste wood via catalytic pyrolysis was studied as a method to valorize waste materials to value-added chemicals. Various factors (e.g., pyrolysis environment, kind of zeolite, Si/Al ratio of zeolite, and Ga loading on zeolite) were considered to maximize the BTEX yield. Five different gas environments ($N_2$, $CH_4$, and streams evolved from ex-situ $CH_4$ decomposition ($CH_4$-D condition) over a $Ni/La_2O_3/CeO_2/Al_2O_3$ ($Ni/La_2O_3/CeO_2$ = 2/1/1) catalyst at 650, 725, and 800 °C) were tested, and the BTEX yield was enhanced in the order of ex-situ $CH_4$ decomposition > $CH_4$ > $N_2$. The pyrolysis of rice husk (a model organic waste) in $CH_4$-D(650) ($H_2/CH_4$ molar ratio = 0.88) led to the highest BTEX yield among the tested pyrolysis media. As lower Si/Al ratio of HZSM-5, a higher BTEX yield was obtained due to a higher Brønsted acid site density. The highest BTEX yield of 18.3 wt.% was achieved over 1 wt.% Ga/HZSM-5 under $CH_4$-D(650) atmosphere. More Ga addition to HZSM-5 decreased the BTEX yield because too much Ga loading on the zeolite resulted in the loss of Brønsted acid sites. The removal of ash from rice husk via pretreatment with 1.0 M NaOH further increased the BTEX yield to 22.3 wt.% because ash (mineral impurities) affects pyrolytic behavior of cellulose and lowers accessibility of pyrolytic volatiles to acid sites on zeolite. This study should provide useful information on the effects of various factors on pyrolysis of waste biomass such as rice husk to maximize the yield of value-added products (e.g., BTEX).

## SDEWES2021.0299

# Continuous Flow Upgrading of Biomass Pyrolysis Oils to Gasoline- and Diesel-Range Hydrocarbons over Bimetallic Rureox/c Catalyst

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## Abstract

The hydrodeoxygenation (HDO) of biomass pyrolysis oils is regarded as the most effective way for upgrading the pyrolysis oils to hydrocarbons by selectively removing oxygen functionalities [1]. To date, the noble metal-catalyzed HDO reactions of lignin model compounds (e.g., phenol, 2-methoxyphenol) have been extensively studied by many researchers. It has been shown that metal-acid bifunctional catalysts (e.g., Pt/H-Beta) or noble metal with reducible oxides (e.g., Ru-$ReO_x$ or Ru-$FeO_x$) are highly active catalysts for the deoxygenation of phenols through a synergy between metal (for hydrogenation) and acidic oxides (for C-O cleavage). In contrast to the massive studies of HDO of model compounds, the HDO of real lignin oils in a continuous flow reactor has rarely been explored. Because lignin oils contained significant amounts of phenolic oligomers along with monomeric phenols and mineral impurities such as sulfur, the activity and stability of noble metal catalysts such as Ru could be drastically changed with real lignin feedstock. In this work, the HDO of pyrolysis oils derived from kraft lignin was studied using a noble metal catalyst of $RuReO_x/C$ in a continuous flow reactor. The effect of various process variables (i.e., solvent, temperature, space velocity) on the reaction products were investigated, and the product oils were fully characterized by using elemental analysis, Sim-Dist, FT-IR, GCxGC-MS, and 2D-HSQC NMR to understand the HDO chemistry of lignin oils. The time-on-stream behavior of $RuReO_x/C$ catalyst were studied over 20 h, and the origin of deactivation was elucidated by using a battery of catalyst characterization methods (i.e., XPS, HR-TEM, ICP).

Compared to other noble metal catalysts of Pd/C, Ru/C, Ru/mesoporous ZSM-5, $RuReO_x/C$ demonstrated significantly higher activity for the HDO of lignin oils. The HDO activity and stability of RuRe/C catalysts in a continuous reactor were largely influenced by the process variables. Tetrahydrofuran was identified as the best solvent due to its high lignin solubility and low reactivity with lignin oils. Medium temperature (350 °C) and low WHSV (0.2 $h^{-1}$) exhibited the highest degree of deoxygenation of lignin oils and the extended catalyst lifetime (> 10 TOS). The formation of coke was the main cause of catalyst deactivation rather than sulfur poisoning. We believe our study would be helpful in the development of an improved catalyst and reactor for the HDO of real pyrolysis oils.

## SDEWES2021.0597

# Condensed Hydrodeoxygenation of Biomass Pyrolysis Oil to Aviation Fuels Using Ni-Based Bimetallic Catalysts

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## Abstract

Biomass pyrolysis oil has shown high potential as a renewable energy source. In this study, we converted biomass pyrolysis oil, or bio-oil, into petroleum-like deoxygenated hydrocarbon fuels by catalytic hydrodeoxygenation using $TiO_2$-supported phosphor-doped transition metals (Ni, Co, Cu, and Fe). The biomass pyrolysis oil was hydrodeoxygenated with phenolic compounds as a model mixture of lignin derivatives, and the products were found to be highly dependent on the catalyst. Among the transition metals, Ni exhibited the highest hydrodeoxygenation activity in the conversion of phenolic model compounds to saturated deoxygenated molecules. We observed the formation of Ni particles with highly dispersed phosphor, and the electron transfer from slightly cationic Ni to slightly negatively charged P, which demonstrated that the formation of Lewis acids improved the hydrodeoxygenation activity of Ni. We also observed the formation of small Ni nanoparticles with the addition of P, which can increase the number of catalytic active sites, accelerating the catalytic conversion of oxygenated reactants. The results of this study are expected to promote the efficient and low-cost conversion of lignocellulosic biomass into chemicals and fuel.

## SDEWES2021.0760

# Production of Oligosacaharides from Macroalgae: Process Development for an Innovative Marine Biorefinery

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## Abstract

Macroalgae production is gaining great relevance worldwide, both offshore and in areas dedicated to multitrophic aquaculture, associated with fish farming systems. Besides the advantages over terrestrial biomass, e.g., no competition for land use, macroalgae also present environmental benefits and are promising feedstocks for the development of marine biorefineries. These can have a pivotal role in the onset of the blue bioeconomy and contribute to climate change mitigation. Among seaweed species, Ulva spp. has demonstrated a high potential due to its worldwide distribution, chemical composition, and ease of cultivation with high productivity.

This work aims to study and provide a framework for an integral valorization of U. lactuca biomass. A detailed chemical characterization was carried out both in the inorganic (38.2% total ash) and organic fractions. Polysaccharides were the main macromolecular components of the later fraction, and a potential source of added value products, namely new classes of oligosaccharides (OS) as they present a high diversity of sugar constituents. Four different processes with increasing operational temperatures were used to study their selective recovery: Soxhlet extraction (SE), Accelerated Solvent Extraction (ASE), dilute acid hydrolysis (DAH), and hydrothermal treatment (HT). All processes present a quite similar OS yield and a high selectivity (high OS/monosaccharide ratio). SE has the disadvantage of a considerable higher operation time (18 h) as compared to the others. Although it is a faster method, ASE presented significant technical operation constraints, e.g., clogging and use of high pressures that may difficult its scale-up. HT and DAH exhibited an overall better performance and the highest values for OS concentration, corresponding to 16.22 g/l (17.02 g/100 g initial biomass) and 20.53 g/l (21.47 g/100 g initial biomass), respectively for HT (150ºC) and DAH (160ºC). These yields were considerably higher than the reported for land (lignocellulosic) plants, and obtained under milder, more economically advantageous conditions.

Besides polysaccharides, the solubilization profiles of protein, ash, acetyl groups, and uronic acids were also established. At the optimal OS production conditions, the residual solid fractions are enriched in protein and still present a relevant amount of glucan, demonstrating high potential for further applications, e.g., as a source of bioproducts for the food, feed, and nutraceutical industries.

## Biofuels and biorefineries 2

## SDEWES2021.0767

# Effective Fractionation Processes for the Upgrading of Microalgae Biomass in the Biorefinery Framework

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## Abstract

The use of microalgae is an increasingly important topic within blue bioeconomy. Together with the plethora of microalgae-derived bioproducts (pigments, proteins, amino acids, fatty acids), their ability to be produced under stringent conditions, e.g., wastewater effluents, in economic/low-tech installations, and non-agricultural competing sites, are important advantages. In particular, their wastewater treatment capabilities and further biomass usage for added-value applications are of increasing importance, conferring relevant opportunities to microalgae.

As for lignocellulosic biomass, to make full use of the microalgae, it is crucial to perform a selective fractionation. However, in contrast to the numerous studies developed for lignocellulosics, there is still a shortage of techno-scientific know-how regarding microalgae.

This work aims to compare and optimize hydrothermal (autohydrolysis) and dilute acid hydrolysis pre-treatments, for the selective fractionation of Scenedesmus obliquus biomass. Microalgae were grown in 70 L vertical photobioreactors using non-supplemented secondary brewery wastewater as a culture medium and harvested by an in-house developed centrifugation method. Hydrothermal and dilute acid hydrolysis (0.5% sulfuric acid) pre-treatments were carried out at lab scale (25 mL microreactors) under isothermal conditions (150°C and 140C, respectively) in a time range of 0 – 300 min.

Results show that autohydrolysis enabled a 50% sugar recovery yield after 120 min treatment, although with a slight recovery increase for higher reaction times, with the most sugars obtained being detected in the oligomeric form (92%). Diluted acid hydrolysis also showed an increased sugar recovery over time but achieving the maximum total sugar yield (50%) after only 60 min, again, mostly in oligomeric form (84%). Although the results did not differ greatly between both treatments, dilute acid hydrolysis allowed a similar sugar recovery in a shorter timeframe and slightly lower temperature. For these conditions, the impact of fractionation methods on protein solubilization was also assessed with a maximum removal yield of 35% achieved for both processes. As compared to other currently available strategies these two approaches are considered extremely promising for microalgae fractionation enabling the production of added-value products, i.e., potential marketable oligosaccharides, and processed solids with a potentially improved upgradability in a biorefinery framework.

## SDEWES2021.0782

# Wet Torrefaction of Digestate from Sewage Sludge in Terms of Energy Application

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## Abstract

Wet carbonization is a thermochemical process which involves the application of heat and pressure to convert the digestate in the presence of water into: solid product (hydrochar), liquid product, which could be use as additional feedstock in biogas plant, and gas product in an amount only c.a. 1 3% of a dry weight of raw material, which is consisting mainly of $CO_2$. Moreover, due to thermal treatment it is biologically sterilizing the digestates. That is why hydrochar has the potential to be used as fertilizer or a soil supplement due to its porous structure or biofuel. The main motivation of the paper was to determine the physical and chemical properties of digestate and its wet torrefaction products by multifaceted description using highly advanced instrumental methods. The tested material is a digestate from anaerobic treatment of wastewater plant. The digestate is a good feedstocks for wet torrefaction method due to high amount of moisture (c.a. 70-80%) and organic origin. The wet torrefaction, also called hydrothermal carbonization process, was conducted in a stainless steel, Zipperclave Stirred Reactor equipped with a MagneDrive Agitator. The process was studied under specific conditions: 200°C temperatures, 2 hours of residence time and slightly basic and acid pH environment. Then, the wide description of physical and chemical properties of solid, liquid and gaseous products was determined. The solid product named hydrochar was analysed in terms of energy, biosorbent or fertilizer applications. Therefore, the ultimate and proximate analysis, energy and mass yields, densification ratio, higher heating value was determined. The combustion behaviour of hydrochar wase studied using TGA analysis. Furthermore, the hydrothermal treatment was studied in liquid solution when the complex reactions take place. The filtrated liquid phase contains a high load of dissolved total organic carbon content and nutrient and has to be adequately disposed. That is why its physical and chemical properties were analysed. The chemical composition of gaseous product was also analysed by gas chromatography method. The novel approach in this study is an application of vacuum distillation of post-processing liquid phase. The project`s research objectives was to eliminate odour and colour and purify the HTC-water taking into account the eco-toxicity and bioavailability of processed HTC product.

## SDEWES2021.0818

# Towards a Sustainable Development Framework: Valorization of Banana Waste Under a Biorefinery Approach

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## Abstract

Food sector contributes approximately 30% of total global energy consumption and 22% of total greenhouse gas emissions. Furthermore, according to the Food and Agriculture Organization of the United Nations, 33% of the food produced globally is lost or wasted along the supply chain. Nevertheless, although food sector contributes to these environmental problems, it is also part of the solution. Sustainable Development Goal 12 (Responsible Consumption and Production) requires the reduction of food waste, either through reduction, recycling and/or reuse techniques, among other issues. The valorization of food waste, with the aim of obtaining value-added compounds, represents a paradigm challenge within the framework of sustainable development. Banana (Musaceace family fruit) is cultivated in tropical and subtropical regions. Europe produced, in 2018, over 620 thousand tons, 62% of which came from Spain. Otherwise, one hectare of banana crop produces approximately 220 tons of waste per year. The aim of this study is twofold that is i) the valorization of banana waste into bioethanol because of its high content on lignocellulosic material and ii) the quantification of the environmental burdens of the proposed valorisation strategy by means of the Life Cycle Assessment methodology. The environmental study is conducted from a cradle-to-gate approach and considering one kilogram of target product as functional unit. The valorization system based on an acid pre-treatment, using tartaric acid instead of conventional organic acids, and an enzymatic hydrolysis followed by yeast fermentation, was simulated with the use of Aspen Plus® software. The inventory is based on data taken from the simulation software. The environmental results suggest that the background activities involved in the tartaric acid production as well as the air emissions from the fermentation stage contribute significantly to the profile being considered as hotspots. Further improvement should be focused on the optimization of the tartaric acid dose as well as on controlling on-site emissions.

## SDEWES2021.0852

# Evaluation of Steam Demand, Water Use and Integration Opportunities in Brazilian Sugarcane Biorefineries

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## Abstract

Brazil has long established itself as one of the largest ethanol producers worldwide. Ethanol is mainly produced from sugarcane juice, along with sugar and electricity. Sugarcane bagasse, a lignocellulosic by-product currently used for steam and electricity generation, also serves as feedstock for second-generation ethanol. Thus, the consumption of steam and electricity generation must be re-evaluated. Another raising concern is the rational use of water in the sugarcane sector, limited by regional regulations. Considering these issues, heat integration using pinch analysis was proven successful by numerous studies in reducing both steam and cooling water demand. However, results show the importance of looking at water in the process beyond utility usage. The objective of this work is to evaluate the steam demand and water consumption in first-generation sugarcane biorefineries and identify opportunities for heat and water integration. It was found that water integration can reduce freshwater demand up to 25 %. For the heat integrated scenarios, this reduction was greater than 50 %.

## SDEWES2021.0908

# Kinetic Study of Biomass Oxycombustion and Pyrolisis

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## Abstract

Global warming and the greenhouse gas effect have forced the reduction of the energetic dependence on fossil fuels. A significant increase in the use of renewable resources has been produced in the last years which is accompanied by an increase in alternative biofuels research. In this context, biomass constitutes an alternative substitute for fossil fuels as it does not depend on the climate to produce energy. Because of that, research focusing on biomass properties, characteristics and energetic conversion has increased in the last decades, leading to the development of new pretreatments, processes, conversion, etc.

The present study was carried out in terms of determination of kinetic parameters, focusing on two different energetic conversion processes: pyrolysis, carried out under nitrogen atmosphere, and oxycombustion, using an atmosphere of air enriched with 30% oxygen. Three different biomasses were selected to carry out the study, all of them lignocellulosic biomass: almond shells, wood pellets, and palm oil wastes (empty fruit bunches). Thermogravimetric analysis (TGA) was performed using four different heating rates: 5, 10, 15 and 20 K/min; in order to carry out a kinetic analysis using model free methods. Three different methods were selected: Friedman, KAS (Kissinger-Akahira-Sunose) and FWO (Flynn–Wall–Ozawa). Those methods allowed the determination of the activation energy and preexponential factor.

Furthermore, a deconvolution process using Fraser Suzuki function was carried out to assess and separate the decomposition steps of the main biomass constitutions (cellulose, hemicellulose, and lignin) for all considered samples.

The obtained results allowed the kinetic comparison between oxycombustion and pyrolysis for the three biomasses, that were characterized using the composition estimation through deconvolution.

## Biofuels and biorefineries 3

## SDEWES2021.0912

# Application of Response Surface Methodology to Describe the Effect of Cooking Process on Selected Properties of Palm-Based Frying Oils Used as Biodiesel Feedstock

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## Abstract

This study examined the combined effect of frying temperature ($X_1$), time of use ($X_2$), and length of reuse ($X_3$) on the acid value ($Y_1$), peroxide value ($Y_2$), and dynamic viscosity ($Y_3$) of frying oils using response surface methodology. A virgin palm-based oil was used for frying potato chips following a two-level factorial design with four center points. The results were processed with statistical regression to generate significant prediction models. The data obtained for $Y_2$ and $Y_3$ was conveniently fitted to a first-order model, but a higher-order model was required to predict $Y_1$. Hence, six axial points were added to compose the design, and the data obtained was conveniently fitted to a second-order model. According to the ANOVA results, the three factors were statistically significant, but their effect on the response variables markedly differed. The region where the acid value and dynamic viscosity are predicted to have the lowest values corresponds to any combination of frying temperature between 120 and 132 °C, four hours of daily use, and two days of reuse. Higher temperatures (up to 146 °C) could give similar results, but a shorter time (up to 3 h) and the same 2-day period would be necessary.

## SDEWES2021.0913

# Effect of Cooking Conditions on Selected Properties of Biodiesel Produced from Palm-Based Waste Cooking Oils

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## Abstract

This study examined the effect of cooking temperature, time of use, and length of reuse, on selected properties of biodiesel produced from palm-based waste cooking oils (WCO). Several WCO collected from restaurants belonging to four categories were subjected to base-catalyzed transesterification. The biodiesel yield was calculated, and the produced biodiesel was characterized as to its kinematic viscosity, calorific value, and cetane number. As a result, palm-based WCO performed better than other WCO in terms of biodiesel yield regardless of the conditions to which the oils were subjected. The biodiesel yield decreased with increasing cooking temperature, use, and reuse, whereas the viscosity was sensitive only to the length of reuse, rising with increasing reuse. Non-compliance with biodiesel standards and technical requirements was observed in some cases. The calorific value did not significantly change unless the conditions were severe. The cetane number dropped with decreasing use and reuse, remaining better than that of petrodiesel nonetheless. Typical restaurants were found to generate the most suitable palm-based WCO to use as biodiesel feedstock. This may be a result of the less severe cooking conditions employed at these restaurants.

## SDEWES2021.0952

# A Feasibility Study on the Development of a Biogas Production System for a Sustainable Business Park in the Hoek Van Holland Area - the Netherlands

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## Abstract

The Netherlands has a mission to use 16% of sustainable energy by 2023, and 100% of sustainable energy by 2050, thus making green energy to be the only source of energy in the future. The aim of this paper is to study the feasibility of the development of a digester with CHP (combined heat and power) system for a Sustainable Business Park. This bussiness area is yet to be developed near the Hoek van Holland municipility in The Netherlands. The amount of waste produced by the Municipality and the business area can be about 1180 kg/day of food waste and 102 $m^3$/day of sewage sludge. An estimate of about 66 $m^3$/h of biogas (containing 39 $m^3$/h of methane) can be produced by the digester. The proposed Digester has a cylindrical shape, with 14 m of diameter, 13 m of height, and 1902 $m^3$ of total volume. Removal of Hydrogen sulphide ($H_2S$), water vapour ($H_2O$), and siloxanes from biogas occurs before it enters the CHP system. Due to the partial efficiency of the CHP, 193 kW of thermal power, and 135 kW of electrical power can be generated. Based on the equipment cost of about 1.3 million euros, the total capital investment was estimated to be 7.2 million euros with a payback period of 58 years. Alternative investment options are recommended.

## SDEWES2021.1017

# Life Cycle Assessment of a Passenger Car Fed with Blends of Petrol and Renewable Fuels and Comparison with a Battery Electric Vehicle

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## Abstract

To achieve climate neutrality in 2050, as aimed by the European Green Deal, the fossil carbon emissions from passenger cars should be progressively and drastically reduced. The objective of the study was to compare the environmental impacts of driving a passenger car fed with four innovative petrol blends, with those of a battery electric car. The considered innovative fuels are bio-ETBE (ethyl tert-butyl ether), bionaphtha, bioethanol, methanol, biomethanol, and e-methanol. The component ratios of the blends were defined in order to maximize the content of renewable components, depending on the requirements specified by the European standard EN 228 for unleaded petrol. Regarding biofuels, different feedstocks used for their production were assessed. The Life Cycle Assessment methodology was applied, including the production, use and end-of-life of the cars, and the results were referred to a functional unit of 1 km. 16 impact categories were assessed. The exhaust emissions were directly measured in laboratory and on road on a GDI Euro 6d-TEMP passenger car. Secondary data were used to estimate the impacts of the remaining phases of the car's life cycle. Regarding climate change, the electric car is the best analysed choice: the battery electric car was found to release -40.8% GHG emissions compared to the petrol car. The tested innovative blends potentially guarantee a reduction of the impact on climate change ranging from 0.8% to 10.2% compared to the conventional fuel feeding. The use of a car specifically designed to be fuelled by a blend containing higher percentage of renewable fuels would probably lower the impact. Although the use of innovative blends and electric cars guarantee a reduction of the impact on climate change and fossil resources, the picture is mixed for the other 14 impact categories.

## SDEWES2021.1030

# Valorisation of Biomass Wastes Through Intermediate Pyrolysis

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## Abstract

Biomass wastes contain an abundant source of energy that can be transformed into high-calorific fuel during pyrolysis, consequently reducing the use of fossil fuel resources. Three types of biomass wastes were selected in this study: medium density fibreboard (MDF), brewery spent grains (BSG) and post-extraction soybean meal (SM). The studied feedstocks were analysed in detail in the range of ultimate and proximate analysis, chemical composition of ash, fibre analysis, and microstructure properties. MDF was a biomass with a high cellulose content (45%), hemicellulose content (46%) was predominant in BSG, while SM had low contents of cellulose, hemicellulose and lignin fibres (8%). The ash of MDF was characterized by titanium, calcium, sodium, and iron contents, while BSG and SM were typical agriculture biomass with significant potassium and phosphorus contents. FTIR analysis confirmed highly cellulosic structure of MDF. The intermediate pyrolysis of these wastes was carried out at 500 °C temperature in a fixed-bed reactor under nitrogen atmosphere. Analysis of process yields has shown meaningful differences in pyrolysis product contents. Pyrolysis of MDF led to the main products such as char (25%) and aqueous phase (31%) whereas BSG oil (32%) was the main product. Elemental analysis demonstrated that MDF char had the highest carbon content. Generally, chars obtained from these feedstocks were characterized by a diverse internal microstructure. The surface of MDF char showed pores with a regular pattern of small perpendicular blocks. On the other hand, irregular open spaces were revealed in the BSG and SM chars. This investigation proved that biomass wastes are perspective feedstocks to obtain high-value bioenergy products.

## SDEWES2021.1038

# Ignition and Combustion Characteristics of Biomass Derived Fast Pyrolysis Bio-Oil in a Combustion Research Unit

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## Abstract

The aim of the current EU H2020 project, SmartCHP, is to develop a small-scale combined heat and power (CHP) system running on biomass derived fast pyrolysis bio-oil (FPBO). The SmartCHP system employs a FPBO fuelled engine and a flue gas boiler to provide a flexible and adjustable combination of power (100 - 1000 kW) and heat supply at a high efficiency over the whole load range.

In this study, the ignition and combustion characteristics of FPBO are studied under engine-like conditions created by a combustion research unit (CRU). The effects of fuel upgrade (addition of alcohol or ignition improver) and various biomass origins (wood, sawmill residue, sunflower husks, and miscanthus) are also investigated. The results show that compared to ethanol, the addition of 30% of n-butanol could significantly improve the ignition and combustion processes of FPBO. However, the gain of Beraid addition is very limited. Higher initial chamber pressure boosts the fuel combustion reaction, while the change of injection pressure has marginal influence. Regarding the different biomass origins, FPBO from wood and miscanthus has higher chemical reactivity than that from sawmill residue and sunflower husks.

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## SDEWES2021.0048

# Integral Analysis of Liquid-Hot-Water Pretreatment of Wheat Straw: Evaluation of the Production of Sugars, Degradation Products and Lignin

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## Abstract

Developing sustainable biorefineries is an urgent matter for a transition to a sustainable society. Lignocellulosic biomass (LCB) is a crucial renewable feedstock for this purpose, and its complete valorization is essential for the sustainability of biorefineries. However, it is improbable that a single pretreatment will extract both sugars and lignin from LCB. Therefore, a combination of pretreatments must be applied. Liquid Hot Water (LHW) highlights as a pretreatment for hemicellulose hydrolysis, conventionally analyzed only in terms of sugars and degradation products. However, lignin is also hydrolyzed in the process. The objective of this work was to evaluate different LHW conditions regarding the content of sugars, degradation products, and lignin. We performed LHW at 160, 180, and 200 °C, for 30, 60, and 90 min, using wheat straw and characterized the extract for sugars, degradation products (furfural, hydroxymethylfurfural, and acetic acid), and lignin. Three conditions reached similar total sugars concentration (~12 g/L): 160 °C for 90min, 180 °C for 30min, and 180 °C for 60min. Among these, LHW performed at 160 °C for 90min allowed the lowest concentration of degradation products (0.2, 0.01, and 1.4 g/L for furfural, hydroxymethylfurfural, and acetic acid, respectively) and lignin hydrolysis (2.2 g/L). These values indicate the potential use of the obtained sugars as fermentation substrate while leaving the lignin in the solid phase for a following stage focused on its extraction and valorization.

## SDEWES2021.0103

# Optimization of the Colloidal Lignin Particle Production Process: Temperature and Lignin Concentration Influence in the Solvent Shifting Precipitation

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## Abstract

The shift from a fossil-based to a renewable-based economy requires an increase in the utilization of materials that are so far only marginally used. Lignin is an example for such materials, as it is currently mainly used for energy production but not as a material. While efforts for commercial lignin applications have shown little success so far, the improved properties of colloidal lignin particles (CLPs) due to the increased specific surface area promise more widespread application in value-added products. However, current production methods for these particles are inefficient and require a better process understanding for optimization.

A common production method for CLPs is the precipitation of lignin from organosolv pulping liquor by controlled addition of an antisolvent, which lowers the solubility of lignin and leads to particle precipitation. However, this process is currently inefficient due to large amounts of antisolvent needed and comparatively low particle yield, since a substantial amount of the lignin stays in solution. At elevated temperatures, more lignin can be solubilized, which could increase the precipitation yield and thereby process efficiency. However, achievable particle sizes are negatively influenced by increasing lignin concentration. Furthermore, the temperature dependent viscosity governs mixing quality of lignin solution and antisolvent, and is therefore a key factor for the precipitation. In order to achieve an optimized process, the influence of these process parameters has to be assessed.

In this work, we investigate the influence the temperature and lignin concentration have on the precipitation of lignin colloidal particles through solvent shifting in a static T-mixer. Commercial organosolv lignin dissolved in aqueous ethanol is therefore precipitated. In the experiments, we varied liquor and antisolvent temperature and lignin concentration in the commercial lignin solution. The results show that the particle size decreases with increasing mixing temperature, which is attributed to changed mixing behavior due to changes in viscosity. Additionally, decreasing the lignin concentration resulted in almost no change in particle yield, which opens up new possibilities for process control and optimization of lignin precipitation.

## SDEWES2021.0540

# The Influence of Transition Metals in Mg-Al Mixed Oxides on Synthesis of Ethanol to Valuable Products: Reaction Pathways

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## Abstract

The largest amount of fuels and petrochemicals is produced from fossil sources such as coal and crude oil, which are limited, and their consumption, is not environmentally friendly. The research of alternative sources of biochemicals and biofuel is a challenge for research groups. One of the alternative biofuels is bioethanol, which is produced by fermentation of sugar crops or lignocellulose waste. Currently, bioethanol is added to gasoline. Ethanol is very hydroscopic and adsorbs water, which can cause corrosion of fuel system. Moreover, ethanol has lower caloric value than gasoline and so its addition to gasoline decreases the caloric value of the fuel. Butanol is significantly less hydroscopic and has higher caloric value than ethanol, so its usage is more appropriate and economical. Butanol is also used as a solvent in many chemical processes.

This paper is focused on the conversion of ethanol to butanol by the Guerbet reaction catalysed by mixed oxides in the microflow reactor. Guerbet reaction is the system of subsequent reactions: dehydrogenation, aldol-condensation and hydrogenation. Each of the reaction steps process on a different type of the catalyst: the hydrogenation and dehydrogenation steps need the redox type, while the aldol-condensation requires acid-based type. The Mg-Al mixed oxides, synthesized from hydrotalcites, have acid-based properties and the redox properties are formed by the addition of transition metals such as Ni, Co, Cu, Cr, Fe, Mn. The synthesized materials were characterised by various methods. The reaction product (butanol) including other side products in liquid phase (ethyl acetate, hexanol, etc.) and gas phase were determined. The reaction pathway for formation of side products was examined.

The aim of the paper describes the physical-chemical properties of mixed oxides and especially their catalytic activities in Guerbet reaction including side products. It was found that the presence of transition metals Co, Ni and Cu positively influenced the catalyst activity. Moreover, it was found that ethanol conversion increased with increasing temperature, but at the same time the selectivity to butanol decreased.

The detailed description of the catalyst enables to choose the appropriate transition metal, which supports the butanol formation with maximum yield and selectivity.

Acknowledgements

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## SDEWES2021.0786

# Transformation of Spent Coffee Grounds Under Near-Critical Conditions of Binary Water-Organic Solvent Systems Towards Value-Added Bioproducts

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## Abstract

The goal of the present study was to examine the possibility of conversion of coffee spent grounds via thermochemical liquefaction using binary solvent's mixtures. For this purpose, we investigated the effect of mixing of additional co-solvent i.e. propan-2-ol, ethyl acetate and hexane to water as a reaction medium. The bio-oil composition was analyzed by means of ATR-FT-IR and GC-MS techniques. It was found that additive of monohydroxyl alcohols and/or esters resulted in a doubling of bio-oil yield compared to pure water, while the biomass conversion increased up to 92%. These advantages are ascribed to the effect of stabilization of certain reactive intermediates by co-solvent. For instance, it was found that using ethyl acetate and propan-2-ol as co-solvents resulted in the noticeable conversion of carboxylic acids to esters via transesterification and esterification, respectively. Moreover, the addition of propan-2-ol led to a significant increase in the concentration of propane in the gas phase product, which clearly confirmed that the organic additives act not only as a solvent but also as reagents.

## SDEWES2021.0877

# Upgrading of Raw Biogas Using Non-Porous Membranes

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## Abstract

- Increasing concern about global warming by greenhouse gas emissions necessitates the development of novel technologies that replace fossil fuels by renewable energy and capture the produced greenhouse gases $CO_2$ and $SO_2$ [1]. An important development in membrane science are the Polymers of Intrinsic Microporosity (PIMs) derived from rigid components such as triptycene, spirobifluorene, Tröger's base, etc., that demonstrate superior separation and transport properties. Recently reported ultrapermeable benzotriptycene-derived PIMs, based on two-dimensional chains that pack inefficiently, were used to re-define the Robeson upper bound for the $CO_2/CH_4$ and $CO_2/N_2$ gas pairs [2]. Here, we report the performance of one of these polymers, PIM-TMN-Trip, with both pure and mixed gas streams, and raw biogas. PIM-TMN-Trip membranes show excellent separation properties for $CO_2/CH_4$ model mixtures and for pre-dried real biogas at low transmembrane pressure difference, with performance lying between the recently defined $CO_2/CH_4$ upper bounds for pure and mixed gases. With increasing upstream pressure, the $CO_2$ permeability decreased, as well as mixed gas selectivity. Pristine membranes had a pure $CO_2$ permeability of around $10 \cdot 10^3$ Barrer, with an ideal selectivity of about 15. Interestingly, $CO_2$ treatment strongly enhanced the ideal selectivity to values in the range of 34-39 without reducing permeability. The humidity in the feed gas did not seem to affect the membrane performance significantly, opening interesting perspectives for the use of this membrane in biogas separation [3].

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## SDEWES2021.0906

# Cleaner Fuel Production via Co-Processing of Vacuum Gas Oil with Rapeseed Oil Using a Novel Niw/acid-Modified Phonolite Catalyst

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### Abstract

Fast traslate Icon translate Clean bio-fuels are a helpful tool to agree with the severe emission norms. The co-processing approach seems to be a compromise solution, allowing the processing of partially bio-based feedstock by utilizing the existing units, overcoming the need for high investments into new infrastructures. We performed a model co-processing experiment using vacuum gas oil (VGO) mixed with different contents (0, 30, 50, 70, 90, and 100%) of rapeseed oil (RSO) utilizing a nickel-tungsten sulfide catalyst supported on acid-modified phonolite. The experiments were performed using a fixed bed flow-reactor at 420 °C, hydrogen pressure of 18 MPa, and a weight hourly space velocity (WHSV) of 3 h-1. Surprisingly, the catalyst stayed active, despite rising oxygen levels in the feedstock. In the liquid products, the raw diesel (180-360 °C) and jet-fuel (120-290 °C) fractions concentrations rose together with an increment of RSO share in the feedstock. The sulfur content was lower than 200 ppm for the entire product collected using feedstocks with the RSO share up to 50%. However, for all the products gained from the feedstock with an RSO share of ≥ 50%, the sulfur level was above the threshold of 200 ppm. The catalyst shifted its functionality from hydrodesulfurization to (hydro)-decarboxylation with the higher RSO ratio concerning the VGO content in the feedstock, which seems to be confirmed by gas analysis where increased $CO_2$ content was found, after the change on the feedstock containing 50% or more RSO. According to the results, NiW/acid-modified phonolite is a suitable catalyst for the processing of feedstocks with high triglycerides content.

## Buildings 1

### SDEWES2021.0125

# An Integrated Deep Learning Based Approach for Real-Time Monitoring of Occupancy and Windows Within Buildings for Demand-Driven HVAC Operations

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## Abstract

Occupancy behaviour in buildings can impact the energy performance and operation of heating, ventilation, and air-conditioning (HVAC) systems. HVAC, which uses conventional control strategies or “fixed” setpoint schedules, could not adjust to the conditioned spaces actual requirements and result in building spaces being over or under-conditioned. While the unintended opening of windows can lead to substantial heat loss and consequently raises energy consumption. To optimise building operations, it is necessary to employ solutions such as demand-driven controls, which can monitor the utilisation of indoor spaces and provide the actual thermal comfort requirements of occupants. This study presents a novel vision-based deep learning framework for occupancy activity detection and recognition, including the manual window operations in buildings. A model based on Region-based Convolutional Neural Network (R-CNN) was trained and deployed to a camera for real-time detection and recognition. Based on the field experiments conducted within a case study University building, overall accuracy of 85.63% was achieved for occupancy activity detection and 92.20% for window operation detection. Building energy simulation and various scenario-based cases were used to assess the impact of such an approach on the building energy demand and provide insights into how the proposed detection method can enable HVAC systems to respond to dynamic changes within indoor spaces. Results showed that the proposed approach could reduce the over-or under-estimation of occupancy heat gains compared with the use of “fixed” or static profiles. In addition, the approach can help alert building users or managers about windows left open unintentionally, which can reduce unnecessary ventilation heat losses. Furthermore, the approach can also predict the room $CO_2$ concentration and advise occupants about a suitable ventilation strategy. The study highlighted the potential of the multi-purpose detection approach. But further development is necessary to achieve reliable and accurate detection within any type of indoor space in order to optimise building internal heat gains by up to 89.97% and ventilation losses by up to 96.85%. Hence, future work includes the optimisation of the deep learning model, full integration with HVAC controls, and further model training and field testing.

## SDEWES2021.0127

# Analysis of HVAC System Operational Fault Impacts on Energy Demand and Thermal Comfort Under Current and Future Climate Scenarios

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## Abstract

The effect of climate change on heating, ventilation and air conditioning (HVAC) systems performances has become prominent in the recent decade and may also affect the fault impacts of HVAC system. Previous studies have not yet explored the fault impacts on HVAC system energy and occupant thermal comfort under future climate periods. The present study assesses the impacts of operational faults on a variable air volume (VAV) system from a medium office building under the current and 2030s weather conditions and investigates the influence of climate change on the fault impacts of VAV system in terms of system energy consumptions and occupant thermal comfort. The energy and thermal comfort impact indicators were proposed and calculated, and the faults were ranked in system energy consumption and occupant thermal comfort based on these indicators. The faults with the top 7 energy impacts under the 2030s climate period remain the same as those under the current climate period and the faults with the top 10 thermal comfort impacts are almost the same as those under the current climate period. In addition, the variations of fault impacts among different climate periods were calculated to identify the faults that may have significantly intensified fault impacts caused by climate change in the future. The largest increase from the current to 2030s period in the air system total electric energy of 6.95% was presented by heating coil supply air temperature sensor negative bias. The results demonstrate the importance of considering the effect of climate change on the development of FDD methods and are also useful for predicting the future development focus of FDD methods on the prioritized faults.

## SDEWES2021.0130

# Enhancing Window Solar Heat Gains in Winter by Nir-Selective Nanofilms

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## Abstract

A few types of metallic nanoparticles have been found to have strong surface plasmon-induced photothermal effects (PPE) by near-infrared light irradiation, paving the way for new designs of spectrally selective building glazing systems for solar infrared modulation that operate without the need to compensate for visible transmittance. Due to the localized heating effects of these plasmonic nanoparticles, the inward-flowing heat can be strongly enhanced, which can improve the thermal performance of building windows in winter. Meanwhile, the condensation effect on the building windows in cold climates significantly diminishes the thermal insulation ability of the original material or structure. The PPE could increase the window interior surface temperature under solar radiation, thus improving the condensation resistance of the window systems and in turn further enhance the thermal performance of windows. However, such combined effects due to enhanced solar heat gains and condensation resistance by the PPE on building energy use have not been investigated. Thus, an approach that can quantify the energy use of PPE on windows was developed in this work. By employing this approach, the results show that the double-pane window model with the nanoscale PPE exhibited about 7.9-18.8% heating energy savings relative to the baseline model with low-e coatings.

## SDEWES2021.0131

# Machine Learning-Based Individualized Comfort Modeling for Smart Buildings

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## Abstract

Personalized thermal comfort prediction model has become one of the trending topics in improving indoor comfort and building energy performance. This paper intends to review and examine the modeling methods used in previously published studies that conducted the experiments in climate chamber or the field. Firstly, the selection criteria for the reviewed papers published in the last ten years were introduced. The papers related to data-driven modeling methods involving the physiological or psychological parameters in predicting individual thermal comfort were summarized. Then the machine learning methods were summarized and compared in terms of the prediction accuracy. Finally, the effects of feature combinations on the model performance were investigated. The previous studies demonstrated that the machine learning technique that integrated three primary types of input parameters: micro-environmental data, individual physiological signals, and individual-specific data could be an effective method to estimate an individual thermal sensation. At the same time, the limitations of these studies in identifying the key features in a thermal comfort model and supporting real-time comfort monitoring were identified.

## SDEWES2021.0132

# Energy-Saving Potentials by Dynamic Spectrally Selective Window Structures

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## Abstract

Windows are one of the main contributors to building energy consumption and emerging dynamic window technologies offer improved performance. Specifically, NIR-focused window technologies are desirable in climates that consume both heating and cooling energy. However, the whole building energy effects of changeable NIR response of building windows have not been captured, largely due to the lack of an appropriate energy simulation method and the NIR-focused window modeling. This study focuses on developing a simulation method enabling the comprehensive evaluation of the whole building energy effects of dynamic NIR modulations. Using an EnergyPlus EMS-based parametric framework, annual energy savings were estimated for a switchable between-glass built-in system across three representative cities in ASHRAE climate zones 3, 4, and 5. This NIR-focused technology yielded energy savings up to 19%. The results demonstrate the effects of NIR-focused window technologies on heating and cooling loads among different climates.

## SDEWES2021.0134

# An Overview of Clothing Insulation Measurement for Use in PMv-Based HVAC Control and Vision-Based Approach for Clothing Insulation Prediction

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## Abstract

The predicted mean vote (PMV) is a widely used index used to quantify the thermal comfort of a group of occupants indoors. A real-time PMV-based control strategy has been developed to increase energy efficiency and indoor thermal comfort in buildings. Clothing insulation level is one of the indices used in the PMV calculation and cannot be measured by simple sensors. Thus, real-time clothing insulation estimation is worth developing for designing real-time PMV-based controls which could be automatically triggered by real-time clothing insulation changes. This paper looked at the conventional (i.e., thermal manikin tests) and real-time clothing insulation measurements. The reviewed studies show that with the help of different kinds of thermal manikin and correction factors, thermal insulation values obtained by thermal manikin showed their reliability for practical use and could be used for real-time clothing estimation through sensing technology. Several studies confirmed the feasibility of real-time clothing insulation measurements instead of using insulation results from thermal manikin tests. Real-time sensing and feedback technologies for capturing dynamic clothing insulation value are evaluated. Furthermore, this study proposed using a computer vision method to estimate the clothing level and clothing adjustment of the occupants. The data generated can be used by control strategies as an additional input when determining and adjusting the HVAC set points and operation. This can help further enhance the occupant's thermal comfort and reduce unnecessary energy demand. Future works will be focused on the development and testing of the approach in different built environment spaces.

## SDEWES2021.0885

# Integration of Numerical and Experimental Approach in Life Cycle Assessment of Stand-Alone Microgrid System

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## Abstract

Mountain hut (MH) is a stand-alone micro-grid system that is usually not connected to a power grid. Its operation poses a burden on the environment and produces certain emissions. The micro-grid for energy generation installed in MH must be flexible to cover fluctuations of the energy demand. Electricity is usually generated with fossil fuels due to simple operation and load following, but with introduction of renewable energy sources (RES) the dynamics will change significantly and that presents a challenge in balancing electricity generation and consumption. On the other hand the electricity generation from RES could be more sustainable with lower environmental impacts. The paper presents the integration of RES in micro-grid MH electricity generation system. Optimization tool was developed using numerical modelling of MH micro-grid. The model was validated using one-year measured operational data of the MH. After that, the approach was used to simulate six different electricity generation topologies to find the configuration that satisfies the dynamics and cumulative electricity demand of MH. Heat is generated partly with biomass, partly with liquified petroleum gas boiler (LPG). Life cycle assessment (LCA) methodology was used to evaluate environmental impacts of all simulated cases for one typical operational year.

## Buildings 2

### SDEWES2021.0135

# The Impact of Using the Application of a Cnn-Based Approach for Equipment Usage Detection on Building Energy

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## Abstract

Heating, ventilation, and air-conditioning (HVAC) systems account for up to 40% of the total building energy use. It is significant to optimize the energy efficiency of such systems, which are the major energy demand in the building sector, to mitigate the carbon emissions and ideally achieve energy savings while maintaining a comfortable indoor environment for occupants. Due to extensive variations in the use of electrical equipment, accurate equipment usage detection is valuable for reducing the building energy demand and greenhouse gas emissions by collecting actual heat emission from equipment. Using the collected equipment usage information, the building energy management system can automatically adjust the operation of HVAC systems to meet the actual demands in different conditioned spaces in real-time. The present study introduces an equipment usage detection approach using computer vision and deep learning methods for efficient building energy controls. The experimental results presented a detection accuracy of equipment detection of 83.33%. To investigate the impact of the proposed approach on building energy performance, the case study building was modelled and simulated. The simulation results showed that up to 35.95% lower internal heat gains were predicted with the use of deep learning influenced equipment detection profiles in comparison with the use of static or fixed schedules. The study highlights the benefits of incorporating real-time deep learning detection method with demand-driven controls which can minimize unnecessary building energy consumption while maintaining a comfortable indoor environment.

## SDEWES2021.0145

# Investigation of the Integration of Wind Buffers on the Wind and Thermal Comfort Performance of Lateral and Peripheral Skygardens

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## Abstract

Skygardens are a unique architectural intervention in the built environment, enhancing the social, economic, and environmental values of the building. It allows occupants to connect and experience outdoor freshness within a semi-enclosed environment. However, skygardens located on a high-rise building can generate intense wind gusts, endangering the safety of occupants. This study investigates the potential of various vegetative barriers in attenuating the high wind speeds encountered at such spaces and also the impact on thermal comfort. Three skygarden configurations were investigated with and without vegetative barriers, modelled as porous zones, and their effect was studied on the velocity and temperature profile at occupants' level. The results indicate that while hedge and trees can offer resistance to airflow, trees provide higher temperature reduction. However, a combination of vegetative and geometrical barrier provides the most optimal condition in the skygarden. The study has identified the importance of assessing wind attenuation characteristics of tree plantation on high-rise skygarden, and the results can be used in designing intervention strategies. Moreover, vegetation can attenuate pollutants and mitigate poor air quality by surface deposition, and future studies should investigate in that direction.

## SDEWES2021.0172

# Economic Optimised Energy Retrofits of a Building When Using Different Retrofitting Materials Under Different Energy Scenarios

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## Abstract

The study analyses different energy retrofit measures used to achieve economic optimum energy retrofit of houses and compare primary energy savings of each measure. The retrofit measures consist of the thermal improvement of windows with varied frame materials, as well as extra insulation of attic floor, basement walls and external walls with varied insulation materials. A bioenergy-based district heating (DH) system is considered. We calculate the final and primary energy savings, as well as the net cost savings of retrofit measures for the thermal building envelope in terms of net present value (NPV). Then, we use the marginal cost difference method to identify economic optimised retrofit measures. In sensitivity analyses, we compare the optimum retrofit measures under different economic scenarios, as well as different DH supply scenarios. Different retrofit measures influence the primary energy savings and retrofit costs. The use of different materials does not influence the economic optimization of retrofit measures significantly, as the economic parameters do. The DH system of Ronneby, which is based on heat-only-boilers, gives higher primary energy and cost savings compared to DH in Helsingborg and Växjö which have systems that cogenerate district heat and electricity.

## SDEWES2021.0234

# Development of an Integrated Passive Heat Recovery Technology and Ventilation System for Reducing the Building Energy Demand

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## Abstract

Passive ventilation of buildings in winter particularly in cold climates usually causes heat loss and increases heating load. In order to solve this problem, a novel wind tower design with solid tube bank heat recovery (HR) devices is proposed in order to enhance the year-round capabilities of natural ventilation systems and enable consistent use during cooler months in temperate-cold climates. Computational Fluid Dynamics (CFD) software is employed to investigate the airflow and temperature distribution around the multi-directional wind tower with heat recovery (HR) under different outdoor wind speeds. The 3D steady-state Reynolds-averaged Navier-Stokes method and the k-epsilon turbulence model are adopted. The longitudinal pitch (SL) and transverse pitch (ST) are suggested to be smaller when the guided ventilation rate is satisfied. SL=25 mm and ST=60 mm are recommended in this study, increasing the supply temperature by 6.4 °C when the outdoor wind speed is 1 m/s. The system can provide sufficient ventilation rate for a classroom occupied by 15 people when the outdoor wind speed is 3 m/s and higher. In addition to sufficient ventilation, the heat recovery system has a positive impact on the heating load, raising the supply temperature by up to 1 °C depending on the indoor/outdoor conditions.

## SDEWES2021.0236

# Evaluating a High Rise Building in Humid Subtropical Climates in Shanghai for Passive House Classification

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## Abstract

A high-rise Passive House building was designed to investigate the energy saving potential of Passive House and possible energy saving technologies for high-rise building in Shanghai with hot & humid summer and cold winter. The Building Energy Simulation (BES) tool IES-VE and Passive House certification tool PHPP were used to validate the simulation model and test the performance of different sustainable technologies, including high-quality building envelope, solar shading, earth tube precooling and photovoltaic. The high-quality building envelope, summer solar shading and earth tube reduced 6.5%, 23.8% and 39.3% of the annual cooling loads respectively. Overall, 98.0%, 66.8% and 38.3% of the initial heating, cooling and dehumidification load were reduced respectively. The building satisfied Passive House standards and the total operational energy was reduced from 113 kWh/m² to 71 kWh/m². The high-rise Passive House was suitable to provide both indoor comfort and low energy consumption in Shanghai.

## SDEWES2021.0239

# Investigation of the Transient Thermal Performance of a Pavement Solar Collector (Psc) for Urban Overheating Mitigation

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## Abstract

Urban overheating is a serious problem for many major cities in the world. Pavement surfaces play an important part in the overall urban thermal balance, which is an essential urban feature that influences the microclimate and building energy performance. Conventional pavement or asphalt pavements can absorb a large amount of light and radiation, and the heat is dissipated to the surrounding air, which further aggravates the Urban Heat Island (UHI) effect. Both short-wave radiation and long-wave radiation impact the pedestrians' thermal comfort, the reflection and absorption of radiative heat of pavement can warm up the ambient air, which can increase building cooling energy consumption, and cause thermal comfort, and overheating problems. Solutions such as pavement solar collectors (PSC) can mitigate urban overheating. The heat is transferred from the pavement surface to the bottom layers, which is then absorbed by the water circulated through a series of pipes. The pavement surface temperature and air temperature would be reduced, and at the same time, heat energy can be extracted and utilised. This work aims to investigate the impact of the PSC system on the urban canyon air temperature and pavement surface temperature using transient computational modelling. Discrete Ordinate (DO) model and Solar-Ray Tracing were utilised to include the effect of solar radiation in the 3D simulation. Furthermore, several experimental studies have been carried out for PSC and urban canyon to validate the Computational Fluid Dynamics (CFD) simulations. Based on the set conditions, the surface temperature can be reduced up to 6.5°C by the PSC system under the set conditions. The asphalt pavement surface temperature was much lower than the internal temperature because of the wind and the convective heat transfer between asphalt and air. While the urban air temperature was reduced by up to 1.4 °C. The high thermal mass of the asphalt and the low thermal inertia of the air delayed the cooling effect to the air, the building surface temperature was also reduced by the PSC system. The initial results have shown the importance of the positioning of the PSC within the urban environment and also the impact of the surroundings on its performance. Future works should consider the use of control strategies to optimise the surface temperature reduction and thermal collection.

SDEWES2021.0924

# Improving the Building Envelope Performance Through Tensile Material in the Iranian Climates

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## Abstract

Buildings currently account for about 40% of the global energy use and consequently contribute to approximately 36% of the overall carbon emissions. Energy consumption reduction was seriously considered because of the energy crisis due to industrial development and population growth rate which leads to the increased heating and cooling demands. One of the most important measures to reduce energy waste concerns in buildings is passive retrofit actions. The building envelope plays an important role in reducing energy consumption as passive action in aspects like insulation and fenestration. Therefore, the use of tensile material which is used as a building envelope has a significant impact on reducing energy usage. In developing countries, like Iran, current building energy consumption trends become a cause of concern by no energy-efficiency plans for buildings. In Iran lots of fossil fuel is produced and also a lot of energy is consumed, especially in the building sector. In this country, the share of energy use by the residential, public, and commercial buildings in electricity, natural gas, and petroleum product is 47%, 49%, and 12%, respectively. Most of building in Iran are old or has historical values and do not have insulation. So, implementing the passive retrofit has a high value. The study investigates the effect of this passive solution in an Iranian office building upon varying the location. In this regard, the office building performance has been evaluated in three different climates of Iran: (i) Isfahan, (ii) Tabriz, and (iii) Tehran, with hot and dry, cold and dry, and temperate climates, respectively. The building simulation is performed using TRNSYS, a dynamic simulation software. The results of the simulations show that the performance of this system has remarkable effects on reducing energy consumption and carbon dioxide emissions, reaching a reduction of up to about 20% in these different Iranian locations. This performance indicates the positive impact and efficiency of this system on the buildings in different climates of Iran.

## Buildings 3

## SDEWES2021.0242

# Ventilation and Thermal Performance of a Novel Windcatcher System with Passive Dehumidification

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## Abstract

In this research, a novel windcatcher consisting of a wind scoop and venturi roof chimney was proposed for low energy ventilation and passive dehumidification. The ventilation system is formed by two vertical round ducts placed in concentric circles above the building. The inside return duct was connected to a venturi roof to extract the air with negative pressure, and the outside supply duct was connected to a rotary wind scoop to provide positive pressure, which faced the wind and captured wind from any directions. A Computational Fluid Dynamics (CFD) model of the windcatcher system was developed using ANSYS Fluent and validated using previous works data. The model was used to evaluate the ventilation and thermal performance of the system. The results showed that the ventilation rate was adequate for occupants, and the pressure provided by the windcatcher was sufficient for passive dehumidification. The passive dehumidification performance was also evaluated, and a reduction of up to 16% relative humidity was achieved.

## SDEWES2021.0269

# Evaluation of the Impact of the Spatial Deployment of Vegetative Barriers on the Building's Thermal and Energy Performance

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## Abstract

Trees can provide passive cooling in different ways; they shade the area behind them and cool the air through transpiration cooling. In addition, trees are often placed around urban infrastructures for windbreaking (shelterbelt) purposes.The spatial deployment of trees should consider how the layout could influence the thermal comfort within a building and its energy consumption. Based on the literature review, limited works focused on the effect of the placement of trees on the cooling and heating loads in different seasons. This study aims to evaluate the passive cooling effect of trees in the summer through shading and investigate the influence of the tree on mean wind, pressure and temperature distribution. In addition, the windbreak effect during the winter will be explored in terms of its impact on the heat transfer through a building envelope and indoor environment. A building energy simulation (BES) model was developed to quantify the beneficial effect of trees on buildings. Following that, a computational fluid dynamics (CFD) model was developed to investigate the surface pressure coefficient and indoor air temperature resulting from trees' effect. The effect of trees and their arrangement on the mean wind, pressure distribution and turbulence within a built environment was investigated. The results showed that the percentage of energy consumption reduction potential (ERP) increased as more trees were added: from 17% (one tree) to 51% (5 trees) for the 2-floor model. The modelling was validated using previous work's experimental data, and a good agreement was observed. In order to verify the CFD solutions independently from the grid, a sensitivity analysis was carried out. Based on the simulated conditions, the solution could obstruct solar radiation in summer without significantly reducing the winter solar gain mainly from the south orientation. It was also observed that the positions of the first two trees had a paramount effect on ERP. The wind flow and thermal analysis have shown that the addition of trees affected the pressure coefficient on the building surfaces and heat transfer which will influence the heat gains and losses of building components. This study will help develop tools that can assist the design of windbreaks to maximise their effects. Future works will focus on looking at the influence on the pressure coefficient and convective heat transfer coefficient around the building surfaces of the different parameters, such as the shape and orientation of building, size and location of trees and spacing between them.

## SDEWES2021.0276

# Thermal Performance Under Future Climate Scenarios for an Enerphit Building in Athens

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## Abstract

Passivhaus standard provides a direct pathway to high efficiency buildings and carbon reductions. Taking into account that around 35% of buildings in the EU are older than 50 years, there is great potential to retrofit following the EnerPHit standard. Extreme and average temperatures across the world are forecasted to increase in the near future, threatening human thermal comfort and causing dangerous health diseases, leading to a high probability that current construction standards of buildings will not provide healthy and comfortable indoor environments. This research study aims to investigate the thermal behavior and the relative humidity of an EnerPHit building under different climate scenarios, in Athens, without active strategies. The building has been modelled using a dynamic building energy simulation with the use of EnergyPlus software to simulate for the current weather conditions and four future climate scenarios and considering their effect in 2050s and 2080s, from low to high future greenhouse gas (GHG) emissions. The results have shown that the EnerPHit standard must consider future weather scenarios to reduce overheating as consequence of climate change and global warning in Mediterranean cities, like Athens. Future works will focus on the thermal performance of future climate to deploy a country wide approach to retrofit in Greece

## SDEWES2021.0278

# Investigation of the Aero-Thermal Comfort Performance of a Passive Cooling and Heat Recovery Windcatcher Using a Modified Thermophysiological Model

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## Abstract

Recently, natural ventilation techniques such as windcatchers are increasingly being employed in buildings to increase the supply of fresh air and reduce mechanical ventilation consumption. Previous research also showed the capabilities of the windcatcher in passive cooling building space to reduce energy consumption for cooling. However, there was little evidence relating to how the system would improve the occupants' thermal comfort levels. This work aims to investigate the aero-thermal comfort performance of roof-mounted windcatcher using a coupled Computational Fluid Dynamics (CFD) and Fiala thermophysiological model. Unlike the predicted mean vote (PMV) model, the Fiala model is transient and multi-segmented, which will enable the evaluation of the thermal responses of local body segments separately. The windcatcher model was incorporated into a test room model. The study employed the CFD code FLUENT with the k-e model for conducting the steady-state RANS simulation. For the Fiala model, the validation process mainly consisted of two parts. The first part was to validate the passive system in a thermally neutral environment (steady-state). The second step was to assess the model accuracy in predicting dynamic human responses in transient environment conditions. The results showed that the self-implemented model could mimic the thermal responses of a human being with high accuracy, even compared with some sophisticated commercial software. The completed model was then used to assess the thermal performance of a passive cooling windcatcher. The results showed that the indoor environment parameters, including air temperature, velocity, and relative humidity, were unequally distributed in the room, and the thermal comfort level varied throughout the ventilated space. Besides, even in the same location, those parameters, especially the air velocity, vary at different height levels, limiting the utilisation of the traditional PMV model that assumed a homogenous environment over the whole human body. Therefore, the present work showed that the Fiala thermoregulation model had its inherent advantages in this context. Future works will optimise thermal comfort distribution by incorporating various control strategies such as dampers and diffusers.

## SDEWES2021.0288

# Design Strategies to Increase the Cascading of Wood Materials in Buildings: Lessons from Architectural Practice

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## Abstract

The substitution of carbon-intensive and non-renewable materials with wood-based products might contribute to the mitigation of climate change and resource depletion in the building sector. However, the increasing demand for wood-based products in the built environment might generate a trade-off affecting biomass availability, forest ecosystem services, and the climate change mitigation potential of forests. Therefore, it is important to couple the use of new wood-based products with the adoption of circular economy principles. To implement wood cascading in buildings, ‘upstream’ and ‘downstream’ circular strategies can be developed. ‘Upstream’ strategies are developed in the design phase and aim at facilitating the cascading of wood during the future life cycle of the building (e.g. Design for Disassembly). ‘Downstream’ strategies can be implemented in different phases of the building’s life cycle and usually concern the salvage or reclamation of materials when buildings are in the process of being demolished/disassembled and the parts disposed of. Although there is growing interest in wood cascading, ‘upstream’ and ‘downstream’ strategies still do not follow a standardized process or protocol. The aim of this study was to increase knowledge about ‘upstream’ and ‘downstream’ strategies to recirculate wood elements, analysing real-world case studies in architectural practice. A survey of a sample of designers and design teams adopting such strategies in their projects, was carried out. It was found that ‘upstream’ strategies are usually based on a systemic approach, enhanced by the use of advanced tools in order to improve the prediction of a building’s transformation throughout the life cycle, while ‘downstream’ strategies are based on a dynamic approach, that boost the integration of non-standardized elements and the adaptability of the project to future changes.

## SDEWES2021.0473

# Occupant Lifestyle: Impact on Energy Use of High-Rise Dwellings in Southeast China

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## Abstract

As lots of the total energy was used by buildings, the number of residential buildings has dramatically increased in China. Occupant behavior has significant impacts on building energy performance and occupant comfort; it is important to understand the critical links between people's lifestyles and energy consumption. In recent years, the Chinese government implemented a series of policies aiming at controlling the increase in primary energy use and $CO_2$ emissions both for public buildings and dwellings. Numerous of papers have studied the relationship between occupancy behaviour and energy consumption in public buildings like office and commercial building. However, the research for occupancy behavior and the connecting between residential building and energy consumption is limited, which is partly due to the intimate information is difficult to collect. Also, since high-rise residential building is the most common type of newly built building in China, the investigate in the energy consumption in high-rise dwellings is necessary. To get more information on the main factors and promote suitable energy efficiency technologies, this paper conducted detailed surveys and simulations of typical examples of urban households for the target area focusing on indoor comfort and building energy consumption. 112 urban households who lived in the southeast of China participated answering questions about their family composition, buildings, energy use and occupancy behavior. Occupant interviews were conducted to gain information on thermal satisfaction levels, occupancy equipment ownership, and their using patterns. Based on the collected data, an energy simulation software program was used to investigate the main factors of occupancy behaviour, which affect the energy consumption. Also, with the new policy of two children in China, the family size and age will change, which will lead to the modification of lifestyle patterns. The simulation of this change is also made to predict the trends of future energy consumption of urban households in southeast China. The results indicated that compare to equipment, occupancy behavior only occupied a small scale but still significant to improve. With the development of urbanization, the trend of energy consumption in the future will increase in per household level.Future works will focus on the more factors that will affect energy consumption in residential buildings as it showed potential to improve.

## SDEWES2021.0930

# The Sustainable Heating of Amsterdam's Historic Buildings

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## Abstract

By the year 2040, Amsterdam aims to be independent from natural gas, and by 2050 the entire city needs to be carbon neutral; to meet these ambitions it is crucial to define a long-term strategy for the historical city centre, the area with the highest heat demand density. The inner city, designated as UNESCO World Heritage site, is now mainly served by natural gas boilers and an extensive energy renovation is difficult due the lack of space and the monumental status of many buildings.

The project presented intends to support the municipality in identifying energy measures allowing for maximum impact while preserving the city's historic and aesthetic values. By identifying key recommendations and collective measures, the work proposes a generic approach on energy retrofit decisions for historical buildings and it explores opportunities for sustainable heating solutions available locally, such as aquathermal energy from canal water, residual heat and other forms of low-temperature heat.

The research contributes to develop knowledge for the gradual energy transition of the historical city centre of Amsterdam but ultimately, the planning approach can be applied to similar urban areas.

## Buildings 4

## SDEWES2021.0573

# E-Safe: Energy and Seismic Affordable Renovation Solutions for the Decarbonisation and Seismic Safety of the EU Building Stock

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## Abstract

This paper aims at showing the scope, the methodology and the main technological challenges of the four-year innovation project “e-SAFE”, started in October 2020 and funded by the EU in the framework of the Horizon 2020 Programme. The project is led by the University of Catania and includes twelve partners from eight different EU countries. e-SAFE aims to develop a new deep renovation system for non-historical reinforced concrete (RC) frame buildings, which combines energy efficiency with a series of further advantages including affordability and reduced implementation time and costs. Most importantly, e-SAFE encompasses technical solutions to integrate energy-efficient with anti-seismic retrofitting actions, and will also address strategies to activate new value chains to boost the deep renovation market throughout Europe.

On the technical side, the proposed building envelope solutions rely on pre-fabricated insulating timber-based panels (e-PANEL) that can be coupled to a structural system to increase seismic resistance according to two innovative plug-in solutions: e-CLT and e-EXOS. e-CLT consists of cross laminated timber (CLT) panels that are applied to the outer walls and connected to the existing RC frame via seismic energy dissipation devices (dampers), while e-EXOS consists of a steel exoskeleton made of bi-dimensional bracings equipped with dampers and connected to the existing RC frame too.

On the other hand, plug-and-play decentralized small-volume water storage tanks will be installed in each dwelling to store the domestic hot water delivered by a centralized electricity-driven high-efficiency air-to-water heat pump. The latter also covers the energy demand for space heating and cooling, through a system architecture that includes large-volume centralized insulated water tanks. A significant share of the electric energy needed to feed the heat pumps is covered by photovoltaic panels, according to the logics implemented on a dedicated Building Energy Management System.

The effectiveness and replicability of the proposed methodology will be demonstrated in one real and two virtual pilot projects, located in different climatic and seismic areas of Europe. Social aspects and stakeholders’ involvement will be duly considered, already from the co-design stage.

This paper will also present some preliminary results about the expected energy and carbon reduction ensured by the e-SAFE solutions both at building scale and EU scale.

## SDEWES2021.0658

# Evaluation of the Ventilation and Cooling Performance of a Windcatcher with Helical Coil Heat Transfer Device (Hchtd) for Hot Climates

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## Abstract

In this paper, a multi-stage windcatcher with Helical Coil Heat Transfer Device (HCHTD) has been developed as a low-energy alternative to air-conditioning in hot and dry climates. A Computational Fluid Dynamics (CFD) model was developed to evaluate the ventilation and cooling performance of the windcatcher with HCHTD through geometric parametric study, with a focus on increasing layers of helical coils in the HCHTD, and operating condition analyses. The modelling approach was validated using the experimental results from previous works. This novel concept achieved a noteworthy range of cooling ranging from 14.25K to 8.6K for wind speeds of 1-4m/s under an extreme cooling scenario, and 4.27K to 3.62K for wind speeds of 5-7m/s under average cooling season conditions. It was concluded that the optimal configuration is the windcatcher with 6-layer HCHTD which can offer competitive cooling whilst meeting fresh air requirements, even at low wind speeds, compared to a windcatcher with the straight cylindrical heat transfer device.

## SDEWES2021.0701

# Investigating High Resolution Profiles of Building Energy Demand and Renewable Production for Increasing Flexibility

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## Abstract

Energy flexibility of buildings is getting a promising solution as further service to the Power Grid in contexts where stability, congestion and weak connection are crucial. This is the case of Geographical Islands where the strong changes in energy loads between winter and summer season highlight the drawbacks of existing connection to the mainland. Improving knowledge and characterizing the flexibility of those buildings can help the energy planning strategy as well as understand the dynamics of energy exchanges. This study analyses a building, in the Island of Procida, Italy. The results are a useful insight to plan the installation of further local renewables as well as the energy retrofitting interventions to empower such flexibility potential. The loads in the buildings are mapped and a detailed characterization is provided. Moreover, the real data of electricity exchanges between the building and the Power Grid at 15-minutes resolution are processed to identify what the potential temporal allocation of such energy flexibility is.

## SDEWES2021.0711

# Possibilities for Deep Renovation in Multi Apartment Building Under Different Climate and Economic Conditions

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## Abstract

Possibilities for deep renovation of apartment buildings to the passive house level under different circumstances were analysed. The variables included different local climatic conditions, degree of economy and market development of the country (energy prices, energy footprint, labour prices, etc.) as well as different levels of insulation of the building envelope and others, related variables.

To obtain an optimal solution for the deep renovation, an adequate methodology was developed. The proposed methodology is based on the interaction of energy simulation and mathematical optimization. In the developed model, the energy performances of the building were determined using the EnergyPlus package and the optimal solution was obtained according to several criteria using a mixed-integer non-linear programming model. The conclusions are drawn in line with the results of the optimization, from which various consequences may follow, including those related to the attitude of policymakers and subsidies or incentives related to the housing sector policies.

SDEWES2021.0856

# Computational Approach to Predict Thermal Comfort Levels in Passivhaus Based on Natural Ventilation

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## Abstract

The Passivhaus building concept has been widely-researched in relation to its performance, especially the aspects of energy consumption and thermal properties, nevertheless, the design stages still do not present a dynamic thermal comfort predictive process that aids investigating the design performance. This research focuses on a methodology that calculates summer months peak conditions in a pilot Passivhaus dwelling in the UK, based on the natural ventilation plan effectiveness in maintaining sufficient airflows, while the mechanical ventilation heat recovery summer bypass mode is on. The methodology's technical aspect involves EnergyPlus dynamic simulations, ANSYS CFD simulations, and the CBE Thermal Comfort Tool. Results found that the majority of the PPD values were of uncomfortable levels at summer peak days, while presenting the effect of individual thermal comfort parameters simultaneously. These findings being produced by the methodology may add a more comprehensive description to the thermal comfort status during the design stages, while employing the mentioned software combination.

## SDEWES2021.0865

# Material Classification and Reuse Framework Based on the Reverse Dismantling of Buildings in Urban Mining: a Study in Tcclab

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## Abstract

Mining and waste have created negative impacts on the city. In this study, dismantling, a substitute for demolition is attempted according to the construction system and materials in order to classify and quantify the building materials from knocking down. It is hoped that this study may contribute to the dismantling classification and recycling of construction waste in the process of urban mining. A building's life cycle goes through design, construction, operation, and removal. The study on urban mining provides a method for macro-statistics of existing building materials in cities. Specifically, the materials and components of buildings in the area are classified in more detail by disassembly method, taking actual buildings as an example, using computer 3D models to simulate building dismantling and field research, to more accurately classify and quantify the materials and components inside the building. In this way, new reversible ways of building components and waste materials are explored and a framework for disassembly is established. In this paper, the case of the Taiwan Contemporary Culture Laboratory (TCCLab), converted from the former Taiwan Air Force Headquarters, is to be discussed from the perspective of urban mining. An office building of the TCCLab (referred to as TCCLab Office in the following paper) is selected as the subject for investigation. Under the concept of dismantling (decomposition) instead of demolition (destruction), the components and materials of the TCCLab Office are classified, numbered, and quantified based on its structural system and material types. Therefore, the disassembled components and materials could be reutilized in the construction of new buildings and the reconstruction of old buildings. This paper aims to help reduce the exploitation of natural resources and the generation of waste, and at the same time, increase the reuse efficiency of materials in the process of urban development.

## SDEWES2021.1034

# Soft Digital Twin for IEQ Enabling the Covid Risk Mitigation in Educational Spaces

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## Abstract

The importance of educational buildings' Indoor Environmental Quality (IEQ) is critically increased due to the COVID-19 pandemic. The need to protect occupants and preserve educational spaces where learning activities could proceed in attendance promotes the development of strategies to monitor and correct the indoor conditions on a real-time basis. The adaptability of building spaces aimed at optimizing comfort and users' health and safety may be connected to a Digital Twin (DT) and a Building Management System (BMS), enabling data collection and diagnostic to trigger corrective actions on indoor air conditions. A soft DT, i.e., one based on a Building Information Model (BIM) with a low Level of Geometry (LOG) coupled with an IoT network, is proposed to collect results from IEQ monitoring in educational spaces. The DT is aimed to measure the $CO_2$ emissions and Particulate Matter (PM) pollutants, balancing the need for increased ventilation rates to dilute contaminants and thus reduce the infection risk and the control of comfort conditions. Besides the DT, a stand-alone particulate matter sensor has been used to verify the possible inverse influence of the increased ventilation on indoor pollutants coming from outside. This approach enables pupils to learn in a healthy and protected environment.

## Buildings 5

## SDEWES2021.0040

# Integration of Environmental Impact Assessment into Parametric Performance-Based Structural Design for Flexible Industrial Buildings

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## Abstract

Industrial buildings are characterised by very short life cycles due to frequently changing production systems. The load-bearing structure strongly restricts the flexibility of industrial buildings and is one of the key drivers of embodied energy and carbon emissions. This paper presents a novel parametric optimisation and decision support (POD) model that enables automated structural design with quantitative flexibility rating, integrating a method for life cycle assessment (LCA) and recycling potential calculation. The proposed framework is tested by means of a variant study. Based on a pilot-project the trade-off between LCA, recycling potential, flexibility and cost is investigated among different structural and enclosure systems. Results show the effectiveness of the framework to identify alternative building materials and low-impact variants in industrial building design, enabling informed decision-making at early design stage. In future research the model will be evolved by integrating a method for life-cycle cost analysis.

## SDEWES2021.0047

# Net-Zero Buildings What are They and What Should They Be?

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## Abstract

This paper shows that the response of the current net-zero building definitions is not adequate for the decarbonization strategies of the European Union because the essential role of exergy destructions in emission responsibilities is not accounted for yet. By giving the relationship between exergy destructions and emissions responsibility, it is exemplified that a `net-zero energy` solar building connected to a district energy system is responsible for direct and nearly-avoidable emissions. This paper discusses the transitioning to low-temperature district energy systems and argues that low-exergy renewable and waste energy sources may be utilized widely only with low-exergy buildings using new hydronic heating and cooling equipment with heat pipes. New metrics about low-temperature solar heating systems and compatible equipment are introduced with a case study, showing that the nearly-avoidable emissions responsibility due to exergy destructions may be reduced by 86%. A three-pronged application of heat pipe technology in solar photo-voltaic-thermal panels, energy storage systems, and new hydronic equipment is described as an asset for the EU goals for decarbonization. It has also been stated that a net-zero energy building may neither be a net-zero exergy building nor a zero-carbon building due to unavoidable exergy destructions.

## SDEWES2021.0073

# Sustainable Use of Material Resources in AEC Industry - a Review

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## Abstract

With the Sustainable Development Goals, the United Nations are pursuing, among others the following goals: Sustainable Cities and consumption, good life on Land and below water, as well as reduction of CO2-Emissions. Therefore, prudent use of resources – material, energy, and space – as well as reduction of emissions into the environment are essential.

The EU aims for similar goals: 70% and more of the building waste should be recycled or reused and therefore reduce resource consumption and land use according to waste sites reduction. Thus, consideration of these aspects of building design is a necessity. In practice, suitable tools to analyse and optimize these building parameters are lacking.

To assess the consequences of resource consumption and support material sustainability an evaluation of the building performance is needed. This paper takes a critical look at which data needs to be implemented into a material sustainability evaluation for an integrated Circular economy approach. A comparison of available methods gives an overview of different assessments and required parameters. Therefore, an extensive Literature review is.

The results show that the approach how to assess different aspects of material sustainability of buildings are available , but require a lot of different data, some are more firmly anchored in practice, like LCA in building certification systems. Problems are different designations for the same, or very similar parameter and isolated consideration of the individual topics. Therefore, a harmonisation of nomenclatur, as well as cross-linking of the different fields is necessary.

Furthermore, some data required is often not available. For an integrated assessment of material sustainability of buildings, the essential parameters must be reduced to obtainable data, harmonised, and implemented in a user-friendly way.

SDEWES2021.0155

# Framework for a Digital Urban Mining Platform for the Building Stock of Vienna

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## Abstract

With 60% of the world`s raw materials extraction, the construction sector is the largest consumer of raw materials. In order to reduce raw-materials extraction, as well as the amount of waste, created by the AEC sector, increasing recycling rates through reusing or recycling materials within existing buildings is of high priority. However, there is lack of information about the urban stock, since in general, there exists no detailed planning documents about the exact material composition of buildings, which makes it difficult to assess their quality and quantity and accordingly their recycling potential. In order to enable a broad reuse or recycle of materials as well as to predict the upcoming waste and plan sustainable waste streams, information about the existing stock is required, which should be available publicly in form of a digital platform.

This paper presents a framework for the generation of a digital urban mining platform for the city of Vienna, in order to assess the quality and quantity of the materials within existing stocks as well as to provide them publicly. This research is based on the funded research project "BIMstocks: Digital Urban Mining Platform for Assessing the material composition of building stocks through coupling of BIM to GIS". This paper will present the framework for generating a digital urban mining platform for the city of Vienna. The main goal is to develop a method for a consistent digital documentation of the material composition of the existing building stock for modeling the secondary raw materials cadaster and prediction of the recycling potential. Information about the geometry and materials of one selected use cases is gathered through applying various methods. Through linking the obtained information with GIS-data, an upscaling to city level and generation of the digital urban mining platform is enabled.

Results show, that by applying invasive and non-invasive methods, the existing buildings can be modelled. Since the project is still ongoing, the development of the digital urban mining platform has not been created yet. The existence of a digital urban mining platform with relevant information regarding quality and quantity of the embedded materials, in the short term can help to decide about renovation options for buildings and in the long term can enhance the reuse and recycling rates as well as reduce waste generation in the AEC industry.

## SDEWES2021.0222

# Investigation of the Influence of the Integration of Vegetation and Evaporative Cooling on the Aero-Thermal Comfort Performance of Buildings with Courtyards in Hot Climates

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## Abstract

Natural ventilation improves the indoor environment by providing fresh air and enhancing comfort levels without consuming energy. The wind-driven natural ventilation in courtyards has been investigated by many researchers, in particular, the influence of the physical parameters of the courtyard and environmental conditions on the natural ventilation and thermal comfort performance. However, previous research has mainly focused on the courtyard area conditions instead of the indoor spaces surrounding the courtyard. In addition, as a microclimate regulator, courtyards are rarely assessed for the impact of vegetation and evaporative cooling strategies, in particular, its impact on energy consumption and thermal comfort levels. Vegetation (via the evapotranspiration process) and evaporative cooling strategies can help lower air temperature around the surrounding environment and the facades. Therefore, quantitative assessment of cooling effects from these strategies becomes essential for scientific understanding of its influence mechanism on buildings with courtyards. In addition, its effect on the distribution of indoor and outdoor airflow should be explored. The present study aims to investigate the impact of the integration of vegetation and evaporative cooling strategies on the aero-thermal comfort conditions in the courtyard and surrounding buildings in hot climates. Four scenarios were developed based on different vegetation and evaporative cooling characteristics. Building energy simulations (BES) Energyplus was applied to assess the influence on energy consumption, and Computational Fluid Dynamics (CFD) Fluent was employed to evaluate the aero-thermal comfort conditions of the courtyard and surrounding buildings at different ratios of vegetation and water to evaluate the natural ventilation effect. The modeling was validated using previous work's experimental data, and a good agreement was observed. In order to verify the CFD solutions independently from the grid, a sensitivity analysis was carried out. Thermal comfort indices were used to assess thermal performance. The study identified the optimum cover, height, and planting area of vegetation in the courtyard, as well as the optimum number and positioning of the evaporative cooling device. The results of this study will help develop tools that can assist the design of vegetation and evaporative cooling in courtyards to maximize their effects. Future works will focus on looking at the influence of the strategies on different designs and layouts of courtyards and atriums.

## SDEWES2021.0228

# An Evaluation on the Effect of Thermal Mass to Modulate Overheating in Different Climates in China and the Role of Night Ventilation

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## Abstract

Overheating in buildings is a growing challenge in the context of climate change and global warming. Many researchers are focusing on developing different passive strategies to minimize overheating and cooling electrical consumption in buildings. Thermal mass provides thermal energy storage, which could be utilized to store extra heat during hot summers to avoid overheating. To fulfill the cyclical behavior of the thermal mass, it must be discharged to store heat again and follow this charging-discharging process on a daily basis to modulate overheating. Night ventilation performs the discharging phenomenon to maximize the effect of the thermal mass. The aim of this study was to evaluate the effect of thermal mass and night ventilation to modulate overheating in different climates in China. A model of the BESTEST ASHRAE Standard 140 Case 600FF was used to perform full-year dynamic building simulations with energyplus at different levels of thermal mass. The Case 600FF was simulated with each thermal mass configuration in five cities (Guangzhou, Kunming, Shanghai, Beijing and Harbi) in China according to the five climatic regions. The results allow optimizing the thermal mass configuration according to each climatic condition and in accordance with the performance of night ventilation availability. The results confirm the important role played of night ventilation to modulate overheating with the potential to reduce maximum temperatures up to 40% by using heavyweight thermal mass compared to lightweight. The results of this study will help to develop specific strategies based on climate to inform the implementation of thermal mass into regional and local building regulations.

## SDEWES2021.0746

# Energy Renovation of an Existing Building in Limassol, Cyprus, with Double Skin Façade and Building Integration of Active Solar Energy Systems: Energy Performance and Life Cycle Cost Analysis

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## Abstract

The high percentage of energy consumption by fossil fuels in the building sector in combination with climate change across the globe increased the need to move into more sustainable building practices. Thus, the integration of sustainable strategies and active solar energy systems into the design process is becoming a tool for the reduction of the energy demand and improvement of the energy performance of existing and new buildings.

This study investigates the energy performance of an existing residential apartment building in Limassol, Cyprus before and after its energy renovation, using a double skin façade combined with building integration of active solar energy systems. The proposed research starts with the analysis of the existing building energy performance, focusing on the energy loads for cooling, heating, and artificial lighting. Subsequently, the results of the existing situation are evaluated using digital energy simulations, and the process moves on to the renovation and energy upgrade of the building by integrating the aforementioned systems. Energy-Plus simulations are performed where the proposed systems' contribution to the energy reduction is investigated including their energy reduction potential. The before and after simulations are compared, with the focus to prove whether the systems can be viable in terms of decreasing the energy demands of the building. Finally, a life cycle cost (LCC) analysis is performed, to determine the viability of the enterprise.

The overall aim of this research is to determine whether the use of double skin façade combined with integrated active solar systems constitute energy and cost-efficient solution for the viable refurbishment of an existing building in the climatic characteristics of the south-eastern Mediterranean region.

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### SDEWES2021.0446

# Influence of Silica Sand on the Structure and Properties of the Gypsum-Based Mortar Under Temperature Load

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## Abstract

The importance of the utilization of gypsum in building increases nowadays because of its very favourable environmental properties (low energy demand and utilization of secondary products at the production). The investigation of this material is therefore important for the larger expansion of this material into the construction practice. Gypsum mortar has the potential to replace the more commonly used lime or cement-lime mortars, which have a significantly higher environmental impact. Nevertheless, the research of the gypsum behavior and properties was neglected for a long time and therefore the information about gypsum is outdated or still missing. Gypsum has excellent fire resistance, but it is necessary to focus on the behavior of the gypsum composites with fillers at high temperatures because of the influence of fillers on the properties and structure of the gypsum composites at high temperatures was not described in detail.

The goal of this article is the description of the structure and properties of gypsum mortar with silica sand exposed to high temperatures. The studied composite was exposed to temperatures from 100 °C to 1000 °C and the sample dried to 50 °C was used as reference material. The changes in the microstructure of heated materials were studied by the means of scanning electron microscopy (SEM) and X-ray diffraction (XRD). The mineral composition, volume changes, and changes in the mechanical properties after exposition to the high temperatures were also investigated. It was found that presence of silica sand has a favourable influence on the volume changes. The samples kept their shape even after the heating to the 1000 °C and maintained residual strength of 10.2%. It was confirmed that the silica sand did not chemically react with the gypsum matrix, but it influenced the shape of gypsum crystals in the vicinity of sand particles.

## SDEWES2021.0598

# Evaluation of the Effect of Climate Change on the Energy and Comfort Resilience of Urban Buildings

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## Abstract

The purpose of this paper is to study the effect of the expected global rise in temperatures in summer combined with the Urban Heat Island effect on the thermal comfort and the energy consumption of typical residential buildings of the city of Lyon. The city of Lyon was chosen as it provides, for us, an excellent work field. Moreover, the Metropole of Lyon ahes developed a climate and Energy plan where the resilience of buildings against climate change plays an important role. In order to achieve this assessment, new weather files have been created in order to predict the temperatures of the year 2070. The methodology used to developed those files are described in the submission. These files are implemented in a building performance simulation of a typical building of the city. The obtained results show a significant rise in both user discomfort and energy consumption, and indicate that recently constructed buildings could still be improved in order to be performant enough under future high temperatures.

## SDEWES2021.0671

# Assessment of Daylight Performance for Typical In-Patient Rooms in Healthcare Facilities and the Impact on Energy Efficiency

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## Abstract

This research investigates the daylight performance of a typical healthcare patient room, focusing on a design direction putting in the first place the visual comfort of a patient. Furthermore, the research examines the impact on the energy efficiency of each design option. The main scope of the study is to investigate whether it is possible to design daylit spaces that improve the health and well-being of patients without though creating a high energy-consuming building. The methodology used is based on computer simulations using the plugin Climate Studio in the software Rhinoceros. Climate Studio has implemented the widely validated simulation engines of EnergyPlus and Radiance, which are used for thermal and daylight simulations accordingly. For this research, the most widely used healthcare in-patient room is investigated, the double room. The parameters under study are eight room orientations, six different window configurations, and eight types of glazing with different characteristics. Various dynamic annual metrics are used for the daylight performance such as the Useful Daylight Illuminance, the Spatial Daylight Autonomy, and the Annual Sunlight Exposure. The findings show that even if the building design process focuses on healthier indoor environments and adequate visual comfort, there are still options that do not compromise the energy efficiency of a building.

## SDEWES2021.0696

# Optimization Method of a Model Predictive Control System for Thermal Activated Buildings

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## Abstract

Buildings with thermal component activation enable the storage of energy with a high level of comfort at the same time. However, a challenge for control of these buildings is the high inertia due to the storage mass of the buildings and the associated problem of intervening the control system during extreme weather events. Predictive controllers, working with weather data, combined with a building model enable a forecast of the system. The building model processes weather data and information about the building and calculates a predictive temperature profile. Optimizing the comfort criteria of the users enables a prognosis of the heating energy demand. The optimization is carried out by periodic perturbation of the elements of the heating power vector to minimize the deviation between the target temperature and the predictive temperature. The change in the error sum o squares is used as the termination criterion. If the change falls below the termination criterion, the optimization is considered completed. The results of the optimization are comparable to classical optimizations such as the generalized reduced gradient non-linear solving method. The optimization algorithm as well as the building model are running in test mode on a single-board computer in a two-family house. The results of the optimization are transferred to the controller of the heating system and allow a predictive control of the building. First results show that the comfort parameters were maintained during the study period and that a high level of user satisfaction can be achieved.

## SDEWES2021.0697

# A Review on Domestic Heat Water Supply via Cascading Heat Pumps

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## Abstract

As the building standards for new buildings, such as passive-houses or low-energy houses increases, the energy demand for heating of the building tends to drop below the energy demand of heating up the domestic heat water. As temperatures are rising in summer month, cooling becomes an important topic to consider when planning residential buildings. Another increasingly important topic in multi-storey housing is hygiene in the domestic hot water system.

Cascading heat pump systems provide a technical concept for energy efficient domestic hot water supply, while providing heat supply and even cooling for the living areas. Within these concepts, several variations of the system components can provide a level of adaptability to special requirements beyond technical and economical factors. Utilizing these advantages requires certain constructional measures and has different user experience in practice than conventional heating systems. The aim of this work is to summarize advantages and disadvantages of selected concepts and gives an overview over best practice examples.

## SDEWES2021.0743

# Measurement of a Refrigeration System and Integration of a Digital Twin for Operational Optimization

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## Abstract

Due to climatic changes, the energy required to operate refrigeration systems for building air conditioning is expected to triple by 2050. In practice, the various components of refrigeration systems usually operate with isolated control strategies, without coordination for optimized overall operation. The aim of this project is to increase efficiency with the help of a digital twin.

For this purpose, first a refrigeration system was measured (2 compression chillers with a total power of 1 MW), which is used to cool a server room all year round and the office area seasonally. Due to missing measurement points in the building automation system, non-invasive and mobile sensors were set up in parallel (clamp-on temperature sensors, ultrasonic flow measurement, Rogowski coils and current transformers for electrical power measurement, Raspberrys Pis as computing units).

Finally, on the basis of the measurement the system efficiency will be evaluated and the optimization potential will be identified. Furthermore, a thermodynamic simulation model of the process (based on energy and mass balances) will be created, which will run in parallel to the real system and will be used for operation optimization. The long-term goal is a direct communication between the simulation model and the building automation system (hardware in the loop solution).

## Cogeneration, trigeneration, polygeneration

## SDEWES2021.0183

# A Dynamic Multi-Objective Optimization Framework for Simultaneous Process Design and Control of a Cogeneration System Considering Uncertainties

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## Abstract

In this study, a dynamic multi-objective optimization model is formulated by integrating design, control, and operational scheduling of cogeneration systems taking ambient fluctuations and model uncertainties into account. The framework is based on a dynamic design and regulatory control optimization followed by employing a multi-parametric model predictive control strategy with a terminal penalty. The design parameters are evaluated under optimal control regarding a problem-specific objective. The employed power and freshwater cogeneration system consist of an organic Rankine cycle, an ejector refrigeration cycle, and a reverse osmosis. The new integrated design and control optimization method improved the energy efficiency, decreased the total cost, and increased the system's reliability. Thus, the proposed method allows for efficient integrated design and control of cogeneration systems.

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## SDEWES2021.0200

# A Multi-Objective Optimization Approach to Design an Integrated Renewable Energy System Including Exergorisk and Reliability Characteristics for Sustainable Operation

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## Abstract

The integration of power generation systems with renewable energy resources and waste heat recovery subsystems is an effective solution to anthropogenic climate change caused by conventional power plants. In present research a novel renewable-based integrated power and refrigeration system is proposed with a simultaneous consideration of several operational, design, and system feasibility parameters. A multi-objective optimization model is utilized to find optimal system configuration considering five decision making scenarios including system risk(I), system reliability (II), cost of energy (III), thermal efficiency (IV) and exergetic efficiency (V). The proposed system achieves a cost of energy of 0.03785 $/MWh and an overall system reliability of 86% allocating R123 in the ORC. The multi-objective optimization showed that the system reliability, cost of energy, and exergetic efficiency can be simultaneously improved in the range of 1.60-3.19%, 6.52-18.97%, and 4.00-9.19%, respectively.

Acknowledgments:

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. 2021R1A2C2007838) and the Korea Ministry of Environment (MOE) as a Graduate School specialized in Climate Change.

## SDEWES2021.0431

# Pilot Process Demonstration of a Feasible, Plastic Pyrolysis We-to-En System Through Biomass Decentralized Heating Business Model

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## Abstract

Ever since the rise of environmental consciousness in the industrially developed world (~1960s onwards), the recycling practice of secondary polymers (waste plastics) entailed collection and shipping to (predominately) China which would utilize it, along with other secondary materials, as feedstocks in its ever-growing industrial development. This made China, by far, the largest waste plastics importer in the world. Therefore, it is not a surprise that the global recycling industry practically collapsed when this practice was abolished by Chinese policymakers in 2017. This could severely increase an already serious environmental issue of plastic waste in the environment as it is predicted that, given the current trend of secondary plastics generation remains unchanged, 111 million metric tons of plastic waste will be displaced between 2017 and 2030. This is why research and development of environmentally and economically feasible solutions for reducing global plastic waste output is increasing rapidly. Thermal pyrolysis of plastics stands as a superior waste reduction method compared to landfill disposal and direct incineration predominately since it can create valuable by-products in the process (fuels and chemicals). Although this approach has been in development by many researchers, specifically on centralized industrial scale processes, feasible economics are still a significant challenge. This is predominately due to large energy input for the process (1.3-1.8 MJ/kg, which reduces the output of liquid combustible products) combined with the necessity of energetically taxing feedstock supply chain. In this work we address these challenges with a demonstration (for the first time) of a modular, pilot-scale cogeneration process which integrates automated biomass (woodchip) boiler (100 kW) with a semi-batch plastic pyrolysis reactor (42 L). Based on the operating results of this system (0.7-85 L of pyrolysis oil per kg of plastics and up to 60 kg of plastics per day) we propose a novel business model for decentralized pyrolysis oil production through seasonal heating. Through techno economical assessment and environmental-energy analysis, encompassing both the cogeneration process as well as the feedstock supply chain our expected results will quantify the improvement of economic and environmental parameters compared to conventional large-scale plastic pyrolysis processes. This in turn will provide a feasible business model for economically self-sustainable waste plastics sink without the need for governmental incentives.

## SDEWES2021.0435

# Numerical and Experimental Analysis of the Operation of the Micro-Cogeneration System with a Wood-Fired Stove and Prototypical Thermoelectric Generator

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## Abstract

Thermoelectric generators (TEG) are useful devices for recovering waste heat for power generation. Among other possibilities, heat may be recovered from domestic stoves and boilers. Generated electricity provides self-sufficient operation of TEGs as well as source of power for some domestic appliances. Nevertheless, problems with proper selection and complicated use of thermoelectric generators do arise. Devices currently available on the market are not proper designed to cooperate with domestic heating devices. The result is the fact that TEGs nominal power parameters are impossible to reach in real conditions.

This paper shows the experimental and numerical analysis of the micro-cogeneration system equipped with a wood-fired stove and a prototypical thermoelectric generator (constructed using four thermoelectric modules and a water cooling system). Mathematical modeling (Computational Fluid Dynamics was used) made it possible to exclude the possibility of installing the thermoelectric generator on the rear wall of the tested stove. Based on the results of numerical works, a flue gas channel was selected as a location for the thermoelectric generator. During conducted tests, electricity generated in the thermoelectric generator was measured by the electronic load, which allowed to simulate of various operating conditions. The obtained results confirm the possibility to use developed thermoelectric generators to generate power from the wood-fired stove. The maximum power obtained during discussed combustion process was 15.4 W (if this value occurred during the whole main phase, the energy generated would be at a level of ca. 30 Wh), while the heat transferred to the water was ca. 750 Wh. By introducing thermoelectric modules characterized by higher efficiency, a higher amount of electricity generated may be provided, as well as sufficient levels of current and voltage may be achieved.

## SDEWES2021.0915

# Predictive Dynamic Model of a Smart Cogeneration Plant Fueled with Fast Pyrolysis Bio Oil

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## Abstract

This paper presents a dynamic model of a cogeneration plant fueled with fast pyrolysis bio-oil (FPBO) originating from different types of biomasses. The cogeneration plant consists of a modified diesel generator (genset) operating on FPBO, an FPBO-fueled flue gas boiler operating solely on the oxygen content of the engine flue gas, flue gas cleaning system including oxidation catalyst, diesel particulate filter, and selective catalytic converter, and heat exchangers/ condensers. At high engine load, the burner of flue gas boiler is constrained with low availability of flue gas oxygen while at low engine load, the flue gas boiler can operate full load, providing a highly flexible ratio between heat and power generation. In this sense, the plant is an integrated smart cogeneration unit that can deal with the fluctuating energy demand and varying availability of wind/solar power. In the current H2020 project, SmartCHP, a prototype of such a plant is being developed.

To enable smart control of the SmartCHP unit, and to determine its optimal working points, a predictive, dynamic system model needs to be developed. Therefore, the focus is on the development of a control-oriented dynamic model of the cogeneration plant. The paper presents the integration of the components' dynamic models into a predictive system model. The input-output relations of different components and their interfaces are modeled and included in the system model. The paper also illustrates partial validation of the model with respect to measurements from a turbocharged four-cylinder diesel engine running on FPBO. To make model simulations comparable with available measurements, simple preliminary controls are designed and included in the system model.

## SDEWES2021.0997

# Theoretical Analysis for the Use of High-Temperature Geothermal Reservoirs with Coaxial Deep Borehole Heat Exchangers as a Heat Source for Cogeneration of Electricity and Heat

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## Abstract

In this work the feasibility of using the coaxial borehole heat exchanger (cxBHE) of deep geothermal wells for simultaneous production of heat and electricity is investigated. Coaxial borehole heat exchangers have advantage for being the single well-system and disadvantage for having lower heat transfer efficiencies when compared to conventional deep geothermal systems with production and injection wells. System consists from thermal and electricity demand, one or more geothermal deep wells, cxBHE's and cascade utilization system for production of electric and thermal energy. The system cxBHE-reservoir is simulated with FeFLOW. Surface equipment is modelled with the in-house model RES2GEO. Theoretical simulations are performed over the one-year time horizon taking into account a single-hour time step. Simulation is providing the detailed in-depth data for analysis of heat transfer which can be used to mitigate the skin effect in vicinity of cxBHE. Also, possibilities for using the high-temperature reservoir as a seasonal heat storage is analyzed. Output data can be used for cost-effective management and design of the new or revitalization of existing wells for decarbonized energy supply.

## Decarbonisation, Energy and water efficiency in industry and mining 1

## SDEWES2021.0033

# Socioeconomic Impacts of Cleaner Production Practices in Chemical Industry

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## Abstract

The development of cleaner production has the potential to transform polluting economic activities. However, current economic models that are based on historical or current relationships face significant restrictions to provide an adequate evaluation of the socioeconomic effects of new production processes and changing inter-industrial linkages. This research develops a new methodological approach that is based on computable general equilibrium (CGE) modelling but uses the advantages of life cycle analysis (LCA) to provide detailed information about the resources used in existing and new production processes.

The practical application of this approach is demonstrated through the case study of chemical industry development scenarios analysed in a recursive dynamic CGE model EnEkonLT. The initial assumptions regarding the cost structures of the industry are based on the life cycle assessment of traditional chemical and biochemical products considered. The scope of LCA is limited to the relationships defined by the production processes, while changes in inter-industrial linkages are endogenized within the computable general equilibrium model. The comparison of the pathways with current production processes and increasing share of biochemistry allows revealing its impacts on the developments of gross domestic product, employment levels, and other socioeconomic indicators.

## SDEWES2021.0079

# Carbon Permit Sharing in Industrial Symbiosis: a Game Theory-Based Optimisation Model

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## Abstract

The emerging effects of climate change due to the rise of carbon dioxide ($CO_2$) and equivalent greenhouse gas (GHG) emissions to the atmosphere has prompted policymakers to revise current emission reduction schemes. One of the schemes is a carbon credit permit which allows plant operators to emit $CO_2$ or equivalent GHG to the atmosphere within the permissible permit limit. However, there are limited literature that explores the effectiveness of trading carbon credit permits in an IS scheme as an alternative to physical resource sharing to optimise a process and reduce waste emissions. Therefore, this research aims to address the above research gaps through mathematical optimisation tools. In this work, a mathematical model is developed to determine the optimal process technology for the plants participating in the IS scheme based on a defined objective. This is done while considering carbon credit permits as a constraint to the technology selection. Through coalition between plant operators in the IS scheme, operators can opt to share their carbon credit permits with each other to help unlock previously hidden technology selection opportunities and improve the collective benefits. The collective benefits will then need to be shared in a fair manner among plant operators in the coalition. This must be done based on the marginal contributions each plant operator made. As such, Cooperative Game Theory is implemented to determine the fair allocation of benefits to each participating plant operator based on their contribution in the IS scheme. To demonstrate the viability of the developed optimisation model, a case study containing three plants (i.e., palm oil mill plant, chemical process plant and co-generation plant) was solved and analysed.

## SDEWES2021.0153

# Life Cycle Analysis of a Cobalt-Free Li-Ion Battery Cell to Support the Renewable Energy Transition

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## Abstract

This study explores the environmental performance of a new battery design for the next generation of Co-free LIB for EVs. For this purpose, the life cycle assessment methodology as per the ISO 14044:2006 standard is used. LCA can evaluate the different stages over the lifetime of a product or service and provide a holistic picture of its benefits and trade-offs. Environmental midpoint categories with their respective methods are used for the evaluation of the LIB, involving climate change, primary energy demand, mineral resources depletion and scarcity concerns, among others. The results show that the cathode active material is the main environmental contributor and Co-free oxides can reduce considerably the environmental impact by 53% when compared to the conventional NMC111 powder production, measured in the Metal Surplus Ore Potential (kg Cu eq), that reflects the material scarcity issues according to the ReCiPe method. These results contribute to the promotion of Co-free lithium-ion compositions to provide new insights into the role of cobalt, and its corresponding impacts, in EVs to support the renewable energy transition.

## SDEWES2021.0281

# Seawater Flue Gas Desulphurization Process for Coastal Industrial Areas

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## Abstract

Sulphur dioxide is a poisonous substance that is vastly formed in the process of fossil fuel burning inside the steam boiler of a thermal power plant, or any other industrial plant that utilizes fossil fuels as the prime source of energy. The technology of cleaning the sulphurous component from the raw, uncleaned flue gas flow in fossil fuel-based power and industrial plants is technology, which has been present for last three decades and is constantly evolving in its characteristics and performance to deliver the high efficient flue gas cleaning procedure. The standard and technologically mature technical solutions for flue gas desulphurization of untreated flue gases are dry, semi-dry and wet flue gas desulphurization processes. The most used and applicable to most of the existing and new fossil fuel-based thermal power plants is a wet flue gas desulphurization process. The aforementioned wet cleaning process can be limestone based (LFOS – Limestone Forced Oxidation System) or magnesium-based (MEL – Magnesium Enhanced Limestone) process. The paper will be focusing on the remaining wet flue gas desulphurization procedure, which is not widely present and known in the industry, the SWFGD (Sea Water Flue Gas Desulphurization) process. This process has numerous advantages such as costless reagent in vast amounts (seawater), optimization of plant design and operational costs. The flue gas cleaning process and its chemical aspects will be presented through the description of the process. The main advantages and disadvantages of the corresponding process will be presented as well as a comparative analysis between main three wet flue gas desulphurization processes (LFOS, MEL & SWFGD) will be performed and correspondingly presented, taking in consideration all crucial points of each aforementioned wet flue gas cleaning processes. As stated before, the main intention of wet desulphurization processes is removing the acid components from the untreated flue gas flow. In the process of doing that, the formation of by-products and effluent is present, which have a different impact on the environment. In the scope of the presented paper, we will evaluate the environmental impact of formed by-products of each corresponding wet flue gas desulphurization process.

## SDEWES2021.0294

# Optimization of Membrane-Based Post-Combustion Carbon Capture Using a Network Flow Model

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## Abstract

The reduction of $CO_2$ emissions is a very challenging issue. The capture of $CO_2$ from combustion processes is associated with high energy consumption and decreases the efficiency of power-producing facilities. This can affect the economy and in specific cases, such as waste-to-energy plants, also their classification according to legislation. To allow the minimization of the energy consumption, a model of a membrane-based post-combustion capture was developed. The optimized parameters are the pressures and membrane properties of individual membrane stages. Model stands on the principle of a network flow problem, where all non-linear dependencies are linearized and replaced by a black box to ensure the optimality of results. The functionality of the model was verified on a case study and the results of the optimization are presented in the paper and implications of the energy consumption for a waste-to-energy plant are discussed.

## SDEWES2021.0380

# Gypsum Based Composites with Improved Water Resistance

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## Abstract

Gypsum binder can be considered as one of the most environmentally favourable building binders because of its low energy consumption at production and also because it can be made from large scale of secondary by-products. Nevertheless its use is restricted mainly to the interiors, because performance of gypsum in the wet environment is rather poor. This disadvantage can be solved by the utilization of composed gypsum-based binders, where gypsum is combined with some supplementary cementitious material (SCM) and activator of pozzolanic reaction. We investigated the behaviour of several gypsum-based composites with combined binders and silica sand. Silica fume, granulated blast slag and waste ceramic dust were used as SCM and hydrated lime served as an activator. It was found that while the gypsum composite was severely damaged after 360 days in water and its strength decreased significantly (0.1 MPa), the composites with combined binders maintained their shape and their strength increased. The microstructure of the materials was studied by the electron microscopy and mercury porosimetry. It was found, that the structures of particular materials differs from each other. Also, the structures of the same materials stored in air and under water were significantly different and the formation of CSH phases and ettringite in the water environment was confirmed. The environmental impact of investigated materials was assessed with the regard to their functional properties. The best combined environmental/functional criteria were achieved by composite with silica fume.

## SDEWES2021.0391

# Debottlenecking of an Existing Gas Pyrolysis Plant for Energy-Saving and Emission Reduction

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## Abstract

Energy consumption in the chemical and petrochemical industry accounts for 28% of the final industrial consumption, according to the International Energy Agency (IEA). It is reported that petrochemical plants in the CIS consume 30-60% more primary energy than existing facilities in Europe, the Middle East and North America. Besides, petrochemical plants are among the largest polluters of the environment. Advanced oil and gas processing plants consume more energy than primary processes due to endothermic chemical reactions and products' separation. Nevertheless, secondary processes help increase enterprises' profitability and the depth of raw materials processing into a more valuable product.

This study's main objective is to determine the existing plant's energy efficiency potential, which uses the gasoline and recycled ethane fraction to produce monomers by pyrolysis. It includes first, defining general energy targets for heating and cooling of products and intermediates; second, the determination of heat recovery and utility potential. The process has multiple utilities that are part of the integrated utility system with electricity generation. The steam is used after gas and steam turbines; there are steam generation facilities as well.

The process and utility system analysis was carried out based on detailed process simulation and methods for integrating continuous processes, including Pinch-based approach and original techniques. The process streams' properties were determined based on the explicit modelling of the thermodynamic equilibrium of stream composition and operating parameters. Modelling of 127 process streams, 66 energy streams and operating 73 units, such as heat exchangers, columns, compressors and other equipment were performed.

The energy-saving potential was determined based on thermodynamically available heat utilisation and different utilities accounting of unit and inter-plant integration. Drawbacks of the particular process were identified, and process and equipment changes were proposed within the existing plant layout. The electricity generation by utility system after the retrofit was compared with the current process, and the impact of the process changes and retrofitted equipment was estimated.

In the result, a significant theoretical potential for energy reduction was identified that is 92 MW, and the pull of preliminary energy-saving measures was created, which pass a plant economic threshold of IRR ³ 50%. They cover 25% of the overall potential and provide a saving of 48,059 $tCO_2/y$. The recommendations for further energy reduction and sustainable energy use within an existing utility system were proposed.

## Decarbonisation, Energy and water efficiency in industry and mining 2

## SDEWES2021.0458

# A Review on Occupancy Prediction Through Machine Learning for Enhancing Energy Efficiency, Air Quality and Thermal Comfort in the Built Environment

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## Abstract

As the largest energy consumer, buildings account for 40% of the global annual energy consumption and 36% of the total carbon emissions. Despite the energy cost, it is common to find buildings with unsatisfied thermal conditions. Occupant behavior has been regarded as one of the most significant considerations for building and system design. During the last two decades, various occupancy models have been developed to mimic occupants' randomness and diversity and generate stochastic occupancy profiles for building performance simulation and heating, ventilation, and air-conditioning (HVAC) controls. Recently, advanced prediction tools based on artificial intelligence are increasingly being employed for predicting occupancy patterns in buildings, in particular, short-term occupancy patterns. The present work carries out a comprehensive review of studies using artificial intelligence and machine learning models to predict occupancy and its applications, covering studies about energy consumption, thermal comfort, lighting use and indoor air quality. This paper provides an overview of hardware and techniques used during data collection, data mining, building modeling simulation and validation, and analysing factors that impact building occupancy prediction. The analyses show that while these studies have revealed that occupancy is a critical contributor in the energy prediction model, they have not paid enough attention to the thermal condition and their effect on occupant productivity and quality of life. With the development of new algorithms, especially data mining algorithms, the accuracy of prediction improved, and the most popular and best performing algorithm are artificial neural network-based algorithms, support vector machines and random forest. The review shows evidence from several field and experimental studies, illustrating the potential benefits of machine learning in predicting occupant thermal comfort. Future studies should focus on carrying out more field tests and the application of such methods i.e. integrating with building control systems.

## SDEWES2021.0469

# Industrial Ceramic Waste as Low Cost and Eco-Friendly Pozzolana Active Filler in Gypsum-Based Binders

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## Abstract

Calcined gypsum belongs to the most environmentally friendly building materials with the potential to partially replace cement in some practical applications. It is commonly used in internal parts of buildings as plaster, protective boards with increased fire resistance, or for decorative purposes thanks to its fast hardening and lightweight. Nevertheless, its wider utilization in external walls remains limited due to its high solubility in water. This drawback can be improved by combining gypsum with commonly used supplementary cementitious materials and an activator of pozzolanic reactions (cement or lime). This paper aims to explore the feasibility of utilizing non-conventionally used industrial ceramic waste, a by-product from brick production, for the design of gypsum-based binders. A comprehensive study of the system consisting of gypsum, ceramics, and lime cured in water was done from a microscopic (XRD, DSC/TGA, MIP, and SEM) to macroscopic (basic physical and mechanical properties) point of view up 90 days of age. Additionally, a simplified environmental study was conducted using the Life Cycle Assessment method. Amorphous phase, ettringite, and portlandite were found to be the main hydration products. Whereas portlandite was gradually consumed, the amorphous phase and ettringite contents had increasing trends. The mechanical tests revealed that the pozzolanic reactions caused by the addition of ceramics waste were delayed, which was reflected by a slow increase of strength within the studied period. At 90 days, the compressive strength of the samples containing the lowest content of ceramics provided the most promising results.

SDEWES2021.0535

# Just Suspended Speed Simulation in Torus Reactor Using Multiple Nonlinear Regression Model

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## Abstract

In chemical and water treatment industries, it's necessary to have a homogeneous solution to achieve maximum contact between the solid and liquid phase, which promote mass and heat transfer. Increasing the stirring speed was the most recommended solution in different types of reactors: stirred tank, column, and tubular reactors. This solution will increase energy consumption which is undesired in industry. The determination of the minimum speed necessary to have a homogeneous solution has been widely investigated; it is called 'the just suspended speed' (Njs). The main objective of this work is to develop a model based on a Multiple NonLinear Regression approach (MNLR), allowing to establish a relationship between the speed of suspension (Njs) and: (i) the geometric parameters of the torus reactor (reactor and propeller diameter), (ii) solid particles characteristics (diameter, concentration) as well as (iii) the intrinsic fluid parameters (density). A dimensional analysis coupled with the MNLR model was carried out to have dimensionless parameters for this study. An improvement in the performance criteria of the MNLR model compared to the empirical model developed previously, thereby enabling a reduction in energy consumption in the torus reactor.

## SDEWES2021.0630

# Optimisation of Multiperiod Heat Exchanger Networks Including Thermal Energy Storages

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## Abstract

Introduction

In times of increasing global warming, enormous efforts are required to rapidly reduce greenhouse gas (GHG) emissions. In Germany the industry is one of the largest GHG emitting sectors and process heat supply is almost exclusively covered by the combustion of fossil fuels. Due to the EU's target of climate neutrality by 2050, it is necessary to systematically increase energy efficiency and decarbonise the industrial heat sector. The methods of heat integration can be used to exploit existing potentials for waste heat utilisation and to integrate thermal energy storages into existing industrial sites. By storage integration, a temporal decoupling of heat sources and heat sinks can be considered and additional savings potential can be achieved. In this paper a simultaneous approach for thermal energy storage integration into multiperiod heat integration problems is presented and demonstrated in case studies.

Method

The presented approach combines mathematical optimisation according to Cerda et al.(1983) and the method of Pinch Analysis, that enables a multiperiod MILP formulation of the optimisation problem. By introducing two separated time periods for heat sinks and heat sources, heat can be transported between different periods via a thermal energy storage. Additional conditional constraints ensure a proper integration and operation of the storage: For loading and unloading of the storage, stream temperatures must fit to the storage temperature and the heat inside the storage must not exceed its maximum storage capacity. The approach can be used to minimise energy demand, total annual costs (TAC) and $CO_2$ emissions. In order to minimise TAC, a market analysis for sensible thermal energy storages was made.

Results

The results from the case study show, that significant reductions of TAC and $CO_2$ emissions can be achieved by systematic waste heat utilisation and storage integration. Due to storage integration 4,2 % additional savings can be achieved for a demonstration case study.

## SDEWES2021.0861

# Hybrid Solvents Based on Des and Amines for CO2 Capture

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## Abstract

The paper is focused to develop the chemical absorption process for capturing $CO_2$ generated in the combustion process especially in the case of fossil fuel combustion. The chemical absorption process using MEA (monoethanolamine) as a solvent has promising results in terms of $CO_2$ capture efficiency but is characterized by relatively high thermal energy consumption and requires high operating and maintenance costs. Thus, the **general objective of the project** is to increase the performances of the chemical solvents used in the chemical absorption technology in order to reduce negative effects (efficiency penalty, higher CAPEX and OPEX cost) of its integration in industrial or energy processes. The solution proposed consists to prepare amine-DES hybrid solvents in order to reduce the disadvantages encountered with amine-based chemical solvents while preserving their high absorption capacity by using **deep eutectic solvents** (DES). The DES's is a blended solvent comprised of two or more elements that form a eutectic with a lower melting point than that of the individual elements. The high purity of each DES can be easily developed using biodegradable resources at a low cost. However, on a mass basis, the solubility of $CO_2$ in DES is still significantly lower than that of MEA (ethanolamine) 30 wt. %, by an order of magnitude, due to the higher molecular weight of DES. The other disadvantages of DES for CO2 capture processes are their very high viscosity, low absorption rates, and high solvent cost compared to chemical solvents. The CO2 absorption process involves equilibrium reaction, where an increase in the CO2 absorption capacity (moles of CO2 per mole of solvent) can be achieved by eliminating one of the reaction products during reaction through precipitation. This could decrease the required regeneration energy up to half that of MEA 30% wt.. In this study, the circulated fluidized bed combustion with CO2 chemical absorption (CFBC) pilot demonstrator belonging to the University Politehnica of Bucharest (Power Engineering Faculty) will be used for experimental tests. The pilot installation was dimensioned for a 30 kg/h fuel flow (110 kWth), lignite. The novelty of the research project is highlighted by the testing activities in the real conditions of the $CO_2$ chemical absorption process integration in the $CO_2$ capture pilot facility using different hybrid amine - DESs solvents. The absorption capacity for hybrid amine – DES's solvent is 0.2 mole CO2/mole solvent while the energy penalty varied between 1.5 and 2 GJ/ton of CO2.

## SDEWES2021.0893

# Techno-Economic Assessment of the Simultaneous Electrocatalytic Synthesis of CO2 and Water to Valuable Base Chemicals Such as Ethylene

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## Abstract

Carbon capture and utilization (CCU) technologies are a chance to reduce global carbon dioxide ($CO_2$) emissions in order to support the energy and climate transition goals, focus is often on fossil $CO_2$ from conventional processes. Hence, using green $CO_2$ from renewable sources like biomass allows to produce fully renewable products that could replace fossil-based materials in the long term while opening up valorization opportunities of up to now unused “waste” streams – finally adding to the development of a circular economy.

The analyzed technology is a CCU and Power-to-X technology that enables the utilization of (excess) electricity from volatile renewable energy resources conversion of $CO_2$. The overall purpose is to produce renewable base chemicals to replace fossil-based chemicals. The targeted olefins such as ethylene and ethylene oxide are crucial intermediates in the production chain of various products. In the novel process, ethylene and hydrogen peroxide are produced from water and $CO_2$ in an electro catalytic reactor, in a second step the intermediates are synthesized to ethylene oxide.

For the base scenario, taking $CO_2$ cost of 0 €/kg into consideration in the base case (due to integration of the process in an existing biomethane upgrading process) and electricity cost of ca. 36 €/MWh, the average production cost range around 0.86 €/kg_product-mix, including side products such as methane, hydrogen and surplus hydrogen peroxide, i.e. are in the order of magnitude compared to other CCU/PtX value chains. If production costs are allocated solely to the main product ethylene oxide, specific product cost rise to 5.78 €/kg, being significantly higher compared to fossil alternatives that have a selling price around 1.5 €/kg. In order to make the sustainable green ethylene oxide compatible with fossil alternatives, the sensitivity analysis shows that $CO_2$-compensation prices as well as energy efficiency (i.e. cell voltage), electricity prices and CAPEX are the most relevant factors. Regarding the latter, increased plant life is a crucial factor as well.

As the analyzed core technology has a low Technology Readiness Level (TRL) of 3-4, only a simplified equipment list is available for the techno-economic assessment. Furthermore, the energy efficiency of the process is assumed to be much higher when the technology reaches a TRL of 7-9 compared to the current state, this was taken into consideration via the scale up to the reference years 2030/2040.

## Decarbonisation, Energy and water efficiency in industry and mining 3

### SDEWES2021.0109

# Opportunities and Barriers of Plasma Catalysis for Carbon Capture and Utilization: a Techno-Economic Assessment

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## Abstract

Carbon Capture and Utilisation (CCU) is rapidly becoming a key instrument to reduce emissions from large industrial sectors. One of the main obstacles is the economic feasibility of these low-carbon technologies. The purpose of this study is to evaluate the economic feasibility of a novel CCU technology, i.e. plasma catalysis in a DBD reactor, in a Techno-Economic Assessment (TEA). Moreover, the most optimal reactor design is sought, by comparing the results of various experimental set-ups. The results show that the technology is not yet economically viable. The empty DBD reactor (without packing material), with short residence times and pure $CO_2$ as feed, has the highest – although still negative – Net Present Value. To improve the economic performance of plasma catalysis, energy costs should be reduced drastically. The insights gained from this study can be used to optimize the design of plasma-catalytic $CO_2$ conversion routes in DBD reactors.

## SDEWES2021.0470

# A Proposal of Process Integration for the Decarbonization of the Steel Industry

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## Abstract

The present work evaluates the production of syngas from thermochemical conversion of $CO_2$ and steam through an oxidization process in a metal oxides bed aiming at producing CO and $H_2$. A computational model was created on MATLAB in equilibrium conditions, to determine the molar and mass flow rate of the components flowing through the system and the energy associated with each reactor at the operating conditions. The analysis was carried out focusing on the treatment of 1 ton/s of $CO_2$. The system consists of a series of reactors, of which the most important are: an oxidizer, where a flux of $CO_2$ and steam reacts with a bed of FeO to produce CO, $H_2$ and $Fe_3O4$, and a reducer, where FeO is regenerated from $Fe_2O_3$. Materials and settings optimization will help to discern the prospects of this technology for a process integration oriented to the decarbonization of the industrial sector.

The MATLAB model was developed and tested in real applications. Furthermore, its predictions were used to set up an experimental campaign to be carried out in the DIMA labs. The oxidizer reactor was designed as a fluidized bed and assembled for experimental test. The experimental tests conducted in the laboratory will determine the actual conversion rate and the production of syngas. The final results will be included in the final paper. Companion CFD simulations were performed to evaluate the hydrodynamics of the bed and the associated reaction kinetics at minimum fluidization conditions. For the estimated minimum fluidization conditions, large bubbles with a low frequency of formation are observed, while almost the entire amount of reactant gases is converted into valuable syngas right after the inlet.

## SDEWES2021.0961

# Conceptual Design of the Steel Industry in 2050 Considering Collaboration with Local Communities

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## Abstract

This paper discusses the role required in the steel industry for the realization of a carbon-neutral society in 2050.

The aim of this research which is the $CO_2$ emissions reduction for iron and steel making process with local energy and material collaboration. To mitigate the large amount of $CO_2$ emissions from the steel industry by 2050, not only conventional energy saving processes but also reformation of the social system is needed. Because, in order for a steelmaking process that achieves high energy efficiency to achieve further efficiency and $CO_2$ reduction, it is necessary to consider not only partial optimization closed in the steel making process but also overall optimization with social system reformation shold be considered.

To evaluate the $CO_2$ reduction rate, we made some input-output energy and material balance models of iron and steel making process with local area, which are BF - BOF route (base case), BF - BOF + EAF (Electric Ark Furnace) route , and so on. In these models, crude steel production set to 10,000 kt-crude steel/year. These material and energy flow diagram of processes are visualized by using input-output energy and material balance models.

In the base case, scrap utilization and excess power are only 7% and 8.8kWh/t-cs, respectively. It means that the iron and steel making process could supply 88GWh/y electricity. It equivalent to 47% of local household's power consumption. In the BF - BOF - EAF route, renewable energy of local area is utilized as electric power consumption of EAF. The ratio of crude steel manufactured by the BOF routes is set to about 60% of the normal operation based on the past BOF operation results. Thus, the remaining 40% will be made with EAF.

The current study examined energy and material collaboration between steel industry and local communities for long-term symbiosis. As an example, we evaluate the improvement effect of CO2 emissions intensity for iron and steel making process with local renewable energy and scrap collaboration. Simulation result indicates that BF - BOF + EAF route case can be reduced ▲25% $CO_2$ emission maximum compared with base case. However, in this case, since the amount of renewable energy that can be supplied in the region is about 8.8 GWh/y. It was indicated that there is a large supply-demand gap. On the other hand, local renewable energy can be self-consumed within the local area as an alternative resource for fossil energy resources that have been purchased from outside.

## SDEWES2021.1013

# Techno-Economic and Environmental Analysis of Carbon, Capture and Utilization of Fermentation CO2 from Ethanol Distilleries

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## Abstract

The sugar and ethanol industry is one of the most important sectors of the Brazilian economy. In this context, the sector has a well-established production chain, and currently, the valorization of agro-industrial residues and by-products (i.e., vinasse, bagasse, straw, and $CO_2$) is a hot topic looking to improve processes and to define further product portfolio under a biorefinery perspective. Hence, the development of innovative processes using these residual fractions could significantly improve the product portfolio of sugarcane mills and reduce greenhouse gas (GHG) emissions. Among the different bioenergy with carbon capture and storage (BECCS) designs, the capture of the carbon dioxide ($CO_2$) from ethanol fermentation, which is more concentrated than other streams, suggests a relevant potential for carbon mitigation in Brazil. This study evaluated an innovative way for the conversion of the biogenic $CO_2$ from the fermentation process to methanol under the sugarcane biorefinery concept. Three scenarios were considered comprising possible biorefinery designs for combined production of ethanol with methanol: i. First generation (conventional process, 1G), ii. Second generation (stand-alone process, 2G), and iii. Integrated process (1G2G). All scenarios were evaluated in the Brazilian context by the greenhouse gases emissions on a life cycle basis, as well as, the economic feasibility for the methanol production unit. The technology selected to evaluate methanol production was $CO_2$ hydrogenation, with an external source for hydrogen ($H_2$). Results showed that $CO_2$ capture from fermentation is technically feasible and losses in surplus per ton of feedstock are meaningful for the 1G2G and 2G biorefinery scenarios. The minimum selling price (MSP) for methanol production presented competitive values to the market price, with a great relevance of the $H_2$ demand to the total costs. Lastly, the environmental performance of the ethanol processes, considering the combined methanol production, could assure, at least 72% of the GHG reduction in comparison to fossil gasoline. In general, the $H_2$ input for methanol production was responsible for the major contribution of emissions and considered the bottleneck for economic and environmental performance. The use of the surplus power to produce internally the hydrogen requirement could improve some indicators eventually, but it was estimated that the amount of the power surplus would not be enough.

## SDEWES2021.1021

# Model Predictive Control Using Mechanistic Data-Driven Model for Optimal Operation in Agro-Food Industry

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## Abstract

Optimization of energy consumption of grain-silos at oscillating ambient conditions is a propitious step towards energy efficient and economically viable grains storage systems. These preserving grains systems are mainly controlled by cooling/ventilation processes that usually consume 50% of the total energy of silos-plant. Therefore, the selected optimized operation of these cooling/ventilation process is essential from the economic perspective. However, this task is not straight forward as the relationship between the operating parameters and the final output of such cooling/ventilation setup is complex in nature. Most of the time in such scenario, first principle modeling or classical rule-based control strategies is hard to implement due to the lack of exact relationship among the operational variables of the physical system. Model based optimization and control technique, like model predictive control (MPC), can overcome this situation if the necessary accurate predictive model is available for the system. Nonetheless, cost, time and effort associated with the identification of such predictive model is one of the key factors prohibiting the widespread adoption of MPC for the complex systems and similar is true for the agro-food industrial process considered here. On the contrary, in this considered case study a large set of operational and physical data are available. In such case, where a handful of real-life silos system data is available, and a desirable control output is expected for the efficient performance, a data driven modeling followed by control using machine learning algorithms and nonlinear system identification method can be the ideal approach.

In this work, first the available data of the grain-silos are analyzed deeply with the help of several regression machine learning algorithms (support vector regression and XGBoost) to find the accurate predictive model based on the historical performance. Later, the characteristic equations and state observers of this predictive model are identified. The results obtained from the abovementioned systematic tasks indicate that a robust data driven MPC framework has the potential to show better performance over the currently used rule-based control strategies especially when very limited knowledge is available for the physical process and the parametric relationship is highly nonlinear providing that the required data are available for the application of advanced machine learning algorithms.

## SDEWES2021.1044

# A Preliminary Study of Calcite Saturation States with Varying pH and Salinity

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## Abstract

The present work explores accelerated weathering of limestone (AWL) as an option to combat the climate change problem posed by the still growing carbon footprint. AWL is a promising low-technology solution that sequesters $CO_2$ through the dissolution of calcium carbonate ($CaCO_3$) in water to form calcium bicarbonate. One aspect of the feasibility of its application is whether the newly formed bicarbonate will remain in solution for the long term. This paper examines the carbonate equilibria for various water bodies by combining Bjerrum plots with the calcite saturation value, omega.

The hydrochemistry software, aqion, was used to simulate a range of water compositions with different salinities at various conditions. The study compares saturation states of rainwater, limestone quarry water, seawater, and reverse osmosis concentrate, with their respective dissolved inorganic carbon (DIC) concentrations, across the full range of pH values. The areas of stability and instability can be observed from the generated plots in order to be able to design effective AWL processes. A key issue for successful implementation of AWL is operating within the $CaCO_3$ saturation limit and ensuring dissolved material does not subsequently reprecipitate.

## Decarbonization of industrial production emissions: special focus on steel industry

## SDEWES2021.0018

# Sponge Iron with the New Black: Production and Use of Bio-Coal in a Direct Reduced Iron (Dri) Plant

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## Abstract

The iron and steel industry is responsible for 4–7% of global greenhouse gas (GHG) emissions. In Sweden, Höganäs AB produces sponge iron for a niche metal powder market using a packed bed DRI process where coke and coal act as a reducing agent (the so-called Höganäs process). One of the most promising ways to reduce GHG emissions from this process in a sustainable manner is to replace fossil-based reducing agents with biomass-based “new black” (bio-coal).

In order to build both practical and fundamental knowledge in evaluating the feasibility of fossil coal replacement with bio-coal, we have carried out a holistic investigation of the entire bio-coal value chain. It starts from the material performance needed for practical utilization of bio-coal in the existing DRI plant, on to assessing strategies for the conversion of biomass into bio-carbon that give required bio-coal qualities, and consequently to the evaluation of available biomass feedstock resources based on defined techno-economic criteria for bio-coal production and use.

First, we have evaluated several bio-coal samples produced from various raw materials in different laboratory and industrial pyrolysis reactors in order to assess the consequence of their use in the Höganäs process. Beyond the choice of raw materials and pyrolysis process, it is the density and particle size distribution of bio-coal that significantly influenced the apparent reactivity relevant to the DRI plant. Furthermore, the in-process behaviour of the ash forming matter in bio-coal will differ from the fossil-based reducing agent according to thermochemical equilibrium analyses. A digital twin of Höganäs process, developed as a multi-scale packed-bed reactor model, implemented such information to evaluate the possible changes in reduction progress due to utilization of bio-coal as a reductant.

Second, a series of laboratory-scale experiments indicated an optimal condition of the slow pyrolysis process to produce bio-carbon with desired properties at high conversion yields.

Finally, we identified the availability of promising forest residues, considering both environmental and economic sustainability aspects related to: current and future competition, expected cost-supply structure, and the spatial resource distribution. Our focus has been on residues from the forestry and forest industry that can fulfil the demand in bio-coal quality and sustainability criteria to keep biodiversity in the forest.

## SDEWES2021.0812

# Coupling Energyplan and LCA to Perform a Scenario Analysis on the Decarbonization of Chinese Steel Industry

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## Abstract

According to the Financial Times the steel industry emissions accounted for 7-9% of total GHG emissions worldwide in 2019. The main share is directly related to the use of fossil coke and coal as fuels and reducing agents. About four solutions can be adopted to address such issue: direct reduction with hydrogen or syngas, electric arc furnaces, carbon capture and storage and use of biofuels (so called “biocarbon”). These solutions can be also integrated. Based on China Energy System model realized in EnergyPlan different industrial energy mixes are evaluated, specially focusing on the steel sector. By chancing the used fuels (from coke and coal to biocarbon and hydrogen) the economic costs and the environmental impacts are calculated. China results are compared with other countries committed in the net zero carbon emission policies, like the UK.

## SDEWES2021.1033

# Production and Characterization of Biocarbon from Woody Biomass Under Different Pyrolysis Conditions

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## Abstract

Biocarbon is a promising alternative to substitute fossil reductants for reducing greenhouse gas emissions and increasing sustainability of the metallurgical industry. Biocarbon can be produced from a wide range of raw biomass materials and carbonization conditions. In the present work, spruce and birch wood chips were pyrolyzed in a fixed bed reactor under different pyrolysis conditions with continuous monitoring of gas products and collection of condensates. The studied woody biomasses were pyrolyzed under different conditions with change of pyrolysis temperature program (i.e., highest heating temperature and residence time), purge flow (i.e., with and without gas purging) and constraint of volatiles and tarry vapors in the reactor. The produced biocarbon samples were characterized by a combination of proximate analysis, elemental analysis, surface and porosity analysis, scanning electron microscopy. The results showed that production conditions, together with chemical and physical properties of feedstocks, determine yields and properties of product streams (biocarbon, gas and condensate) and energy efficiency of biocarbon production processes. Pyrolysis of birch wood with continuous purging of $N_2$ flow offered lowest biocarbon and fixed carbon yield. The biocarbon and fixed carbon yields were improved without purging of $N_2$, which were further enhanced with a lid partly covering the top the sample bed, constraining the volatiles flow. The highest biocarbon and fixed carbon yields from birch wood were obtained from staged pyrolysis experiments, with a first slow pyrolysis step from 105 °C to 350°C with 60 minutes residence time, followed by a second pyrolysis step with same heating rate of 10K/min to 500 °C. The biocarbon yield gradually decreased with increase in pyrolysis temperature. The biocarbon and fixed carbon yield from spruce wood was greater than from birch wood, influenced by the higher lignin content of spruce wood. Analysis results indicated that carbonization temperature is the most influential factor affecting properties of the produced biocarbon.

## SDEWES2021.1035

# Study on Densification of Biocarbon for Metal Production Application

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## Abstract

Biocarbon is a promising alternative to fossil reductants for contributing to decarbonization of metallurgical industry. In comparison to conventional reductants (i.e., petroleum coke and coal), biocarbon has low bulk and energy density, poor mechanical strength and high reactivity. Densification is an efficient way to upgrade biocarbon and improve its undesirable properties. In this study, woody biocarbon was densified into pellets using condensates produced from laboratory scale fixed bed reactor and industrial scale continuous counter flow reactor. The biocarbon densification process, basic fuel properties and mechanical strength of the biocarbon pellets were studied. Effects of type and pre-treatment of binder on properties of the biocarbon pellets were evaluated. It was observed that both densification behaviour and pellet quality are different for biocarbon produced under different conditions and from different feedstocks. The mechanical properties of pellets using biocarbon produced at high carbonization temperature (i.e., 700 °C) are evidently better then those by using biocarbon produced at lower carbonization temperatures. The condensate from industrial scale biocarbon production process showed best performance as binder for producing pellets with compact and dense structure. In contrary, the condensates from laboratory scale reactor had rather poor capacity to bind biocarbon particles to making high strength pellets. The capacities of the condensates as binder are partially related to content of water and chemical fractions of studied condensates. The results of the present work indicate that densification of biocarbon is a promising measure to upgrade biocarbon properties for further logistics and final utilization as reductant and contribute to decarbonization of metallurgical industries.

## SDEWES2021.1056

# Integration of Power-to-Hydrogen with Direct Iron Ore Reduction for Low-Carbon Steelmaking

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## Abstract

The design and dynamic operation of a power-to-hydrogen ($PtH_2$) system integrated with direct reduction of iron (DRI)-electric arc furnace (EAF) processes and hydrogen storage, and driven by a mix of variable on-site solar photovoltaic (PV) and grid electricity, are investigated for South European solar conditions. For base-case system design/operating conditions and current technology performance and cost data, the integrated $PtH_2$-I&S facility and dynamic operating strategy are found to abate I&S process carbon intensity from 677 to 438 $kgCO_2$/tLS (35.3%), relative to exclusive use of grid electricity and no hydrogen storage, and by 63.5% and 76.6% relative to conventional blast/oxygen furnace and natural gas DRI-EAF processes, respectively. In parallel, the levelized cost of steel is reduced from 569 to 547 USD/tLS, resulting in 32.8 MUSD annual savings. The energy and emission intensity, and cost-competitiveness of the $PtH_2$-I&S processes, would improve substantially with future enhancements in technology performance and cost reductions.

## District heating and/or cooling in smart energy systems

## SDEWES2021.0565

# Evaluation of a Solar-Driven Heat Pump for Power-to-Heat Applications: from Building to District Level in a Distributed Energy System

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## Abstract

One of the main goals set by the EU Green Deal Strategy is the transition to a net-zero energy system by 2050. This ambitious achievement can be obtained only by a combined set of technical actions in multiple directions, among which the integration of thermal and electric grids through a set of renewable-based solutions is a key one. Given the current development of District Heating and Cooling (DHC), accelerating the sustainable transition toward future 4$^{th}$ and 5$^{th}$ generation of DHC is a key approach to achieve the EU climate goals toward 2050. However, 4$^{th}$ and 5$^{th}$ generation of DHC still face several challenges, such as the need to integrate a distributed energy generation (DEG) and to increase renewable penetration up to 60% (4$^{th}$ generation) or 80% (5$^{th}$ generation). One of the key features of the newest generations of DHC is the low temperature of the thermal grid, i.e. 20-30°C, which requires a distributed system acting for temperature regulation. In this context, heat pumps can answer to multiple needs: (i) flexibility in operating a different temperature levels to provide both heating and cooling; (ii) power-to-heat operation, thus operating also a peak shaving function for the electric grid while reducing renewables' curtailment; and (iii) operation with different renewable source (PV or wind to drive the compressor, ambient, solar thermal or ground source heat at the evaporator). The aim of the present work is the numerical modelling in Matlab/Simulink environment, of a heat pump system for application in multi-family districts, for DEG, or connected to the DHC network and driven by PV. The model is based on a dataset for heat pump performance available in the open literature and obtained through linear regression from big data analysis. Different climate conditions were evaluated. The use of heat pumps at building level and in a small residential district with decentralized generation was evaluated in different EU climates and the application of the heat pump as an asset to both the thermal and electric grid was discussed.

## SDEWES2021.0566

# Heating and Cooling Networks: a Comprehensive Review of Modelling Approaches to Map Future Directions

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## Abstract

Future energy systems rely on the integration of renewable energy resources in order to decarbonise the heating and cooling sectors and contribute to global net zero targets. Traditional approaches to energy modelling are segregated as focus tends to be on individual objectives such as minimising operational cost. Furthermore, they are limited with respect to computational time, level of precision and scalability. This paper evaluates the current tools and techniques used to model heating and cooling networks, and then proposes a more up to date hybrid approach which utilises recent technological advancements. A detailed literature review outlines existing modelling methods and assesses the capabilities of available software tools. The results are summarised in a Pugh Matrix using relevant criteria to compare and select the most appropriate methods. The review concludes that energy models must evolve to become interdisciplinary and multi-objective, in order to simulate a smart energy system.

## SDEWES2021.0729

# Mutual-Benefit of District Heating Market and Network Operation for Prosumers Integration

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## Abstract

The integration of prosumers (consumers who can both consume and produce energy) in a current district heating network (DHN) brings new challenges to the market and DHN operation, since they can change the thermal flow in the DHN and increase competition in the district heating market.

In this scope, this work proposes the implementation of a coordination methodology based on a peer-to-peer (P2P) market to enable bilateral energy trades between producers, prosumers and consumers, coupled with the DHN operation.

A Nordic DHN containing prosumers is used to test and validate the proposed methodology. The results point out that the coordination methodology is able to provide compromise solutions between the market negotiation and the DHN operation. An important conclusion is that the coordination methodology encourages prosumer integration in DHN, increasing market competition that may pull down the energy costs for consumers while avoiding DHN's operating and management burdens.

## SDEWES2021.0823

# Optimisation of Urban Waste Heat Source Integration into Existing District Heating Systems

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## Abstract

District heating systems are almost always located in densely populated urban areas where various heat sources are available, such as cooling and refrigeration systems in supermarkets, shopping malls and power transformers. These urban sources often have a large share of waste heat which is usually emitted to the environment. Such waste heat could be used to partially cover thermal load in district heating systems. The biggest challenge for their integration is the spatial distribution of urban heat sources in relation to the existing heat network and the temporal distribution of the availability of waste heat energy throughout the year. For this paper, we have developed an optimization model for the integration of urban heat sources into existing district heating systems. By hourly merit order of waste heat utilisation technologies based on pinch analysis, we have defined the most suitable integration of urban heat sources into existing district heating systems. We have considered different temperature regimes of the urban source and the existing heat network. Finally, the method was tested on the case study of Zagreb while the sensitivity analysis was carried out focusing on various technical and economic boundary conditions.

SDEWES2021.0926

# An Innovative Approach to Model Positive Energy Districts in Italy

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## Abstract

Public and private sectors are nowadays focusing their interest on new solutions to fulfil climate-neutral goals by 2050. Due to the rate of human and urban development, energy consumption in buildings requires particular attention. A promising approach is moving energy performance targets beyond individual buildings towards an urban district level that has a zero, or even positive, energy balance. Such a solution must be investible whilst providing co-benefits to the citizens and local authorities. This paper aims to provide a method for quantitative, qualitative, and cost-benefit analysis for the development of a positive energy district with technological renewable solutions. As case study, a realistic district based in Milan has been designed via a Building Information Modeling software to simulate buildings energy consumption profiles and the impacts of efficiency measures, resulting in 2505 MWh of saved energy and 2209 tons of not emitted $CO_2$. Finally, two cost-effectiveness scenarios were developed.

## SDEWES2021.0939

# A Sectorial and Process-Based GIS Methodology for Mapping Denmark's Industrial Excess Heat Potential for 3DH and 4DH Systems

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## Abstract

Current efforts towards tackling climate change by limiting global warming trigger vital energy planning practices where the decarbonisation of energy systems as well as the increase of its efficiency play a key role. This analysis refers to renewable integration for district heating (DH) technologies within the heating sector. Specifically considering the usable waste heat from industrial processes that is released into the environment. Although energy intensive industries show major potentials, and methodologies and tools have been used for its estimation, the quantification of other lower temperature industrial excess heat potentials that could contribute to the decarbonisation of DH systems is yet to be explored. Excess heat is process and sector dependent, and therefore the need of usable methodologies for its quantification in non-energy intensive industries. In this context, this analysis develops a broad methodology for sectorial industrial excess heat mapping by using industrial and commercial georeferenced data, and additional harmonized datasets that feed into a model for examining its potential. Moreover, an analysis for its spatial potential in 3$^{rd}$ and 4$^{th}$ generation DH systems follows, considering current DH infrastructure and heat demands. The results show, where and how, temperature conditioned industrial excess heat would contribute to specific DH systems within the different geographical domains.

## Energy markets

## SDEWES2021.0647

# Electricity Consumption and Market Prices in Serbia – Impact of the Pandemic of Covid-19

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## Abstract

The COVID-19 pandemic has begun in early 2020 and still continues to strongly affect the entire world delivering a significant global shock, but varying across countries and commodity sectors.

The Government of the Republic of Serbia has been adopting different measures to slow down the dissemination of the coronavirus, specifically nationwide lockdown in March and April 2020. Business activities have been reduced. The pandemic situation has changed the lifestyle as people are mostly staying home and working from home.

This paper provides a review of unprecedented impacts of COVID-19 pandemic, with restrictions and lockdown in Serbia, on electricity sector at this stage of the crisis. Sets of statistical indicators are used to analyse changes the electricity sector has been facing. Data visualization is used to compare developments during the pandemic with those of previous years.

Our research and data-driven analysis of these impacts should improve the understanding of the techno-economic effects of unforeseen events, such as a pandemic, on the power system, scrutinizing if effects could be relatively short-lived or longer-lasting, and to be able to respond adequately to similar events in the future.

SDEWES2021.0668

# Evaluation of the Participation of Residential and Commercial Consumers in Energy Communities, a Case Study in València, Spain

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## Abstract

Energy communities have the potential to play a big role in the energy transition and in this sense the European Commission is pushing with different directives to have a consumer-centered electricity system. This work analyses a 100 kW PV installation placed over a public roof and shared among residential and commercial consumers living nearby in an urban area of Valencia. The objective of this work is to evaluate the best options available to fund and operate the installation considering the different members of the energy community. Currently, the Spanish legislation forces communities to have static coefficients to share the communal electricity but this legislation will move to dynamic ones. To study how consumers should organise themselves and share the electricity, a mathematical model is developed to represent the behaviour of the energy community. Afterward, the model runs diverse scenarios to assess the project viability under different circumstances, price sensitivities, and technology structures. The viability of the community considers the savings generated on the electric bill of the users of the energy community as a whole in comparison with the current situation. The scenarios contemplate four main cases: the first one considering just the photovoltaic generation with grid support. The second case includes stationary batteries as an energy management technology. The third one uses electric vehicles batteries parked on communal charging points instead. And, the last case, considers both stationary batteries and electric vehicles for the energy management of the energy community. From these main cases, several scenarios emerge to evaluate the impact of many variables on the project viability. Variables considered include whether the energy allocation uses static or dynamic coefficients, the sharing rate between residential and commercial loads on the community, whether battery ownership is individual or communal, a different number of charging point for electric vehicles installed, or the acceptance for power surplus by varying the number of users joined. The results provide comprehensive conclusions regarding the technical and economic point of view of the energy community. These analyses can help future research to make assessments regarding the social and environmental impact of energy communities in urban areas, especially under the Spanish normative framework.

## SDEWES2021.0672

# Selection of Appropriate Variables to Analyze Renewable Energy Strategic Investments in Power Markets Considering Diversification Issues and the Effects of Weather and Competition Uncertainty

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## Abstract

In addition to the environmental benefits of introducing renewable energy in power generation, there is a benefit related to diversification of the energy mix, improving system reliability and security. However, addressing diversification in power sources is not an easy task, and one of the main issues is to select the appropriate variables that have to be considered to analyze complementarity among resources. Specifically, this paper shows the preliminary results of a larger research project that studies renewable energy strategic investment decisions for generation assets in competitive power markets, focused on comparing hydro and wind power resources and validating with information from the Colombian power market. These are very volatile resources because they depend mainly on weather fluctuations, and several variables can be used to determine their complementarity; these include physical flows (water flow, wind speed), Levelized Costs ($/kWh), and operating variables such as the capacity factor. In addition, an appropriate methodology has to be applied in order to obtain the desired results. In this case, a Game Option model is developed (integrating real options and game theory). This paper shows the process of testing and selecting the variables to be included in it. A conclusion of this project is that capacity factor is the most appropriate input for this kind of model since it allows to simulate volatility within realistic results in the real option lattice, and also helps to correlate operative and financial risk in cash flow analysis.

## SDEWES2021.0725

# Short-Term Load Forecasting Using Time Series Clustering

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## Abstract

Short-term load forecasting has a major role in energy planning. The accuracy of load forecasting has a direct impact on the way the power system is operated and managed and it is essential for power markets' strategy. For system operators, short-term load forecasting can be used to perform fundamental operations such as economic dispatch and unit commitment, as well as to coordinate generation between hydro and thermal units. It can also be used to establish spinning reserve values in advance of any critical situation that might arise in the power system and it is based on load time series.

Load time series are volatile, non-linear and non-stationary and depend on multiple factors, namely, meteorological (e.g. temperature), calendar (e.g. holidays, weekends, working days), network topology (e.g. load shifting) and random noise.

We propose a new approach to deal with short-term load forecasting. It resorts to a clustering algorithm, using K-Medoids with a combination of different dissimilarity measures to deal with the complex nature of load data, capturing differences in time series trends, values, cyclical behaviors and autocorrelation patterns. A summated indicator of several (normalized) cohesion-separation indices is used to determine the number of clusters. Since load data depend heavily on meteorological factors, the temperature time series is also considered. Finally, we resort to similarity pattern sequence searching in the historical data set.

The proposed approach is applied to 2014-2017 time series data of a system operator including load (at the power system level) and temperature data in 15-minutes intervals. They are used to obtain the load forecast for the 96 periods of the day-ahead which is an important input for internal processes of the system operator such as operational planning. The results obtained are promising, when compared with alternative similarity pattern sequence approaches.

## SDEWES2021.0785

# Heading Towards Sustainable and Democratic Electricity Systems

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## Abstract

In the history of electricity systems in several countries different boundary conditions existed and exist with respect to price formation in the market. After the periods of state regulation and the first phase of liberalisation of the wholesale markets currently the electricity system faces the third huge challenge: the change towards a bidirectional system, which should be more democratic and sustainable. This process is currently under way in some countries as Germany, Austria, UK and California. And in these countries also a change in the principle how prices come about is already under way. A major reason for this development is that in recent years the electricity generation from variable renewable energy sources (RES) especially from wind and photovoltaic (PV) power plants increased considerably while on the other hand generation from nuclear and coal has already been reduced, respectively, in the case of coal a phase-out is discussed or has already been agreed on.

The final conclusion of this analysis is, that it will be necessary to accept a paradigm shift in our understanding of the whole electricity system where no longer the generators are the centre but the balancing groups respectively the supply companies. And finally we state that the evolution of such a creative system of integration of RES in Western Europe may also serve as a role model for electricity supply systems largely based on RES in other countries world-wide.

## SDEWES2021.0869

# Assessing Flexibility Options in the Electricity Markets Clearing

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## Abstract

This work presents an optimization model for the co-optimization of the energy and reserves market, considering the penetration of various flexibility providers and their participation in both markets. In particular, a detailed unit commitment model has been developed based on mixed-integer programming techniques incorporating energy storage systems with both charging and discharging options, electric vehicles with both grid-to-vehicle and vehicle-to-grid modes, and demand response programs for cost-optimal energy and ancillary services scheduling. The balancing services considered include Frequency Containment Reserves (FCR), Frequency Restoration Reserves (aFRR), and manual Frequency Restoration Reserves (mFRR), in both upward and downward directions. The impact of all these flexibility providers on both operational and economic aspects has been assessed through an illustrative case study of a power system with high penetration of renewable energy sources, also including thermal and hydroelectric power units. The results highlight the superiority of results when considering the participation of all flexibility providers, especially in the ancillary services market, in terms of economic competitiveness, renewable energy curtailment, associated $CO_2$ emissions, and utilization of costly energy resources. The growing share of the flexibility providers in both energy management and reserve provision mix highlights the importance of those sources on power mixes with low carbon content. The developed methodological framework can be employed by system operators, market participants, and policymakers to provide price signals for the optimal utilization of their resources and portfolio.

## SDEWES2021.0884

# The Nonlinear Relationship Between Household Composition and Residential Electricity Consumption

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## Abstract

This study employs the threshold model to investigate the nonlinear relationship between household composition and residential electricity consumption. Household size and the level of electricity use are considered as the threshold variables. The household data are from Taiwan's family income and expenditure survey in 2018. The results verify that the effects of household composition and household size on household electricity use would differ according to household size and the level of electricity use. The economic scale of electricity use per capita due to an additional member would only exist when household size is equal to and more than 3 persons. Among the small households with one or two persons, the increase of members aged 25-44 result in more electricity use than other age groups, reflecting the inefficiency electricity use of the young group. Moreover, the economic scale effect of increasing members would be weakened as household electricity use rises. If households are at the highest level of electricity use, the elderly member would contribute to more electricity use than other age groups. With the trend of demographic change and global warming, it can be expected that population ageing, declining family size, and higher dependency on electricity would induce electricity demand in the future. The policy makers should improve residential electricity efficiency and adopt some strategies for the small-size households. These results can help to identify the future trend of electricity demand as household characteristics change and make effective strategies for electricity saving.

## Energy policy 1

## SDEWES2021.0025

# Improving Thermal Comfort in Poor-Energy Dwellings Through Test Cells for Climate Change Mitigation in the Mediterranean Area

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## Abstract

If the current human activities rate is maintained, global warming is likely to reach 1.5 ºC in 2030-2052. Recently published energy efficiency and comfort international standards demand new low-carbon emission and sustainable targets in the building sector. In 2018, the existing residential building stock accounted for 26.1% of the final energy consumed in the European Union. Improving energy performance of the existing stock, while maintaining an adequate indoor environmental quality, becomes a noticeably complex task in low-income households, given their significantly high-energy poverty. Thus, climate change impedingly leads to adverse consequences for occupants' health and wellbeing.

This research aims at assessing whether window operation may be used to achieve acceptable indoor thermal comfort results for retrofitting the social housing stock in the Mediterranean area, considering future climate change. The ultimate objective is to provide a useful tool to householders, so that adequate operation window techniques are implemented in low-income homes. Passive and low-cost strategies related to ventilation and solar protection aspects are assessed under different climate scenarios, given their high dependency on users' operation and sensibility on thermal comfort results.

To do so, a methodology that combines monitoring and building modelling is used. On-site ambient measurements were recorded in some Test Cells (controlled environment with no users' influence), recreating characteristic housing units, typical of the social housing stock in southern Spain (Mediterranean area). Monitoring data were later used to calibrate and validate energy simulation models. Different climate change scenarios (2030, 2050, 2080), Mediterranean climatic zones of southern Spain (Csa Köppen climate classification) and orientations (N, S, E, W) were considered, analysing their impact on ventilation rates (ACH), type (natural, mechanical) and use schedule, as well as blinds for solar protection (internal, external) and use schedule.

Among the conclusions reported, it must be highlighted that natural ventilation and mechanical ventilation achieved similar thermal comfort results in low thermal inertia spaces, with high outdoor temperatures. Likewise, the combination of natural and mechanical night ventilation during high occupancy periods has proven to be quite effective with outdoor temperatures between 15-30 ºC and indoor-outdoor temperature differences of around 0-5 ºC.

## SDEWES2021.0169

# Hope and Reality of Renewable Energies in Rural Areas

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## Abstract

La conciencia actual del cambio climático y sus consecuencias ha motivado a diferentes organismos internacionales y nacionales a alcanzar un desarrollo sostenible como sus objetivos fundamentales. Para lograrlo, se deben reducir las emisiones de gases de efecto invernadero, lo que se asocia implícitamente a un proceso de transición energética. Este proceso conlleva un incremento de las energías renovables, siendo la eólica actualmente la fuente renovable de mayor crecimiento y mayor producción de energía.

Las zonas rurales, por sus condiciones naturales y su relativa abundancia de fuentes de energía renovable, atraen una proporción significativa de estas instalaciones. Además, el desarrollo de las energías renovables ha sido reconocido explícitamente como un instrumento clave para apoyar las economías rurales a través de la creación de empleo, la revitalización de sus sistemas productivos y la transformación hacia industrias más sostenibles, nuevos ingresos para propietarios, productores y administraciones locales. Sin embargo, la instalación de energías renovables tiene, a corto y largo plazo, diferentes impactos en el territorio donde se ubican.

En este contexto, se exploran los efectos económicos, demográficos y laborales de las instalaciones eólicas en una región española, en concreto, en la comarca del Campo de Belchite (Aragón), que se utiliza como caso de estudio por su representatividad.

Desde el punto de vista metodológico, se aborda un análisis cualitativo con base en encuestas a diferentes grupos de actores de la región. Estos resultados permiten evaluar, desde el punto de vista de la ciudadanía, los efectos socioeconómicos y las expectativas de las energías renovables, en el presente, pasado y futuro. Los hallazgos muestran una gran heterogeneidad entre agentes y territorios, tanto en la evaluación de impactos como en sus expectativas. El modelo de gestión juega un papel fundamental para lograr su aceptación social. Este trabajo aporta conocimientos sobre políticas industriales y energéticas que exigen modelos de gestión más descentralizados, participativos y transparentes.

## SDEWES2021.0196

# Competition in the Heat Market: District Heating System as the Infrastructure for Competition Among Producers

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## Abstract

This paper aims to analyse the introduction of competition in district heating and its implications on price development. The study builds on a theoretical discussion of different approaches to competition and lessons learned in the energy sector, particularly the electricity market. The paper describes the differences of conceptual frameworks and quantitative outcomes of the district heat markets in selected European Union Member States and discusses the consequences of the different approaches. The paper also considers the possible impacts on consumer prices relative to the market opening to competition among heat producers. An important conclusion is that introduction of the third-party access on the supply-side coupled with a one-side auction may have positive effects on consumer price developments. Finally, we provide suggestive insights for a European policy concerning the initial steps for the future development of district heating markets.

## SDEWES2021.0389

# Estimating the Marginal Cost of Renewable Energy Certificates in South Korea

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## Abstract

Many countries have introduced the Renewable Portfolio Standards (RPS) with the market systems that allow transactions of the relevant Renewable Energy Certificates (RECs) in order to foster the installation of renewable energy. In this system, the reliable prediction of long-term RECs price plays a vital role in market participants' and policymakers' decision-making. This study focuses on the estimation of the long-term RECs prices based on the marginal pricing approach that leads to the social optimum. There exist several research results to find the marginal cost of RECs, but most of them have not clearly considered the relationship between the wholesale electricity market and the REC market. However, since the electricity market and the REC market are tightly interrelated in the modern electricity market with a high share of renewable energy, the two markets should be dealt with simultaneously in one mathematical formulation. In the proposed method, the mathematical model was constructed as bi-level optimization problem where the upper level problem considers the REC market while the lower level problem considers the electricity market. The proposed bi-level optimization problem is further transformed into a single-level mixed-integer linear programming model using the Karush-Kuhn-Tucker (KKT) conditions to improve the converge. The proposed method allows us to: (1) determine the optimal capacity of renewable energy to implement the RPS system; (2) derive the marginal costs of RECs and electricity simultaneously; and (3) perform quantitative analyses on the RPS system. The simulation studies performed on the actual large-scale Korean electricity market. The optimization results indicated that the solar PV accounts for the most considerable portion of the cost-optimal mix in South Korea from 2021 to 2030, and the marginal cost of RECs (in 2020 constant dollars) was estimated to gradually decrease from 35.71 USD/REC in 2021 to 25.88 USD/REC in 2030.

## SDEWES2021.0863

# Prospective Scenarios for Madagascar's Electrification by 2050: Discussing Energy Policy Framework

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## Abstract

An increase in energy production characterizes socio-economic development. However, in Madagascar, where most of the population lives below the poverty line, the electrification rate is only 20%. Recent studies on renewable sources of energy in Madagascar propose the energy transition as a solution to increase this electrification rate. Therefore, the country's new energy policy faces two challenges: increasing the electrification rate while ensuring the energy transition. To give more insights on the strategies to be adopted, this work aims to analyze a holistic view of the optimal energy transition pathways for Madagascar until 2050. This work assessed and discussed the techno-economic and environmental implications due to the projected evolution of the electricity sector.

According to four different scenarios, the Reference Energy System (RES) of the Madagascar electricity sector has been defined and implemented in a LEAP-OSeMOSYS model. The Business as Usual scenario (BAU) represents the current trend in the evolution of the energy mix. The NPE scenario (NPE) replicates the national energy policy. The NPE modified (NPE-m) and the "Use of fuels" (UoF) scenarios are based on the NPE but adapted to the possible evolution of the socio-economic context and current Madagascar's energy potential. Indicatively, the NPE-m scenario has a production cost of $0.052 / kWh and an emission factor of 27.3 g $CO_2$eq / kWh for a fully renewable system by 2050 with 75% hydroelectric plants 10% wind turbines, 10% solar energy, and 5% biomass. Between 2025 and 2040, the UoF scenario has an environmental cost of about three times higher than the other scenarios. However, it allows meeting demand with a lower investment cost before starting the energy transition. So, the comparison of the different scenarios shows that for a developing country like Madagascar, the transition to a 100% renewable system must go through intermediate steps: (1) Firstly, satisfy demand and ensure access to electricity to support economic development. (2) Initiate the energy transition while optimizing production costs. (3) Continue the transition to a 100% renewable system.

## SDEWES2021.0886

# A Long-Run Perspective on World Energy Demand: Risk and Sustainability Implications

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## Abstract

The objective of this research is to design a model to project - forecast and simulate - aggregated world energy demand at distant horizons in time. This is done by statistically estimating a simplified structural and interrelated model for the three variables, energy demand and supply, total world population, and global income. Standard available simulation models used to forecast energy demand rely almost always on ad-hoc forecasts of population and income, and from there derive energy demand with complex and detailed models of economic behaviour. This procedure is subject to several uncertainties and based on too many prior assumptions. Alternatively, a rigorously statistical estimated model for the three key variables may provide a better insight. These results can be used as a yardstick to assess the likelihood of the assumptions commonly made in standard published roadmaps for the transition to a low carbon society.

The model is based on long historical series starting in 1850, available from renowned researchers in their respective fields. Several estimation procedures considering shorter/longer periods, and other techniques are conducted. The models estimated allow a forecast of future energy demand, as well as a risk analysis derived from the inherent statistical uncertainty, properly quantified in the estimation procedure. Several alternative solutions and simulations methods are implemented to support the robustness of the results derived.

The results of key roadmaps put forward in the literature by relevant international institutions are assessed against those produced by the estimated models. The general conclusion is that the aforementioned roadmaps assume huge efficiency savings never observed in history before. Even more, accounting for uncertainty this discrepancy becomes significantly higher. The paper also discusses possible future sources of breaks in current trends and patterns in energy demand, both increasing and decreasing.

The results reported allow an estimation of future required availability of renewable energy and related supplies in a low carbon society - raw materials, available arable land, rare earths, etc. These results and the related discussion show that although it may be possible to reduce energy consumption significantly, this will require an active political stance to accelerate efficiency savings and lifestyle changes

One important implication is that the unbounded income-growth paradigm, including the green-growth proposal, may not be feasible, and should be replaced by other targets as suggested by the prosperity approach and related measures.

## SDEWES2021.0972

# A Common and Coherent Transformation? Comparison of Policy Approaches for the German Bioeconomy

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## Abstract

Transforming towards sustainable development constitutes an enormous governance challenge, as the necessary changes cut across multiple sectors and levels of decision-making. In the case of the bioeconomy, a sustainability strategy built on the use of biomass in place of fossil resources, the political debate has been strongly driven by EU and OECD research and innovation policies. However, since local, context-specific approaches are expected to play a central role for realizing sustainability, identifying and comparing the different policy options proposed by various actors is a key task. In this paper, an analytical framework for analysing policy suggestions within the broader context of the policy debate is developed based on discourse and network analysis, and tested for the case of the strategic policy debate about a bioeconomy transformation in Germany. Objective is to determine the coherence of transformation policies, by identifying potential gaps and conflicts between the framing of measures by different policy actors.

## Energy policy 2

### SDEWES2021.0173

# A Just and Clean Energy Transition: Resilience and Competitiveness of the European Regions

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## Abstract

The increasing political and social pressure in the fight against climate change and its consequences have led to the need for a change in the current energy model, a process of decarbonization of developed economies. In order to meet the environmental objectives proposed by national and international organizations in most countries, the development of renewable energies plays a fundamental role. Environmental objectives must be linked to economic and social objectives, in order to achieve an energy transition process that is fair to the territories and places where these processes take place.

The infrastructures associated with renewable energies cause a series of socio-economic and environmental impacts and externalities on the territory, which can be both positive and negative. In this context, the main objective of this work is to evaluate the impacts, retrospectively, that renewable energy facilities have on the territory, in the short and long term in these different areas. For this purpose, we will identify those European regions (NUTS 2 level of disaggregation) with the highest installed power (megawatts) of renewable energies, evaluating the socioeconomic effects that these installations have had on them.

From the methodological point of view, the synthetic control method is applied to all those selected European regions, in order to try to characterize in the best possible way the compatibility of economic, social and environmental objectives; as well as to analyze similarities and differences between their observed results. It is identified that not all types of renewable energy sources have the same effects on economic activity and employment, as well as the key role of local policy.

## SDEWES2021.0415

# Decarbonising Italian Gas Network: Possible Scenarios for Green Hydrogen for 2030-2050

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## Abstract

Decarbonization is one of the most crucial dilemmas in the research field of our era. One of the most promising solutions, because of its flexibility as an energy vector, is green hydrogen. EU Commission has already defined its hydrogen roadmap for 2050 and several EU countries, like Italy, Germany, and France have also developed the national ones. In the Italian roadmap, with 10B € investment, it is foreseen that by 2030, hydrogen will satisfy 2% of the total energy demand and deployed 5GW electrolyzers. A favourable advantage of using hydrogen is that is possible to use the existing natural gas network for its storage and transport, where the hydrogen is blended with the natural gas (blend ratios up to $20\%_{vol}$ are being currently analysed). Because of its extensive natural gas network (more than 34 000 km of pipelines). Italy results as a major potential deployer for this solution. This paper presents an analysis – from an energy planning perspective – of the impact on the energy matrix of the injection of hydrogen at different blending ratios (5/10/15/20%vol) in the national natural gas network under different scenarios. The analysis is based on real yearly gas transport operation data – aggregated in daily resolution – provided by the national natural gas grid TSO, both for the internal and cross-border interconnection nodes, considering the effects of $H_2$ blending ratio on the transported gas quality (e.g., density, calorific value, Wobbe index). The overall energy balance implications of each scenario are analysed as a consequence of the required electrolysis capacity and renewable power and energy dedicated to hydrogen conversion. The impact of each scenario is assessed by overall parameters such as hydrogen cost, injected hydrogen.

## SDEWES2021.0582

# Extending the Capabilities of Energy Signature Modelling – Lessons Learned from a Case Study

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## Abstract

In building refurbishment projects, efficient technologies such as heat pumps are increasingly being used as a substitute for conventional technologies such as condensing boilers, with the aim of reducing carbon emissions and determining operational energy and cost savings. Measured building performance, however, often reveals a significant gap between the predicted energy use (design stage) and actual energy use (operation stage). For this reason, we present in this paper a scalable energy signature modelling approach to verify building energy performance from measured data. Regression models are built with data at multiple temporal resolutions (monthly, daily, and hourly) and are used to verify the performance improvement due to smart heating controllers and Gas Absorption Heat Pumps (GAHP). The case study chosen is Hale Court sheltered housing, located in the city of Portsmouth (UK). This building has been used for the field-testing of these innovative technologies within the EU Horizon 2020 project THERMOSS. The results obtained are used to illustrate possible extensions of the use of energy signature modelling, highlighting implications for energy management and innovative building technologie

## SDEWES2021.0611

# Comprehensive Analysis of the Energy Legislative Framework of Kyrgyzstan: Investigation to Develop a Roadmap of Kyrgyz Renewable Energy Sector

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## Abstract

Kyrgyzstan – a Central Asian country – faces a high degree of energy insecurity. Especially the Kyrgyz power sector suffers from outdated infrastructure and is not capable to fulfil the growing and fluctuated inter-seasonal energy demand. Because of the long and harsh winter (-25 to -30 °C in the mountainous areas), the majority of the urban population practice electricity-based house heating system. This increases the burden on the power sector and turns out to persistent power shortages / outages. Hence, the current electricity access is neither reliable nor affordable, especially for rural people because of their low-income. Therefore, rural population directly depends on the environment and uses solid fuels (coal, cow-dung, firewood) operated traditional heating stoves for house heating. The high reliance on natural resources turns out as serious indoor and outdoor air pollution. Besides, the over usage of firewood leads to a negative impact on the riparian forests in Kyrgyzstan. Because of the high dependency on the environment, Kyrgyzstan is most vulnerable to climate change in Central Asia.

On the contrary, the country is endowed with an abundant amount of renewable energies (RE) which can significantly contribute to bringing stability to the energy sector. For example, the solar potential of Kyrgyzstan is 60 % higher than Germany. However, even with the existing RE potential, the actual employment of renewable energy sources across Kyrgyzstan remains very low or limited.

The current energy policy is considered as one of the key barriers to develop the RE sector in Kyrgyzstan. Because of the low Feed-in-tariff (FIT) provision for all RE sources (0.029 €/kWh), investors are not motivated enough to invest in the RE sector. Hence, there is an immediate need to assess the formulated energy policy to investigate gaps and uncertainties. However, scant research and investigation for this topic couldn't provide a detailed illustration of the existing energy policies.

In response to that, the presented study portrays an in-depth assessment of the current energy legislative framework of Kyrgyzstan. It determines the basic mechanisms for the operation and conduction of RE sources in terms of legal and economic aspects. Furthermore, it provides detailed insight into the current FIT calculation methodology and scrutinizes the special provisions for private investors who want to invest in the RE sector. The article recapitulates the detailed assessment of energy insecurity in Kyrgyzstan, the current status and challenges for the Kyrgyz RE sector in connection with the existing energy policies. Furthermore, the article articulates the suggestions for the policymakers to open the door for private investors in the RE sector.

## SDEWES2021.0898

# Diving Towards a Complete Decarbonisation of the Spanish Energy System from a Top-Down Viewpoint and Data Analysis

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## Abstract

Several countries have recently published their respective national plans of energy and climate to having an economy partially decarbonized in 2030, leading the worldwide task of climate change mitigation towards a net zero-carbon economy by 2050. In the Spanish report, the objective scenario expects to achieve a renewable share in the power system as much as 74%. This research aims to contribute in the discussion by providing a detailed method based on data analysis helped by an energy model.

Data collection has allowed an excellent representation of the Spanish energy system structure for the reference year of calibration, 2017. Inputs of the EnergyPLAN model have been properly connected with national final energy balance (FEBs) to expand the analysis further, getting hourly results and a transparent set of policies for the two reference years. The role of hydrogen and power-to-heat technologies managing variable renewable energies, as well as complete decommission of nuclear and fossil fuels units have been included and discussed. Furthermore, top-down viewpoint of the method aims to define a feasible framework to work in future connections with Integrated Assessment Models (IAMs).

Results evince positive conclusions regarding renewables. Commitment of 74% is fulfilled facing 2030, and Spanish economy could run with a 100% renewable energy system by 2050. Respect to 2017, fifteen and five times more installed capacity of solar-PV and wind onshore by 2050, respectively, would be required to achieve the desired target. Discussion addresses the biomass potential of this region. Limitations of the method and further work are esteemed throughout discussion and conclusions.

## SDEWES2021.0981

# Energy Justice Conceptual Framework for Technology Assessment

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## Abstract

Energy policies and mitigation actions usually focus on the operation of technologies within countries' boundaries. Nevertheless, low-carbon technologies' impacts are spread across lifecycles in globalized supply chains. Based on an exploratory review of academic and non-academic works, this work investigates how electric vehicles (EVs) relate to the achievement of SDGs and identifies associated injustices, synergies, and trade-offs from resource extraction to disposal. Additionally, a conceptual framework for technology assessment and mitigation of resulting negative impacts is also presented. Among the conclusions, it was perceived that EVs can produce high distributional injustices across the North-South divide. Its utilization might exclude poor as well as remote and rural communities given upfront costs and infrastructural issues. EVs have potential negative social, environmental, and economic impacts at local and global scales, which have to be mitigated for an inclusive and sustainable energy transition.

## Energy system analysis 1

## SDEWES2021.0104

# An Interdisciplinary Approach of a Local Peer-to-Peer Energy Trading Model for a More Sustainable Power Grid

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## Abstract

The effects of climate change poses numerous challenges for our existing energy infrastructure. A direct effect of this is a decentralization of energy production. In such decentralized networks a distinction is made between consumers and prosumers, where the latter produce and consume energy in contrast to the consumers. However, it is currently the case that most energy suppliers offer a much lower feed-in tariff compared to the energy purchase price. Subsequently, prosumers are force to optimize their self-consumption due to economic considerations as well as to limit the size of their photovoltaic (PV) system suiting optimally the self-consumption need. To increase the overall decentralized electricity production it is necessary to introduce new energy billing models such that PV-systems optimally use the available roof spaces. These models stimulate the transition of a consumer to a prosumer.

In this work, we present a computational study, i.e., a so-called mixed integer linear program, of an exemplary local energy market enabling to analyze the drivers and obstacles behind the transformation of a centralized energy system into a decentralized one. Despite economic considerations, it is important to take the social acceptance of such peer-to-peer energy trading models into account. Therefore, we evaluated the acceptance of the proposed solution via surveys illustrating the different aspects of a transformation from consumer to prosumer.

The proposed optimization model is used to obtain the operation state with the minimum costs for the prosumers and consumers. The pricing in the presented exemplary local electricity market is based on the spatial distance between consumer and prosumer. The further away a consumer is located from a prosumer the higher the electricity price. The market model is extended by additional constraints modelling investment decisions for energy storage systems and PV-systems.

Our simulation results show that the incentives for a prosumer are significantly increased by the proposed market model. At the same time, the charging scheme ensures that local energy production is only profitable up to a certain maximum amount. Based on the simulation data, it can be concluded that the pricing structure promotes the installation of additional PV-systems. In addition, the expansion of storage capacities was also examined. The conducted survey revealed that about 45 percent of those questioned want to purchase a PV-system or already own one.

## SDEWES2021.0195

# Agriculture in the Context of Economy Decarbonisation Modelling

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## Abstract

The climate crisis is the most crucial challenge worldwide. The European Commission has recently raised an initiative to reduce GHG emissions by 55% in 2030 compared to 1990 and to reach carbon neutrality by 2050. Such emission reduction requires a concerted effort by different sectors of the economy at EU, and national level. To develop a balanced least-cost GHG reduction strategy, a system of mathematical models designed to analyse this problem and covering all economic sectors is being developed in Lithuania. To facilitate models' interoperability, the principles of decarbonisation modelling for all sectors are based on those applied to the analysis of the energy sector. This paper will focus on the decarbonisation model of the agricultural sector, which is responsible for around 21% of GHG emissions in Lithuania.

In the mathematical model, agricultural processes are represented by technologies with multiple inputs and multiple outputs. This allows the representation of crop production technologies differing in tillage, fertilization intensity, pesticide use, production yield, and GHG emissions. For example, a distinction can be made between different intensities of conventional and ploughless soil management. For each of them, the tillage method, the scope and consistency of the use of fertilizers and pesticides are defined. The cultivation of crops using different crop rotations or growing crops on different soils is represented by different technologies. In the mathematical model, GHG emissions through emission factors are related to the consumption of fertilizers and fuel or energy for tillage, harvesting, and crop care. Similar technologies, representing the cultivation of different crops, together with the assessment of the land balance (land needs for other purposes), raising livestock, import/export of agricultural products, etc. form possible food and feed supply chains. In modelling, optimal chains are selected that ensure exogenously given demand for food products, result in the lowest GHG emissions and contribute to energy supply in form of energy crops or agricultural waste for energy production.

The paper will present a modelling approach for the analysis of decarbonisation in the agricultural sector, discuss the data used, the obtained results, linkage to other sectoral models.

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## SDEWES2021.0235

# Modelling Transport Sector in Energy Planning Model: a Part of Multi-Sectoral Approach for Modelling the Decarbonization of Lithuania

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## Abstract

In Green Deal, the European Union has set a target to decarbonize the economy by 2050. Therefore, each Member State has to research possible pathways on how it can contribute to a common goal. In the course of an ongoing project funded by the Research Council of Lithuania, we are developing a methodology for exploring how to decarbonize the economy of Lithuania in the least cost way, using a multi-sectoral energy planning model. Decarbonization model consists of 6 joined models, representing different economic sectors. This paper describes the developed modelling approach for the transport sector.

Even though a developed modelling approach for the transport sector was created for Lithuania, the same approach can be applied to most of the countries. It includes road, rail, airborne and naval transportation modes, with a particular focus on road transport as emissions in it are the greatest. The model is based on total discounted cost minimization. It looks for the least-cost way to satisfy exogenously set short and long-distance travel as well as freight delivery demands within set emission and other constraints. To satisfy travel demands, the model can choose a combination of vehicles from more than 300 options modelled based on type, fuel, build year and car class. Road vehicles were differentiated by age groups and cars also by class to represent fuel consumption and subsequent emissions better. The model includes the blending of conventional fuels with biofuels as an emission reduction measure. To account for travel behavioural aspects and to allow modal shift, additional constraints including travel time budget, were implemented. Additionally, since Lithuania is a small country that has a vast foreign used car market, most first-time registered cars in Lithuania are pre-owned from foreign markets. In order to evaluate this peculiarity vehicle fleet was constrained to match the actual vehicle age distributions. This paper contains the modelling results of a standalone version of the transport model applied to the Lithuanian case, with an aim to reduce transport $CO_2$ emissions by 90% till 2050.

A transport modelling approach was developed within MESSAGE modelling software. However, with minor modifications, it can be applied to other energy planning models, created in different software, like TIMES.

Acknowledgement: The ongoing project has received funding from the Research Council of Lithuania, agreement No. S-MIP-19-36.

## SDEWES2021.0577

# Technical, Economic and Ecological Effects of Lowering Temperatures in the Moscow District Heating System

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## Abstract

This work focuses on evaluating the technical, economic and ecological effects of the transition from the current high temperature charts to the lower temperature charts in the Moscow DHS by means of a developed spreadsheet-based model. A methodology suitable for assessing results of potential transition to lower temperatures in DHS of cities in Russia and worldwide is proposed and implemented in the model. The reference case of 2016 and three cases with decreased heat demand in buildings by 5, 10, and 20 % were considered. The results show that fuel savings of 678-872 ktce/a can be achieved with respect to the current temperature charts in the Moscow DHS. The 110/50 °C temperature chart is the most profitable option, with net present values varying from 4.64 to 10.74 bn RUB depending on the case. The 95/50 °C chart, which leads to a reduction of 1.325-1.387 Mt CO2/a, has the least impact on the environment. A more significant $CO_2$ emissions reduction can be achieved by strong energy-saving measures and broad utilization of renewable and waste energy. The essential prerequisite for the transition is a reduction of the heat demand in buildings by at least 20 %.

## SDEWES2021.0631

# Hydrogen for the Decarbonization of Maritime Sector: Feasibility Analysis of On-Board Power-Train System Based on Pemfc Technology

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## Abstract

Maritime transport is one of the largest greenhouse gas (GHG) emitting sectors of the global economy, responsible for around 1 Gt of $CO_{2eq}$ every year. The International Maritime Organization (IMO) has adopted a strategy to reduce greenhouse gas (GHG) emissions from international shipping >50% by 2050, compared to 2008's emissions. To comply with the new standards, the maritime sector hinges on the deployment of low- and zero-carbon fuels and innovative propulsion technologies. On-board fuel cell powertrains run on renewably sourced hydrogen can play a crucial role due to their low criteria pollutant and GHG emission.

In this paper, we perform a techno-economic feasibility analysis to replace the conventional diesel engine powertrain of a tanker chemical ship with an innovative system based on polymer electrolyte membrane fuel cell (PEMFC) technology. The ship is characterized by a typical route of 2,856 nm, performed at an average speed of 11.8 kts, with a carrying capacity of about 50000 Dead Weight Tonnage. The tanker's powertrain features an 8.3 MW diesel engine and an auxiliary power system of 2.8 MW to be used only during docking and in-port operation. We sized the PEMFC powertrain at the same maximum power output as the main reference diesel engine and, thanks to the modular nature of fuel cells and their flexible performance at partial load, we verified the possibility of eliminating the auxiliary engines. Given these design choices and knowing the fuel cell off-design performance data, we calculated the hydrogen consumption of the new powertrain. We considered three on-board hydrogen storage technologies: i) compressed hydrogen; ii) liquefied hydrogen, and iii) metal hydrides. A final comparison of the gravimetric (kWh $kg^{-1}$) and volumetric (kWh $m^{-3}$) energy densities of these storage technologies allows identifying the best solution for the ship's weight and space requirements.

Results highlight that a cargo reduction is necessary to fit the storage system compared to the space available in the reference ship. In particular, the cargo should be reduced by 1.3%-1.1% for compressed hydrogen (350 bar and 700 bar, respectively), 0.3% for liquefied hydrogen and 9% for metal hydrides, respectively.

Finally, we carried out an economic assessment estimating CAPEX and OPEX for each $H_2$ storage technology and by evaluating the specific breakeven cost with respect to the diesel-based system, considering the economic incentives per ton of $CO_2$ avoided.

## SDEWES2021.0640

# Simulation of a Prototypal Micro-Orc for Residential Application When Driven by Solar Source

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## Abstract

The improvement of Organic Rankine Cycle (ORC) technology can bring significant advantages in terms of consumption in both industrial and residential areas. ORC systems not only can recover part of the waste heat released by numerous industrial processes, but they can also be used to convert the energy available from renewable heat sources (i.e., solar, geothermal and biomass) into electric energy, ensuring a decrease in the consumption of fossil fuels and, therefore, a reduction of greenhouse gases emissions. Even though the ORC technology for medium and large size applications is quite established on the market, small size ORC systems are still under development, due to their promising great potential. The purpose of this study is to estimate the electric energy production that would be obtained by coupling a prototypal micro-ORC with a solar collector, with the aim to satisfy the electricity demand of a single-family user, during a typical yearly operation. With this purpose, a detailed semi-empirical steady-state model, calibrated and validated against experimental data, based on a lumped parameters approach, is employed for the power plant modelling. A parametric analysis was performed by varying different design parameters and boundary conditions. Then, a comparison between the performance estimated by using R134a and its low global warming potential (GWP) alternatives, as working fluid, was carried out: results show a penalization in electricity production with low-GWP fluids, despite the environmental benefit.

## SDEWES2021.1079

# Modeling Hydropower to Assess its Contribution to Flexibility Services in the Bolivian Power System

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## Abstract

Bolivia has important hydroelectric potential that can guarantee an energy supply even when the large gas reserves are depleted, this potential is due to the topographic characteristics of the country and that there are two large hydrological systems, the Amazon and La Plata basin, with a power of 34,208.50 (MW) and 5,359.90 (MW) respectively. Hydropower has been increasing in the Bolivian territory in recent years and with expansion plans in the future to guarantee energy sovereignty, the industrial development in Bolivia and the export of electrical energy.

Bolivia's power plant system has a 33 % share of hydraulic component, a 61% share of thermal component, and the rest of other renewable energy sources. Such a composition makes the system vulnerable to hydrological that can affect production costs and flexibility of the energy system. Therefore, this study aims to assess the effects of different rainfall years on the ability of hydropower to generate and store electricity in a Bolivian energy system. This is done using the hourly power system simulation software Dispa-SET developed by the European Commission. For the application of the methodology, the Dispa-Set Bolivia model is taken as a basis.

For this study the hydroelectric systems are disaggregated by hydro unit plants, this variation makes it possible to include the flows of sub-basins in run-of-the-river plants. As for the information on water inputs for different years, it is obtained from the Surface Water Balance of Bolivia 2017, which uses the Soil Moisture method (rainfall-runoff) through software Water Evaluation and Planning (WEAP), for a period from 1980 to 2016. All the information is added to the Dispa-Set model which is configured for long-term optimization, this makes the effects of seasonal variation of water inflows included in the simulation. Modeling has allowed to obtain a broad vision of different scenarios, where main results show that heavy rainfall years affect the electricity production of hydro plants by having an impact on the flexibility hydropower can provide to the system. This results in changes on the average production costs, which is quantified by differences in terms of electricity production of hydropower plants.

## Energy system analysis 2

## SDEWES2021.0656

# Electric and Thermal Energy Communities Comparison Assessment: a Case Study in a Mediterranean District

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## Abstract

Energy communities play a key role to move towards a decentralized production and consumption system with renewables energy, as they offer new opportunities for citizens to actively participate in the energy transition. However, energy communities are mostly referred to photovoltaic energy communities. This research work compares throughout simulations with georeferenced models the performance of photovoltaic energy communities and heat energy communities over a real district in the city of València, Spain. The results show higher emissions savings and economic savings (up to 92.5% and 78.6%, respectively) for the heat energy communities. The main limitation to implement the PV energy communities in urban areas is due to the reduced available space without shadows on the rooftops and its consequent reduced electricity production, which covers an average of 14.2% of the electrical demand of the dwellings.

## SDEWES2021.0666

# Planning Possitive Energy Districts in Meditarrean Cities, Methodology and Approach to València, Spain

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## Abstract

Cities consume two-thirds of the energy supply, and 70% of $CO_2$ emissions come from urban environments. Positive Energy Districts (PEDs) are seen as innovative strategies to reach energy and climate neutrality in cities. PEDs are regions or neighbourhoods with a positive annual energy balance, achieved mainly through energy efficiency and energy generation from renewables.

Given its novelty and lack of previous methodologies, this work aims to provide a methodology that has been developed to design PEDs in Mediterranean cities. Thus, aiming to easily replicate this ambitious planning action.

The first step is to set the project definition, which requires three sorts of studies: background, past performance, and available local renewable resources studies. Firstly, the background is studied and a complete understanding is achieved of the district, its necessities, and their likely evolution. Second, an energy audit is conducted to assess the past and current energy performance of the district. Thirdly, opportunities for energy efficiency improvement and the availability of local renewable energy resources are studied. Furthermore, the alternative technologies are assessed, and their features: mainly maturity and costs. Then, the potential savings or energy production is obtained for the selected technologies. Once this information is known, and after carrying out a SWOT analysis and defining the objectives, the proposed actions are set out.

These proposals lead to the creation of strategic scenarios that will be simulated and compared with each other. Besides, a sensitivity analysis is carried out to assess the influence of possible changes on different aspects. Finally, a Multicriteria Decision Making process with the different scenarios and criteria is performed to select the most suitable strategy. The methodology is applied to the case study of “La Marina de Valencia”, a Mediterranean city’s waterfront and business area.

## SDEWES2021.0733

# A Deep Learning Prediction Module for the Iot System Energysaver for Monitoring and Estimating Power Consumption

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## Abstract

Energy consumption and energy efficiency are topics that have attracted attention of researchers in the last years, seeking solutions for sustainability and reduction of costs. Thus, one of the alternatives is the usage of IoT and Deep Learning technologies, which are the base of the EnergySaver framework. This framework aims monitoring of electricity consumption, from data capture to the estimation of consumption. The development of the EnergySaver, included open source technologies applied to IoT, embedded systems and Long Short-Term Memory (LSTM) Neural Networks. The components used for the framework development enable its usage as much for the data capturing of individualized equipments (using sensors, Raspberry Pi and Arduino), as for electric measurement instruments and equipments. The system works in the following way: captured consumption data are sent via MQTT protocol (through a Mosquitto broker) to a Flask server, its stored in a MongoDB database and, its shown in real time in a webpage. The data is used for training, test and estimate by LSTM network. We obtained 256,092 records of electricity consumption from January to August 2019. And an LSTM neural network predicted the last month of the time series. These data were collected from a building belonging to West of Pará Federal University (UFOPA) located in the city of Santarém, Pará state, Brazil, in the lower Amazon region. The results obtained by LSTM network were evaluated and after 10 (ten) LSTM network model executions. The time series prediction obtained RMSE = 0.041, MSE = 0.0017, and MAE = 0.0263 averages. It was noticed that the network proposed model learned with training data and, when applied in the tests, the estimates were close to the real value. Thereby, the system was implemented and validated from experiments showing estimate precise results, applicable to Energy Efficiency, considering that the system, from estimate performed by LSTM network, can direct users actions to promote energy economy.

## SDEWES2021.0741

# Participation of a PV Power Plant to the Italian Ancillary Service Market via a Hydrogen-Based Power-to-Power System: Economic Impact of Secondary Frequency Reserve Provision

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## Abstract

This work investigates the economic profitability of Secondary Frequency Reserve (SFR) ancillary service provision to the Italian electric grid through energy storage systems. The operation of a hydrogen-based Power-to-Power system, designed to supply a constant uninterruptible 1 $MW_{el}$ load with locally generated electricity by a solar PV field, is studied when acting on both the Day-Ahead Market (DAM) and the Ancillary Service Market (ASM). Considering historical time series of PV generation, electricity prices on the DAM, and price-quantity combinations of accepted offers on the ASM, a mixed-integer linear optimization problem is set up that minimizes the annual average cost of electricity to the load. Provision of SFR services with an optimal bidding strategy allows the average cost of electricity to decrease by about 15% with respect to the operation on the DAM only.

## SDEWES2021.0751

# Sector Coupling and Flexibility Solutions in the Italian National Energy Systems with 100% RES Supply to Power and Mobility

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## Abstract

The pressure on decarbonizing the energy system is increasing worldwide and moving into the goal of net-zero carbon economy, such as proposed in California for 2045 or stated by the EU Green Deal plan for 2050. Although most countries recognize the need for a substantial transformation of exploited energy sources, adopted conversion methods, and final uses, the actual achievements and the implementation of adequate measures are still slow, as many intergovernmental studies report, such as the 'Stated Policies Scenario' by the IEA.

Moving beyond scenario analyses that assess the planned system evolution, this work aims to identify the long-term required system structure (in terms of power generation capacity, storage capacity, and sector integration options) to achieve a very highly or fully decarbonized energy system. The required RES and storage capacities appear to be extremely high in most cases (e.g., for PV close or above 10x with respect to the current installations), but in general positively affected by sector integration and energy vector multiplicity. The analysis adopts a multi-node energy balance model to simulate the national energy system year-long behavior, with hourly time resolution and spatial aggregation by market zones. The model considers power generation from different sources, power demand from regular and new users, and mobility demand for energy vectors, as well as exchange of energy vectors from abroad. Energy storage, hydrogen, and green gas are essential to decouple generation and consumption, which can occur via Power-to-Hydrogen, battery storage systems, smart charging of electric vehicles, and vehicle-to-grid.

The 100%-RES Italian scenario is investigated, considering the long-term evolution of the power and transport sectors in terms of expected demand, with and without heavy-duty vehicles. Results show the massive need of over 300 GWp of PV capacity when the installation of wind capacity is limited to the estimated techno-economic potential of 60 GW. Then, the further limitation of PV installed capacities to the estimated techno-economic potential of 230 GWp of PV (buildings + residual or abandoned areas) leads to significant import requirements. The options of low-cost hydrogen from Africa or nuclear electricity from France are compared, while the vehicles' stock switches between mostly electric- and largely hydrogen-based.

## SDEWES2021.0817

# Transient Thermal Modeling of Aluminum Cells for Renewable Energy Integration

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## Abstract

Aluminum is the most abundant metal on the earth's crust. Aluminum is extensively used in construction, aerospace, marine, rail and primarily the automotive industry. However, the production of aluminum is highly energy intensive. Aluminum production accounts for 3.38% of the world's electricity demand. Some of the biggest aluminum production plants worldwide are located along the solar belt. On one hand, due to wide availability of oil and gas resources in some of the solar belt regions, and the need of a tight temperature control of the aluminum cells, constant power operation with gas turbines has been preferred. On the other hand, in countries like the UAE, solar energy plants have been tendered with record low prices of 0.24 $/kWh, making solar energy competitive with fossil fuel sources. Furthermore, the installed solar capacity is rapidly growing. There is a strong incentive to integrate renewable energy in aluminum smelting in the sunbelt smelters. The purpose of this research is to develop the methodology to find the possible power modulation to existing smelters to integrate renewable energy. The methodology comprises the calculation of the extended operating window of an aluminum cell using commercial technologies and the development of a thermal-electric finite element model (FEM) of the aluminum cell to simulate the thermal response of the aluminum cell under variable power input. To achieve the research objective, firstly, a thermodynamic model of an aluminum cell was developed and a review of the operating limits of an aluminum cell was conducted. Secondly, a thermal-electric FEM of an industrial aluminum cell was constructed to determine the necessary heat transfer coefficients to enable the power modulation of the aluminum cell. The FEM was built upon an industrially validated thermal-structural model of an aluminum cell. It was found that using a commercial heat exchanger can allow a power modulation between -14.5% and +8.6% from the nominal power. The finite element model is being concluded to determine the necessary performance of a heat exchanger to enable wider modulation keeping the aluminum cell thermal balance. This research contributes to fill the gap in the study of power modulation to accommodate variable renewable energy sources in aluminum production by quantifying the benefits of switching to a power modulation operation and estimating the requirements of the heat exchangers needed to achieve this transition.

## SDEWES2021.1084

# Data Centers Cooling: On-Site Integration for Smart Energy System

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## Abstract

It is estimated that data centres consume between 2% to 4% of the total electricity consumption worldwide. Around half of this consumption is used for the cooling of data centres. As data centres continue to expand rapidly, increasing cooling efficiency presents a significant hurdle towards their sustainable operation. Recently, many data centres started using Aquifer Thermal Energy Storage (ATES) technology to cool their data centres. The ATES consists of two deep boreholes, one used as hot storage and one used for cold storage. During summertime, cold is extracted from the ground to cool data centres, while during winter, storage is recharged using cold ambient air by means of free coolers. However, due to climate change, summers are becoming hotter than expected, and winters milder than anticipated. As a consequence, ATES is continuously imbalanced, and its economics is becoming infeasible. In order to counteract this occurrence, an on-site integration with heating demand was proposed in order to increase the total efficiency of the energy system. A mixed-integer optimization model was developed in order to calculate the optimal investments and operational behaviour. The model was applied for the case of medium-sized data centres located at Naviair, Danish airspace control. The results showed that two heat pumps need to be installed. The project's payback period was calculated to be 6.51 years, and the internal rate of return was 13%. Initial gas consumption used for heating was reduced by 76%. $CO_2$ emissions dropped from 658 to 331 tons (49.6%). The results showed that there are low-hanging fruits regarding data centres operation that are located within urban areas. However, silo-thinking is currently a significant obstacle to the broader adoption of the proposed solution.

## Energy system analysis 3

## SDEWES2021.0833

# Assessment of Waste Heat Recovery in Uae's Steel Industry

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## Abstract

A considerable portion of the energy consumed in the steel industry is rejected as waste heat from the electric arc furnace. Capturing this energy impacts the efficiency of production significantly by reducing operating costs and increasing the plant's productivity. It also presents great opportunities to increase the industry's competitiveness and sustainable operation through a reduction in emissions. This work presents an assessment of steel manufacturing in the UAE and demonstrates the potential of thermal energy storage systems (TES) in recovering heat from the high-temperature exhaust fumes of the electric arc furnace. Our investigation entails mapping the material and energy requirements of one of two-phase of the current steel production method, i.e. natural gas reforming for syngas production, direct reduction of the iron ore, and secondary refining to obtain the steel in the electric arc furnace (EAF). Analysis of an obtained EAF off-gas temperature and flow rate profiles are then used as a basis in the development of a WHR model. Simulation results from the waste heat recovery module reveal that in a period of 4 days, an output power of 2108 kW can be achieved from a continuous charge EAF. This can be harnessed and used either internally or externally in the steel manufacturing process. This is inevitably coupled with a reduction in $CO_2$ emissions, which works to actively address climate change.

## SDEWES2021.0873

# Modeling and Optimization of Sector-Coupled Energy Systems Using Milp

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## Abstract

By 2050, the EU is to become climate neutral, i.e. greenhouse gas emissions are to be reduced to net zero. Due to the necessary expansion of renewable energies (RE), the efficient coupling of electricity, heating and cooling, transport and industry sectors is gaining in importance. In the next few years, as the generation of RE continues to increase, periods of negative residual load will increasingly occur in which storage and flexibility options are necessary. For the planning, evaluation and operation of such flexible energy systems, modeling and forward-looking optimization are important.

In this presentation the modeling and optimization of an energy system consisting of a waste incineration plant, a sewage treatment plant and a district heating network using MILP (mixed integer linear programming) will be shown. As a target function variable, the $CO_2$-emissions of the overall system are to be minimized. The modeling procedure and the parameterization/validation based on real process data will be presented and issues arising, such as the consideration of nonlinearities in the model, will be explained and possible solutions discussed. In the second part of the presentation, optimization results are presented. The focus is on the question of how far the system can be operated to serve the grid. The influence of various factors, such as environmental conditions and the assumed $CO_2$-emission factor, will be shown and discussed. In operational tests at an existing waste incineration plant, it has already been shown that the optimization results can also be transferred to real operating modes.

The project results were achieved in the ELMAR project “Generation and load management in waste incineration plants as a contribution to sector coupling” is funded by the European Regional Development Fund, EFRE.NRW. The project duration is three years from June 01, 2018 to October 31, 2021.

## SDEWES2021.0900

# The Role of Wastewater Treatment Plants in Sector-Coupling and Reduction of CO2 Emissions by Flexible Operation – a Case Study

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## Abstract

Germany has recently revised Climate Change Act 2050 to reach climate neutrality by 2045 with a target of 100% renewable electricity production. The energy grids driven by solar and wind-based energy should handle the fluctuations due to varying weather conditions. Therefore, energy surpluses and deficits should be balanced by a flexible load management with storage options. Wastewater treatment plants (WWTPs), with flexible energy consumption and production processes and storage units, can play an important role for the stable operation of energy grids and further integration of renewable energy sources within the frame of energy transition.

This research focuses on the flexible operation of a WWTP with anaerobic digesters, which are additionally fed with co-substrates to improve the efficiency. The WWTP is integrated to a waste incineration plant on the same site, which burns dried sludge and biogas produced in the WWTP along with the waste, and supplies steam to the WWTP. Firstly, the energy production and consumption processes of the WWTP have been analyzed. Afterwards, an optimization model of the WWTP has been built, validated by the plant data and optimized by a Mixed Integer Linear Programming solver with a target of reduction in $CO_2$ emissions. The operation of the WWTP has been shown to be flexible in following the $CO_2$ emission factors of the electricity grid, which is possible with the utilization of the storage components and a flexible co-substrate feeding. In this paper the optimization model and the results will be presented and the role of WWTPs in flexible load management and sector-coupling will be discussed.

This research has been conducted within the "Generation and load management in waste incineration plants as a contribution to sector coupling – ELMAR" project, which is funded by the European Regional Development Fund, EFRE.NRW. The project is three year-long and will end on Oct 31, 2021.

## SDEWES2021.0902

# The Potential Role of Microwave Heating on the Decarbonisation of the Pigment Industry - a Numerical Study

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## Abstract

The high demand for thermal energy in the pigment sector may pose a problem due to the high greenhouse gas (GHG) emissions when fossil fuels are being used. It is well established in the Scientific Community that it is imperative to limit the increase in the average temperature of the planet to 2◦C, which is one of the goals defined for this century in the Paris Agreement. This will require the net balance of GHG emissions to be null or negative in 2050.

In this work, a mathematical model concerning the production of two ceramic pigments is implemented in COMSOL Multiphysics to access the feasibility of microwave technology in the industry of pigments. The aim is to develop a highly efficient method to produce ceramic pigments using microwaves and perform an efficiency analysis regarding the production process.

The mathematical model includes two couplings: one between the Maxwell's equations and the energy one, and another coupling between energy and the kinetic equation, the latter one is used to predict the chemical conversion with time. The model-fitting method was employed to extract the Arrhenius parameters and the kinetic model from experimental data from the Literature. The kinetic triplet was then used to predict the isothermal and non-isothermal conversion profiles, which were compared with the experimental data for Validation purposes.

In the 3D case, the electromagnetic efficiency is practically unitary, which further reinforces the role of microwave heating as a promising technology to increase the energy efficiency and to lower the CO2 emissions, relatively to the conventional methods. This work proves that a careful choice of the axial velocity of solids may lead to an increase in the thermal efficiency up to 40%. The highest global efficiency (54%) was obtained for a yield of 2.26 kg/h in a tube with 28 mm of radius.

The specific GHG emissions reduce with the velocity due to the increase of the global efficiency, which reinforces the importance of the velocity magnitude in the process. Moreover, in the countries where nuclear and renewable energies dominate the electricity production, the specific GHG emissions are lower. Nevertheless, for the higher velocity tested, significant reductions were obtained for all countries relatively to the conventional process, with a reduction of 98% for the case of Sweden. These conclusions show the importance of combining microwave technology with renewable sources of energy.

The high efficiencies and the electrification associated to microwave heating are the main advantages of this heating mechanism. Microwave technology, when combined with renewable sources of electricity, may be a successful strategy to reach their carbon neutrality goals. Moreover, these results can be used in the development of energy policies to make this energy intensive industry consistent with the Paris Agreement and other decarbonisation strategies.

## SDEWES2021.0916

# The Future Role of Bioenergy in the German Heat Sector Under Consideration of Consumer Choice in Energy System Optimization Modeling

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## Abstract

Biomass is the largest renewable energy contributor in the German heat sector today. However, the resource biomass is limited, and a large share of the German yearly usable potential is already exploited. The share of renewable heat options needs to increase in order to meet climate targets, but the future role of bioenergy is unclear. The aim of our investigations is to determine possible least cost system pathways towards a renewable heat supply and to determine the future role of bioenergy within these pathways. For this purpose, an energy system optimization model (ESOM) was set up for the German heat sector, optimizing the resource and technological deployment until 2050.

ESOMs are widely used to inform policy about energy transition strategies. However, consumer heterogeneity and consumer behavior that deviates from economic rationality are rarely considered in ESOMs. Especially in the heat sector, which not only from a technical view is characterized by its heterogeneity. Investment decisions by various stakeholders can be influenced by many factors that deviate from the assumption of economic rationality. In this study, for the first time, heat transition scenarios are analyzed, considering consumer choice to provide policy insights with a higher level of confidence.

First, a literature review identified survey-based empirical data on influential factors on consumer investment decisions for residential heating systems in Germany. This data was integrated into the ESOM for the German heat sector, using established methods from literature and combining them with a novel approach for calculating indirect costs, representing non-economic factors. In comparison to previous studies and sensitivity analyses, the results show that solid biomass in the form of wood chips from residues and Miscanthus is not solely distributed to (high temperature) industry applications, which would be the most cost-effective option. The integration of consumer heterogeneity and behavioral factors leads to a higher diversity of technology market shares. Especially, log wood technologies gain higher market shares compared to former studies, indicating that an additional future demand for small-scale bioenergy combustion plants in the private household sector persists in certain scenarios. Further findings lead to the conclusion that in houses with high insulation standards, economic factors are predominant and exceed the willingness to pay for other, preferred technologies.

## SDEWES2021.0918

# Data-Driven Energy Planning in Practice: a Study Based on German and Chinese Cities

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## Abstract

Cities offer both challenges and opportunities for securing global sustainability. A growing number of cities acknowledge their role as prime actors in the low carbon development and are committed to take actions towards a clean energy transformation. However, many cities lack the experience and the relevant data to develop long-term energy concepts. As a result, decisions are often made without an evidence-base and little is known about the effectiveness of the implemented measures. This paper presents the approaches in data collection and the methodological framework for optimised energy system planning. It reviews the status quo of energy planning in German and Chinese cities. By comparing the approaches in the development of energy statistics in the two countries, it reveals the existing gaps. To address the gaps, the paper demonstrates methods for collating energy statistics at the city level that can provide detailed insights on the local energy flows. The methods were applied to the case study city Jingmen in China to test its applicability. The results include a detailed energy balance of the city, which forms an important basis for the strategic planning of a green transformation.

## SDEWES2021.1086

# Planning of the High Share of Renewable Sources Within the Republic of Serbia Energy System: from 21,7To 40 % - Can We Reach 100%?

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## Abstract

Planning of energy systems in Serbia has long tradition and has been regularly performed for more than 60 years. Higher shares of renewable sources have been included just recently. The costs of such insufficiently planned energy future have been seen through the significant devastation of the environment and negative economic consequences of the locking into the electricity production from lignite. The draft of the National Energy and Climate Plan for Serbia, expected in the early September, could be the first in the history official document with ambition to reach higher shares of renewable sources in energy system (up to 40%) and the first step towards decarbonisation, and way forward to open negotiation with EU regarding energy sector. The first steps could be switching from small hydro to small PV systems all across the countries households, additional wind production, usage of large hydro potential, but it must be achieved through sectors coupling approach. In order to rich 80% renewable energy system and decarbonize to 25% of current level, the 30 GW of PV and 10 GW of wind have to be integrated through flexibilization of demand, flexible power plants and pumped hydro plants, heat pumps in the district heating, electrification of the transport, increase of the interconnection, and use of hydrogen in industry, transport and heating as well as firing biomass instead of lignite. The 100% renewable energy system for Serbia with ambition of Denmark or Spain is feasible, due to resource availability, energy efficiency measures, and moderate increase in consumption contrary to leading industry nations of G8 and China.

## Energy system analysis 4

## SDEWES2021.0934

# Techno-Economic Feasibility of a Small Renewable Energy Community: a Case Study of Office Buildings in South of Italy

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## Abstract

European climate policies have recognized that the energy communities can play a key role in the energy transition. Indeed, the Clean Energy for all Europeans Package pushes the promotion of renewable-based distributed systems that share electricity produced exclusively from RESs among neighbours connected by electric micro-grids, constituting the so-called Renewable Energy Communities (RECs). In this framework, this paper proposes a techno-economic analysis of a small renewable energy community composed of two office buildings located in Naples (south of Italy). On the roof of each building a rooftop photovoltaic plant (9 $kW_{El}$ and 14.25 $kW_{El}$ peak power) is installed and one office is equipped with an electric vehicle. The heating and cooling demands of both offices are satisfied by two reversible air to water heat pumps. Buildings and plants are modelled and simulated by means of TRNSYS 17 simulation software. Each office is able to self-consumed the electricity produced by the photovoltaic plant installed on own roof and to share the surplus electricity with the neighboured office.

Thus, an energy, environmental and economic analysis has been carried out to compare the performance of the systems achieved in renewable energy community configuration and from individual buildings in terms of quantity of electricity imported, exported from/to power grid and consumed on-site. The economic analysis has been carried out by considered the current economic support mechanism available in Italy under the transposition of Renewable Energy Directive (RED II) included in the Clean Energy for all Europeans Package. The outcomes evidence that the amount of electricity exported to the grid significantly reduces and the quantity of electricity consumed on-site increases a lot when the buildings are connected within the community. The share of self-consumed photovoltaic electricity rises up to 79% when energy sharing is allowed.

SDEWES2021.0937

# Modelling Tool for Energy Consumption of Freezing Chambers in Seafood Sector

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## Abstract

Introduction

Food supply chain is very complex in an ever more globalized and connected world. This is particularly relevant for seafood supply chain, where fishing grounds, processing plants and retailers are thousands of kilometers away from one another and generally located in different continents. Frozen logistic operations are high energy intensive because of freezing chambers consumption—mainly electricity from the grid. The latter is even more relevant in the current context of high electricity cost and energy transition towards zero carbon emissions.

Objective

The NEPTUNUS project aims to promote the sustainable development of the seafood sector in the Atlantic area. Hence, in the framework of this project, it was developed a management tool able to predict the energy requirements during frozen storage of food products and to detect the occurrence of any malfunction of inefficiency. The tool is developed to guide facilities managers and other seafood supply chain stakeholders (e.g., researchers, engineers, etc.) on how to predict and monitor the energy consumption of freezing chambers based on several variables: dimension; insulation type and thickness; indoor and outdoor temperature; and stored product and packaging.

Material & methods

The tool development was divided into two parts: i) collection of data for thermal demand modelling in freezing chambers: transmission load, product load, internal and infiltration load; and ii) energy consumption of the refrigerant circuit to calculate thermal demand. Python was the programming language to develop the tool.

Results and conclusions

The tool was tested and validated with real operational data of freezing chambers during several years. Thus, it was obtained a good correlation between the data obtained from the tool and real consumption data.

SDEWES2021.0984

# Parametrising the Energy Transition for LNG Export-Dependent System; Qatar

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## Abstract

Qatar hydrocarbon-based energy system drives the entire economy of the country. The economy is founded over LNG exports and petroleum refining industries. This increasing industrial activity resulted in a large carbon footprint initiating environmental concerns. In many occasions, Qatar ratified at international environmental mitigation agreements, and established its National Vision and environmental initiatives. Alongside these efforts, transitioning towards cleaner energy has encouraged intensive research on the subject. Energy transition can be explored theoretically using energy modelling tools. The quality of the model is highly dependent on the quality and granularity of the input data. Therefore; data acquisition and parametrisation is a significant task which will primarily enrich the energy database of Qatar, and ultimately will form the basis for concise modelling. This paper manifests the mapping out of Qatar energy system and the insight gained during the phase of extensive data search prior to the phase of scenario analysis and forecast.

## SDEWES2021.1027

# Techno-Economic Analysis of Green Hydrogen Production in Poland

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## Abstract

The European Commission's plan to decarbonize the economy using innovative energy carriers has brought into question whether the existing national targets for the development of electrolysis technologies are sufficiently ambitious to lift local hydrogen production. While several research works have investigated the economic viability of individual hydrogen production and storage facilities in the Western European Member States, only a small number of studies have examined the potential of large-scale hydrogen production and utilization in Poland. Moreover, to the best of the authors' knowledge, no research has yet been carried to specifically examine crucial financial and technical uncertainties that may impact the economics of green hydrogen production in Polish coal-dependent regions. In this context, the objectives of this study are threefold: (1) to characterize the local renewable energy resources that can be used to produce hydrogen through water electrolysis; (2) to conduct a quantitative analysis of the potential and economic viability of hydrogen production from solar photovoltaic and onshore wind potential at the NUTS-2 level; (3) to examine, using a Monte Carlo-based approach, the underlying economic and technical factors that may impact the success of the Polish green hydrogen strategy. In order to fulfill the research objectives, a comprehensive analysis of local technical, financial, and policy-related aspects of green hydrogen production was conducted. Moreover, a Monte Carlo simulation framework was developed for the techno-economic assessment of large-scale hydrogen production systems in Poland. The paper contributes to the existing literature in the following ways. First, it proposes a simulation framework for the techno-economic assessment of green hydrogen production. Second, the paper documents the results of various assumption-driven scenarios and discusses the economics of renewable hydrogen in Poland. Third, the study provides a unique analysis of the prospects and challenges of green hydrogen production in high-carbon intensity NUTS-2 regions.

## SDEWES2021.1037

# The Role of Biomass Energy in a 100% Renewable Energy System for Akita Prefecture, Japan

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## Abstract

In October 2020, the Japanese government declared that the entire country would be carbon neutral by 2050. In line with this, more than 400 local governments have declared that they will reduce their carbon emissions to virtually zero by 2050. However, many municipalities have yet to find concrete measures other than the introduction of renewable energy devices such as solar power. The purpose of this study is to design and analyze a 100% renewable energy system in Akita Prefecture, one of the most rural areas in Japan, and to show the equipment, infrastructure, and production required to decarbonize the region.

The results up to last year showed that the potential for onshore wind power in the target region is greater than the primary energy consumption, and that decarbonization is possible in terms of energy balance. However, even if the cost of energy equipment is reduced in the future, the cost of energy supply will increase. The main reason for this is the need to introduce large-scale storage batteries to supply electricity during times when renewable energy is in short supply. This study examines the use of biomass energy in order to reduce the scale of storage batteries required.

Previous studies in Japan have shown that the use of biomass as a heat source for combined heat and power (CHP) or district heat supply, rather than for power generation alone, is effective in reducing carbon dioxide emissions. However, in Akita Prefecture, the target area, district heat supply has not been introduced despite the fact that it is a cold region. In addition, it has been shown that heat demand can be supplied by electricity and hydrogen. Therefore, it was decided that biomass would be used for power generation.

As results, the capacity of storage batteries required decreased from 41.3 GWh to 23.5 GWh by the introduction of woody biomass power generation, even though the amount of electricity generated from woody biomass in the target area is only 7.5% of wind power. In addition, the capacity of water electrolysis equipment increased from 11.9 GW to 12.2 GW when all surplus electricity is used for hydrogen production.

In conclusion, the introduction of woody biomass power generation can be expected to reduce the cost of energy supply. Future prospects include the analysis of an operation method that generates electricity only when wind power generation is low, and the analysis of a system that newly introduces district heat supply and uses CHP as a heat source.

## SDEWES2021.1068

# Open-Source Backbone Model for Studying the Development of the Baltic Energy System

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## Abstract

The Baltic countries – Estonia, Latvia and Lithuania – are facing new tighter 2030 emission reduction targets proposed by the EU from a unique position. In the next ten years, the Baltic countries are looking to desynchronize from Russia's electricity grid and join the synchronous grid of Continental Europe while phasing out a substantial share of power generation from fossil fuels. Until recently, Estonia has been a net exporter of electricity due to a large-scale oil shale industry, while Lithuania has been a major electricity importer since the shutdown of their nuclear power station some ten years ago. The Baltic countries look to renewable power generation – especially wind and PV – as well as electrification of transport and heating to transform their energy system while maintaining security and cost-efficiency.

We have developed an open-source energy system dataset and model for the Baltic region using the Backbone modelling framework to investigate these energy system changes. We model both annual and hourly operation of the system. The developed model includes Estonian, Latvian and Lithuanian power and heat production, transport and building sectors. New technologies, like hydrogen and storage technologies, have been added to the model. The results yield annual data on electricity and heat generation, hourly cost-optimal unit commitment, system costs, $CO_2$ emissions and shares of domestic and renewable power production.

Our first results investigate the national plans of the Baltic countries as they prepare for 2030. A significant transition from fossil power production towards wind and solar is taking place, which results in substantial $CO_2$ emission reductions in power and heat generation. However, thermal capacity phase-out and disconnection from Russia may bring operational and economic challenges, especially for Estonian and Lithuanian systems. In contrast, the role of electrification in transport and heating will likely remain relatively small between 2020 and 2030.

The next steps include studying impacts of different scenario settings and sensitivities on energy security and system economics, inclusion of neighboring energy systems, and a pathway analysis towards carbon-neutrality. While development continues, we encourage the research community to use the openly available data and model as tools and references.

## Energy system analysis 5

## SDEWES2021.0056

# Closing the Gap Towards 100% Renewable Energy System in the Case of Scarce Renewable Source Availability

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## Abstract

The energy transition towards net-zero greenhouse gas emission energy systems puts a challenge in front of countries that aim to base their production portfolio on the variable renewable energy sources. The energy system of Switzerland is the example of such development. With the shutdown of all nuclear power plants by 2034 the Swiss energy system has to undergo some major changes in order to reach its sustainability goals. With the current energy strategy, the $CO_2$ emissions will stay at a high level and nuclear power would nearly completely be substituted by combined cycle power plants and imported electricity. In this study, an alternative scenario is presented, aiming to reach a 100% RES share of PES and to fulfil the net-zero emission goal by 2050. For the years 2018 (reference year), 2035 and 2050 the energy system was modelled in the EnergyPLAN software. In comparison to Switzerland's official strategy, the district heating system was further expanded, the full potential of renewable energies was included and the electrification of the transport sector was intensified. With these improvements the $CO_2$ emissions could be lowered to 6.6 Mt/year and the RES share of PES could be increased to 83%. The electricity production from renewables is at 87.5% and 2% of the demanded electricity needs to be imported. It became clear that the renewable electricity production will be a major issue in the future since Switzerland's capacities can not cover the increasing demand, which comes with a more sustainable energy system. To further advance towards a 100% renewable energy system it would be necessary to replace the combined cycle power plants with renewable sources and increase the sustainability in the aviation sector. It could be profitable to exploit options of running renewable energy plants in other countries or of overcoming political measures of protected land to increase the capacities.

## SDEWES2021.0091

# First Approach for a Techno-Economic Analysis of Storage Components Used for Improving Energy Management Strategies in Microgrids

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## Abstract

Microgrids are essential elements of the energy transition because they allow optimal use of renewable energy sources (photovoltaic panels, wind turbines, etc.) and storage devices (batteries, supercapacitors ...) by connecting them to consumption poles (buildings, charging stations of electric vehicles, etc. ...). Lithium-ion batteries and supercapacitors are the main electrical storage devices usually used by microgrids for the energy and power transient management. In the present paper, microgrid's simulations have been performed. Electrical and aging models of storage components are presented. Strategies and scenarios for the batteries are presented either based on state-of-charge limitation, or towards hybrid association with supercapacitors, in order to extend their lifetime in microgrids operation, while in the meantime searching for minimizing the installation costs. The first approach for a techno-economic study provided in that study enables to improve the strategies by optimizing the use of the battery. The results obtained in this paper demonstrate the key role of the techno-economic approach, and knowledge of the aging processes of storage devices for improving the energy management and global feedback costs of microgrids.

## SDEWES2021.0128

# Modelling of 100% Renewable Energy Systems in Integrated Assessment Models by Multi-Timeframe Regression Analysis

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## Abstract

Working on holistic approaches that aim to capture a wide range of knowledge, researchers are usually faced with phenomena characterized by different time and geographical scales. This is the case of energy systems and Integrated Assessment Models (IAMs). More specifically, the nature of the variable renewable energy supply (VRES) has traditionally posed a barrier to accurately capturing the effects inflicted by VRES in the energy system.

This research provides a soft link between an energy system model running with an hourly time step, on the one hand, and a yearly-based IAM, on the other hand, by the implementation of an emulator. The proposal here presented is a bridge, based on different types of knowledge, which successfully allows the flow of information between time scales. Results achieve a 100% renewable energy system on a case of Bulgaria. After a brief literature review on the topic, the method is explained in detail, including some results between EnergyPLAN (energy system model) and MEDEAS (IAM) for Bulgaria. Results show that the ability of assessment is notably increased from the previous MEDEAS version.

Finally, both results and limitations of this method are discussed. The authors hope this article captures interest in the field of IAMs, especially those which address with energy transition studies.

## SDEWES2021.0181

# Model for the Assessment of Decarbonisation in the Industry Sector

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## Abstract

This research is based on the ongoing project of Lithuanian Energy Institute on developing a methodology and modelling system for integrated analysis of deep decarbonisation of the economy (2019-2022). The main objective of this paper is to present the created model (as part of complex methodology) for analysis of the industry to investigate various decarbonisation pathways. The industry sector usually consumes high shares of fossil energy, for example, it was responsible for 23.1% of GHG emissions (2019) in Lithuania.

We constructed our model using the Lithuanian industry sector as an example. It is modelled from the perspective of final fuel and energy consumption and includes more sectoral details compared to typical models that include industry sector. In industry, fuel and energy consumption is driven by many different industrial processes to produce process heat, refrigeration, mechanical energy, lighting, heating, cooling. These processes require utilising a wide variety of fundamentally different technologies (boilers, engines, refrigerators) and fuels. We model them by aggregating technologies according type of fuel used to reduce the size of the model. We have calibrated the model using statistical information on final fuel and energy consumption in the industry. The created model allows analysing the scenarios for industrial $CO_2$ abatement and exploring the dynamics of fuel and energy consumption mix in the industry until 2050. The model is based on a bottom-up approach (optimisation modelling tool MESSAGE) with the representation of the current and emerging technology mix.

For the current model application, we included only the chemical industry (including ammonia production responsible for 75% of total Lithuania's industrial process emissions in 2019). We conclude that decarbonisation of Lithuania's chemical industry is technically feasible. To implement substantial reduction of GHG emissions in the chemical industry, the deployment of CCS technology is necessary to capture process emissions. In addition, to completely decarbonise this sector, green $H_2$ as feedstock for ammonia production is the only realistic option. $CO_2$ reduction targets (by 40 to 100%) for the chemical industry increase total costs of the sector by 1.09–1.15 times compared to business-as-usual activities.

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## SDEWES2021.0261

# Modeling of the Chemical-Looping Combustion of Syngas in Packed Bed Reactors

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## Abstract

Numerous methods can be found for greenhouse gas emissions reduction (mainly CO2) into the atmosphere; for instance, possible solutions could be the decrease in global energy consumption thorough more efficient energy conversion/consumption techniques or a careful transition to alternative renewable sources. Chemical looping combustion (CLC) is an energy conversion technology designed for fossil fuel combustion, capable of CO2 separation at minimum energy requirements and cost-optimal levels by circumventing direct contact between air and fuel. During CLC, an oxygen carrier (OC) material is used to bring oxygen and fuel into contact. The OC is usually a metal/metal oxide capable of undergoing cycles of oxidation and reduction. In a packed bed reactor based CLC concept, the OC solids are stationary and are alternately exposed to reducing and oxidizing conditions by switching of the gas feed streams. The main advantages to such an approach are that separation of gas and particles is naturally avoided, a more compact reactor design is achieved and the OC can be fully utilised. At least two beds are needed to mimic a continuous operation, with one undergoing the oxidation step and the other the reduction step, with a purge step in-between transition. Evaluating the behaviour of a dynamic CLC unit is paramount in designing a flexible power plant concept.

In this work, a dynamic model has been developed in order to simulate packed bed reactors used in a CLC process with syngas and iron-based OC. Mass and energy balance equations for the packed bed reactors, together with equations describing the kinetics for the oxidation and reductions steps, were implemented in MATLAB/Simulink. The developed models solved the equations in space and time and were used to predict gas flow profiles, gas composition distributions, OC behaviour and temperature profiles during both oxidation and regeneration steps.

Models were validated with literature data by fitting the oxygen breakthrough curve for the oxidation step and hydrogen, carbon monoxide and carbon dioxide breakthrough curves for the reduction steps. As model predictions displayed high accuracy, a study on flow rate changes was undertaken. The flow rate was varied by +/- 20% of the initial value during oxidation. The increase to flow rate led to less time required for achieving process stationarity (by approximately 120 s), while the decrease in flow rate showed longer time required for OC regeneration (around 480 s).

SDEWES2021.0437

# Performance Analysis of Four Data-Driven Prognostic Models for Lithium-Ion Batteries Capacity Prediction Based on Data Multiplicity

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## Abstract

Owing to the increasing dependency of modern civilization's mobility needs on battery powered electric vehicles, the ability to monitor and maintain the health condition of battery is of utmost importance [Jianfang Jia et al, 2020]. Prognostics of batteries involves state estimation and remaining useful life (RUL) prediction based on the current state. It is highly desirable to have accurate prediction of remaining useful life of battery as it enables effective maintenance leading to reliable operation. Various data driven approaches are studied to achieve accurate RUL predictions and state of health estimations. The Gaussian process model is a statistical approach which accommodates the nonlinear nature and small sample size of battery data to effectively predict the RUL of lithium ion batteries [Lifeng Wu, 2016]. The neural networks have the ability to approximate nonlinear data and given the fact that battery degradation is a nonlinear process, neural networks-based models can also provide accurate RUL predictions for lithium ion batteries [Jiantao Qu et al, 2019]. Support vector machine (SVM) solves nonlinear tasks by transforming data into a higher feature space, where a problem becomes linear. it is capable of handling small sample size and non-linear approximations based on statistical learning theory [4]. The long short-term memory (LSTM) is a deep learning neural network capable of learning long term dependencies. The gates allow it to remember information for longer periods of time [5]. In this paper, various datasets with varying levels of data diversity such as training: testing data ratio, single vs multi sensor data, and single vs multi battery data are prepared. All four data driven prognostic models of interest are trained using these datasets. Extensive comparative analysis is performed among the various prognostic approaches mentioned with respect to data multiplicity and its influence on the performance and prediction accuracy of these models.

## Energy system analysis 6

## SDEWES2021.0709

# An Mip Model with Endogenous Capacity Investment for Energy Transition Pathways - Interrelation Between Power-to-X, Demand Response and Market Coupling

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## Abstract

This research proposes a new long-term energy planning model with endogenous capacity investment and energy dispatch with consideration of Power-to-X and demand response technologies. The model represents an energy system and minimizes the total capacity investment cost, across all technologies, and the operational cost incurred in satisfying demand levels. Different demand sectors and their links are also modeled. Particularly, we explicitly consider the links between the electricity, heat, and electro-fuels (Hydrogen), and V2G. The model is used to analyse the Croatian energy system under different policies of RES levels and CO2 reduction targets. We show that Power-to-X indeed provides the required flexibility to the new capacity additions of variable renewable sources, reaching systems with lower levels of critical excess of energy production. Battery storage and Power-to-heat strategies are largely adopted for renewable shares and CO2 savings around 80% while below such values their adoption is limited. Also, power-to-heat technologies become predominant when a limit on CO2 emissions of the heating sector is required and particularly when the renewable share in electricity reaches a value of 60%.

## SDEWES2021.0735

# Optimization of the Possible Pathways for Gradual Energy System Decarbonisation

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## Abstract

The goal of the European Union and the Paris Climate Accords signatories is to limit global warming within 2 °C in relation to the preindustrial levels. There have been a number of studies performed which demonstrate possible end goals of energy system which aligns with climate neutrality goals. This paper focusses on addressing the intermediate steps towards decarbonization. The steps are quantified as the percentage share of renewable energy sources. The objective of optimization is to reach predetermined level of RES, minimize curtailment of renewable energy sources, minimize emissions, minimize system cost and limit the use of natural resources as biomass in energy sector. Considered technologies in optimization process are energy generating capacities, demand response technologies as well as energy storage. Results of such method reflect through the use of considered technologies and are displayed as a function of the share of RES which also represents the decarbonization timeline from 2020 towards 2050. Method is carried out with the use of energy planning software EnergyPLAN and highly modified Python based optimization software EPLANopt. The results presented in the paper display necessity for continuous implementation of variable generating capacities as well as demand response technologies, mainly V2G.

## SDEWES2021.0951

# Smart Energy and Smart Abatement for Chile's Energy Transition

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## Abstract

Chile has set ambitious goals for transitioning towards a decarbonized, clean, and sustainable energy system towards 2050. However, it is uncertain how this transition should occur, especially when considering all energy sectors. In addition, other sustainability objectives, notably using biomass sustainably and reducing impacts from particulate matter air pollution, require consideration. In this context, this study develops scenarios aiming at transitioning the Chilean energy system in 2050 to 100% renewable energy, taking into account local resource potentials, demands, and cross-sectoral integration among the electricity, heating, transport, and industrial sectors. The energy system model EnergyPLAN is used to simulate the hourly operation of the energy system.

Moreover, the relationship between potential $CO_2$ emissions reductions and relative costs is estimated using marginal abatement cost curves with the EPLANoptMAC tool to assess optimal capacity expansion alternatives. The analysis demonstrates that it is possible to carry out this transition from a technical perspective and that in different phases of the Chilean energy transition, certain options could be prioritized based on an improved balance between carbon abatement and costs. Furthermore, the use of marginal abatement cost curves provides added transparency for policy-makers about the scenario alternatives and how these might align to Chile's nationally determined contribution (NDC), atmospheric decontamination plans, and climate actions.

## SDEWES2021.1025

# Time Series Sectoral Mapping of Energy Transition Paths and Greenhouse Gas Emissions

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## Abstract

The Paris Climate Agreement and the 2030 Agenda for Sustainable Development Goals declared by the United Nations set high expectations for the countries of the world to reduce their greenhouse gas (GHG) emissions and to be sustainable. The European Green Deal defined in 2019, also supports this mindset by the concept of net zero greenhouse gas emission in all member states of the European Union by 2050. In order to judge the effectiveness of energy transition strategies, the evolution of carbon dioxide, methane, and nitrous oxide emissions in countries around the world have been explored based on statistical analysis of time series data between 1990 and 2018. The carbon dioxide equivalent of the gases has been calculated to provide a comparable global overview. A utility function has been defined based on the European Green Deal target for 2030 to decrease at least 55% of GHG emissions compared with 1990 levels. The transition trajectories of the countries are studied based on the percentile-based visualisation and time-series analysis of the empirical distributions of the emission data. We study the evolution of the sector-wise distributions of the emissions to assess how the development strategies of the countries contributed to climate change mitigation.

Based on the proposed analysis the main drivers of climate mitigation and evaluate and their effectiveness were identified and characterised, which can form the basis for the planning of sectoral tasks in the coming years.

## SDEWES2021.1072

# Techno-Economic Analysis of Coupling Thermochemical Energy Storage with Power-to-Heat for Increased Utilisation of Solar PV in Residential Space Heating Systems

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## Abstract

Thermochemical energy storage (TCS) is a promising technology due to its virtually lossless heat storage over a span of months. As a result, TCS has been extensively investigated as key enabler of decarbonization of heating supply in buildings though seasonal shifting of solar thermal energy.

However, growing evidence demonstrate that a zero-carbon future urgently necessitate solutions that couples electricity and heating sectors. Coupling TCS to solar PV via power-to-heat technologies could present therefore incentives and wider benefits, reducing overall installation constraints by adopting PV technologies already installed while increasing solar energy utilization thanks to TCS.

The techno-economic performance of such PV-TCS installations in the residential sector is however unexplored, and it is unclear how this performance compares to other equivalent technologies, such as TCS/solar thermal, or PV with battery storage. Furthermore, there is a general gap in the knowledge surrounding the impact of realistic operating conditions on the final performance of TCS systems.

This article studies the integration of low-temperature TCS systems coupled to electrically-driven heaters powered by solar photovoltaics in UK dwellings. Dynamic simulations were used to model the behaviour of the TCS system in relation to available solar energy and the building's heat demand during the year. A time-dependent, reduced geometry model was utilised to simulate a TCS reactor, while accounting for dynamic reaction kinetics and thermochemical equilibrium which impact real system performance.

The interplay between humidity and temperature of the local weather conditions and the thermochemical equilibrium properties of the selected salt/water pair was found to have significant impact on overall system performance. Utilisation of magnesium chloride, due to its low equilibrium humidity compared to other inorganic salts, along with the calculated optimal TCS size / solar PV surface area pair, lead to a building solar fraction in excess of 80%. The levelized cost of energy for the whole system was in the range 350 €/MWh – 450 €/MWh, with estimated simple payback time of approximately 18 years – 22 years for the optimal cases. These results place TCS/PV-P2H in techno-economic contention with other equivalent storage mediums for residential applications. However, calculated storage volumes in the range of 10m$^3$ – 20m$^3$ could present a technical barrier to TCS/PV-P2H implementation.

## SDEWES2021.1074

# Optimal Heat Storage in District Energy Plants with Heat Pumps and Electrolysers

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## Abstract

District energy (DE) plants are undergoing a transition away from being providers of district heating through cogeneration of heat and power (CHP) units along with electricity to the public grid. Rather than being electricity producers, DE plants will transition to being electricity consumers, thereby switching fuel usage to renewable energy-based electricity production. In addition, hydrogen production for transportation fuels (electrofuels or power-to-x) should optimally be combined with DE systems that may exploit the inevitable thermal losses from the electrolysers. Where CHP units favour high electricity spot market prices and electric boilers or heat pumps in DE systems favour low prices – thus providing incentive for heat production at both high and low electricity prices, future systems with heat pumps and electrolysers both call for low electricity prices, increasing the need for thermal storage. Hydrogen storage will also enable such systems to operate with a higher degree of flexibility – however at a cost orders of magnitude higher than thermal storage. In this work, the business-economic energy systems simulation model energyPRO is applied to investigate optimal system compositions with a focus on storage capacities with a view to enabling the systems to operate flexibly according to electricity system needs while also meeting heating and hydrogen demands.

## Environmental policy and management 1

## SDEWES2021.0217

# Evaluation of Properties and Composition of the Mixed Municipal Waste

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## Abstract

Estimating the composition of mixed municipal waste is important to increase waste separation and related recycling. Many studies have presented their methodologies for analysing the composition of mixed municipal waste, but no uniform approach is available. Very often, a significant part of mixed municipal waste is the fine fraction, the more detailed composition of which is unknown. This contribution aims to present a methodology for obtaining essential information about the fine fraction. A proposed approach for chemical analyses of the fine fraction is feasible in a simply furnished laboratory. For fine fraction, the amount of moisture and the combustible part of the waste are first monitored. The elemental composition of non-combustible waste and its phase composition is further evaluated. The outputs of the analyses were presented on five selected samples. The approach to chemical analysis has been designed to be easily repeatable, time-saving and can complement routine manual waste analyses.

SDEWES2021.0251

# Climate Emergency Declarations and Climate Ambition of Local Plans: a Comparative Assessment for Italian Cities

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## Abstract

Italian cities are experiencing a wide range of climate-induced extreme events due to its position in the Mediterranean hotspot and its peculiar geomorphology, climatic, and socio-political conditions. They have recently become key actors in climate planning, also due to delays in national climate legislation, limited actions by regional authorities and reduced legislative power of provincial authorities. The "climate emergency" movement has involved local populations who are advocating for concrete climate action by local councils. This study investigates the relationships between the commitments of the Climate Emergency Declaration (CED) of Italian cities and their current climate action, as documented in Local Climate Plans (LCPs). The results provide an in-depth and timely investigation on the movement of Climate Emergency Declarations in Italian cities and a comparative assessment of CEDs and LCPs in terms of availability, goals, greenhouse gases (GHGs) emissions reduction targets, size of the city, and engagement of cities within transnational climate networks.

## SDEWES2021.0505

# Characterization of Biofilms Made from Pigmented Native Potato Starch Solanum Tuberosum Subspecies Andigena and its Biodegradability Capacity as an Alternative to the Use of Artificial Polymers

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## Abstract

Native potatoes are used for the consumption of the population throughout the world. The extraction and use of starch from this variety of potato is used as an ingredient in a wide variety of industrial and food applications, increasing an added value to them. The purpose of the research was to obtain, synthesize and characterize biofilms made from pigmented native potato starch Solanum tuberosumm andigena subspecies. 6 kilos of pigmented native potato obtained from 5 producing areas (Kiswara, Quisapata, Huancarama, Pacobamba, Pacucha) of the Andean zone of Apurímac have been evaluated, avoiding obtaining samples of spoiled, deteriorated and decomposed potato. The condensation polymerization method has been applied to obtain potato starch. The method applied to evaluate the evaluation of thickness and tensile strength has been by scanning electron microscopy. The gravimetric method has been used for the biodegradability process and the standard method for the attenuated total reflectance spectrum of the Fourier Transform infrared spectrometer to determine the presence of anthocyanin in biofilms. The sample has been non-probabilistic, with a design with multiple treatments (factorial experimental) with 03 treatments and 3 repetitions of each treatment that do not differ in the application modality, with 2%, 3% and 4% concentrations of potato starch native pigmented to obtain the biofilm. The biofilms of native potato starch pigmented at 2%, 3% and 4%, were evaluated at different amplitudes of 400x, 1000x and 2000x microscopy, showing a more homogeneous matrix, more uniform particles, homogeneous surface, smooth did not present cracks , giving rise to the formation of a more continuous material with greater compaction, being the concentration of 2% of pigmented native potato starch the one that observes a much more homogeneous surface than 3% and 4%, exposed to fragmentation due to low starch concentrate. In the second phase, the biodegradability was evaluated in the laboratory at different concentrations of the biofilms (2%, 3% and 4%), all of them in organic soils and controlling the physical chemical properties of the soil as well as the time of the biodegradability process, finding that At a 4% concentration of potato starch it presents better results, the degradation process controlling weight and size culminated in 14 days with traces and 21 days at 100% in a soil with controlled pH, humidity, electrical conductivity and organic matter. It is concluded that the biofilms obtained have shown optimal characteristics for use in the elaboration of materials for alternative use to other artificial polymers, at a higher concentration of starch the biofilms have a better cohesion of the structure and presented some air bubbles, small lumps and pores. probably due to the high permeability to water vapor and showing excellent biodegradability as an alternative to the use of artificial polymers.

## SDEWES2021.0583

# Oil Tank Farm Emission Trends of Russian Refineries

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## Abstract

Russia is a leader in the primary processing of crude oil in Europe. However, most of the country's oil refineries have outdated production capacities of tank farms for storing oil, and the issue of emissions from Russian refineries is a research gap in this area. The aim of this study was to identify the dynamics of changes in the amounts of emissions from tank farms for oil storage at Russian refineries. A study period from 2008 to 2018 was considered. The contributions of this paper include the development of methods for estimating emissions for the regions. In Russia, a unified methodology is in place for determining emissions of pollutants into the atmosphere from tanks. However, the use of this technique presents significant difficulties for conducting research on a regional scale, because in this case it is necessary to have detailed information about the technological features of each refinery. In this study, an approach was developed that, based on the existing expressions of the unified methodology, allows us to estimate the emissions of tank farms at a regional scale.

The results showed that the greatest emissions occurred in the Volga Federal District. The volume of emissions from that region exceeded the total emissions of the next three districts: the Central, Siberian, and Northwestern Federal Districts of Russia. The largest growth rate of emissions was demonstrated by the refineries of the Southern Federal District, exceeding those of the Central, Siberian, and Northwestern Federal Districts during the study period. In the Far Eastern and Ural federal districts of the country, annual emissions were much lower. During the study period, the total accumulated emissions exceeded 2.5 million tons; therefore, the country needs to carry out work to modernize the tank farms of oil refineries in accordance with the proposed direction.

## SDEWES2021.0591

# The Optimum Energy and Wood Procurement Scenario for its Dynamic Management in Carbon Neutral Forest Industry

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## Abstract

The digitalization of the forest industry, the increased demand of energy wood and faster market changes have increased the challenges for wood procurement, which have given rise to this research. The aim of the study is to model and analyze the wood procurement for energy and material production in different market situations, and to consider the effects of the changes on practical procurement management from the perspective of the procurement organization in carbon neutral forest industry.

The material of the study was collected from Harvestia LTD's information system on 48 municipalities. There are a total of 21 factories and energy plants, of which there are 5 plants that use pulpwood, 10 using logs and 6 using energy wood. The optimization method bases on dynamic linear programming which optimizes wood flows of markets by minimizing the total cost of wood procurement. The optimization problem of the study was solved by an optimization program called PH-Opti, which's code edited for this company of forest industry. Three possible future scenarios described different market situations. The scenarios were based on existing research results and targets and assessments set at EU level. The results of the optimization runs were compared to the scenario, which were designed from the wood procurement volumes from 2017 and 2018.

The cost efficiency of wood supply affected the competitiveness and operating conditions of the forest and energy industry. Therefore, more dynamic management of purchasing, functions and inventories, as well as increasing the utilization rate of the resources, are at the heart of the success. In addition, as team, municipals' sensitivity to change between different market situations was the corner stone in the success. The results show that it is possible to change operative team's wood procurement in municipals at a market-oriented and at the same time cost-effective way. Based on the results obtained, the dynamic management should operate with optimum local procurement, a functioning raw material market and optimum resources, which can be considered as key factors in the success of the change in new market situations in carbon neutral forest industry.

## SDEWES2021.0608

# The Impact Assessment of No2 Emission from District Heating Plant on Local Air Quality, the Case of Zemun, Belgrade

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## Abstract

The Belgrade district heating system relies on fossil fuels in heat production, where natural gas has the largest share of around 95% and fuel oil with around 4.4%. The Zemun heating plant is completely fueled with fuel oil. Currently, it is the largest plant that is not fueled with natural gas. The objective of this paper is to assess the impact of $NO_2$ from the Zemun heating plant on local air quality by analyzing and comparing the concentration of $NO_2$ which originates from the heating plant and the total concentration of $NO_2$ measured at the nearest local measuring station. For the $NO_2$ spatial distribution modeling from the heating plant emitters (stacks), the AERMOD model was implemented. The stacks were modeled as point sources. The meteorological data were processed using the AERMET data preprocessor. When comparing case study model results with the results from the nearest local monitoring station, it can be concluded that the heating plant contributes with the maximum share of approximately 10% in total $NO_2$ concentration in air. In order to investigate the effects of emission control measures, the implementation of the flue gas recirculation technique that reduces $NO_2$ emissions from the heating plant was modeled. The results showed that with the application of the recirculation measure, the modeled $NO_2$ concentrations in the surrounding of the heating plant could be reduced by up to 50%.

## Environmental policy and management 2

## SDEWES2021.0623

# Assessing Interlinkages Between Climate Protection and Resource Conservation on Global Level – Trends and Insights from System Dynamics Modeling

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## Abstract

According to UNEP's International Resource Panel the share of total global greenhouse gas (GHG) emissions stemming from natural resource extraction and processing has risen from around 15% in 1995 to 23% in 2015 – and is expected to increase further until 2050. Therefore, using less primary resources appears key to achieve both the Paris agreement climate goal and the SDGs, e.g. SDG13 on climate action and SDG12 on responsible consumption and production. E.g., producing metals from scrap requires only a fraction of the energy needed for extracting and producing metals from mining and processing activities, thus significantly saving GHG emissions. However, climate protection, in particular via renewable energy generation, energy storage and electric mobility, causes a massive increase of demand for certain raw materials, e.g. copper and lithium.

In order to better understand potential synergies and trade-offs between climate protection and resource conservation – the so-called "climate-resource-nexus" – we explored potential interlinkages via system dynamics modelling.

Applying a conceptual and a simulation model of key interlinkages between resource use and GHG emissions we show for a common economic baseline (based on the World Energy Outlook) that

material availability for a long-term continuous use of renewables would be possible, if design for recycling is provided

- biotic resources could to some extent replace abiotic resources and act as carbon sinks, and

- decreasing resource use offers significant potential for reducing GHG emissions on an aggregated scale.

In this context, pushing a circular economy and resource conservation is essential for ensuring long-term supply of raw materials needed for the energy transition. Likewise, circularity principles and a bioeconomy must go hand-in-hand, e.g. substituting non-renewable with biobased construction materials and using modular building design. This will also require efforts to minimise and prevent rebound effects associated with efficiency gains in economic processes. Hence, lifestyles and consumption patterns become a central policy lever for a sustainable future.

These analyses of the models reveal a technological and socioeconomic context that calls for concerted policy action at international level in order to design policies that foster intelligent and long-term sustainable solutions with low environmental footprints and high opportunities for human well-being. Thus, the future needs to – and can be shaped.

## SDEWES2021.0687

# Raising Public Awareness of Pollution in Skopje as a Basis for Conducting Social Marketing Activities

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## Abstract

In this modern day and age, urban pollution is a global problem that causes particular concern. One of the number of cities facing this problem is the capital of the Republic of North Macedonia - Skopje, which, according to the significant pollution occurring during winter, ranks on the list of most polluted cities in Europe and the world.

According to several surveys done by line ministries and international organizations (UNDP, UN), the habits regarding the use of public transport, car pollution, construction works and households that use solid fuels for heating are most often pointed out as sources of pollution in Skopje. An additional source is road traffic, which contributes to the increase of greenhouse gas emissions, caused by the absence of car-pooling, the lack of high-speed roads, frequent stopping of vehicles due to traffic lights and the like.

The sources of pollution can be significantly reduced if the awareness of citizens about the basic causes and consequences of this problem is raised, through targeted campaigns and social marketing activities. For social campaigns to be effective, first of all, it is necessary to conduct research that will determine the level of public awareness and identify target groups of citizens to whom these campaigns and activities will have the greatest impact.

For that purpose, a survey was conducted on a sample of respondents in Skopje selected according to age, education, ethnicity and gender classification. By analyzing the answers of the respondents, it can be concluded that the citizens do not feel that they themselves have any part of the blame for the problem of pollution. Compared to the findings of some previous surveys in which households and road traffic are pointed out as the biggest polluters, according to this survey, the citizens of Skopje believe that industry and real estate development are the main sources of pollution. They believe that more rigorous legislation is needed to encourage conscious and more responsible behavior in the real estate development business, in industrial facilities and in road traffic, to reduce the problem of pollution. But, what raises a flag is the data indicating that the citizens do not show awareness of their own habits and behavior as a cause of pollution of the city of Skopje.

The main findings of the research indicate the need to undertake a social marketing campaign targeted at specific groups of citizens to raise their awareness of the sources of pollution. Social marketing activities should cause a change in the habits and behavior of each individual towards the environment, which will contribute to their active involvement in reducing pollution both locally and globally.

## SDEWES2021.0904

# Performance Analysis of a Hybrid Electro-Mechanical Air Purifier for Particulate Matter Control in Large Rooms

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## Abstract

Many countries including Thailand are suffering from air pollution, especially particulate matter smaller than 2.5 micrometer (PM2.5). This particulate air pollutant can potentially causes various diseases related to human respiratory systems, such as lung cancer and chronic airway inflammation. During high episodes of PM2.5, indoor air quality in enclosed rooms is of particular concern since small children and elderly people will have to reside to avoid direct exposure. An air purifier is an essential device employed to clear up PM2. 5 in the indoor air. However, most commercially available high-performance air purifiers are usually designed for a small room, and come with a high-efficiency particulate-free air (HEPA) filter which is very costly and has a rather short lifetime. Here, in this work, we developed a high- performance air purifier for large room area that adopted a hybrid electrostatic and mechanical filtration system ( a compact electrostatic precipitator and a normal grade fibrous filter in series). The assembled hybrid system was tested for filtration performance in a sealed 200 m3 room, against popular commercially available air purifiers. For the comparison, our system had similar filtration efficiency of over 90%, but higher clean air delivery rate. The electrostatic technique appeared to enhance removal of PM2.5 in combination with normal filter. Our device was able to reduce the indoor PM2.5 concentration by 90% in 20 – 30 min, while single-stage air purifiers with HEPA filters took about 45 min or more. The hybrid electromechanical filtration system proved to be effective and promising for controlling indoor air quality in large room areas.

## SDEWES2021.0909

# How Do Climate Change Mitigation Policies in the Waste Sector Affect the Sustainable Development Goals? A Case Study of North Macedonia

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## Abstract

As nations draft their national policies to mitigate climate change, the effect of these policies on other strategic goals, such as the Sustainable Development Goals, is to a large extent non-examined and creates conditions for unintended consequences, such as policy incoherence. This is addressed through a participative case study on mitigation policies and measures in the waste sector in North Macedonia. Results show considerably more synergies than trade-offs. The strongest synergies concern goal 8 (Decent work and economic growth) and goal 3 (Good health and well-being) since new jobs will be created through the formalization of the recycling sector, economic productivity will improve as a result of increased resource efficiency in industry and declining pollution will increase health through adequate waste management in landfills. Whereas, the strongest trade-off concerned goal 1 (No poverty) because the incomes of low-earning families will be affected, as they are more likely to be informal workers in this sector.

## SDEWES2021.0956

# Ecological Risk Assessment for Pesticide Pollution at Sultan Marshes Wetland, Turkey

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## Abstract

Pesticide pollution of surface water resources is a major environmental problem in agricultural basins. Sultan Marshes is a large wetland complex located at the center of semi-arid Develi Basin, Turkey. Irrigated agriculture is widespread around the Sultan Marshes and the marshes act as the receiving medium for the agricultural drainage flows collected with drainage channels from agricultural areas. In this study, we examined the pesticide levels at the Sultan Marshes ecosystem and evaluated the ecological risks associated with pesticide pollution. Water sampling was performed four times with three-monthly intervals from two sampling stations. One of the sampling stations was located in the marshes (Ortuluakar Marshes) and the other was located on the main drainage channel (Camizgolu Pumping Station). Water samples were scanned for 149 orgonochlorous and orgonophosphorous pesticides. The pesticide concentrations were evaluated based on Environmental Quality Standard (EQS) values determined by the priority list of Turkey. The risk assessment was performed using risk-quotient method for four taxonomic groups (i.e., phytoplankton, zooplankton, insect, fish) at two effect levels (i.e., the acute and chronic) levels. Results showed that various pesticides were detected in water samples (dichlorvos, tribenuron-methyl, pyrimethanil, propham, omethoate, fenhexamid, piperonyl butoxide, tebuconazole). However, concentrations of majority of the pesticides were lower than EQS values except for the bifenox, dichlorvos and fenpropathrin. Risk analysis showed that although ecological risks associated with these pesticides are in general low to moderate, there are significant risks for some of the species particularly due to dichlorvos.

## SDEWES2021.1066

# The Possibilities of Application of Artificial Intelligence in Environmental Monitoring Systems

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## Abstract

Awareness of environmental pollution has been continuously growing in the last decades and is at present reaching its maximum. Europe and most of the developed countries are resolute to ensure safe breathing air for their citizens and measures to accomplish so are stricter than ever before. The presence of various chemicals in exhausts from combustion processes has been proved in many research and identified several organic compounds of complex structure and different chemical and physical properties that are beyond regulations. In order to meet these regulations many laboratory and real-condition tests, including examinations of fuel quality, exhaust toxicity or mechanical and thermodynamical parameters of processes occurring in a combustion chamber, are required. Recently, the advanced methods have been sought to improve and to predict the mechanisms processing while exhausts producing and pollutants releasing to the atmosphere. Artificial neural networks (ANN) find more interests among researchers. They are still mainly applied in economy for tracking of change of exchange rates or for creditworthiness assessment. However, their application has become wider , i.e. including the environment monitoring systems. This work serves for the review of usage of ANN and machine learning in atmosphere and water ecosystems protection.

## Environmental policy and management 3

## SDEWES2021.0204

# Assessment of Water Quality Deterioration at Laborec River Basin

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## Abstract

The framework of environmental risk assessment presents a good overview of the process and provides a good foundation for conducting assessments for individual chemical or physical stressors and single endpoints. This article provides guidance for all types of environmental risk; single stressor as well as multiple stressors. Environmental risk assessment facilitates this approach first by providing a logical method for estimating risks, but moreover, by providing clear links from this method to activities that typically occur in watershed management. The developed model that determines concentrations of pollutants in water stream is based on dimensionless analysis. Fundamentals of the modelling of the pollutants prediction in water stream consist in derivation of function dependency from expressed dimensionless arguments. Dimensionless arguments are stated from variables, which influence the occurrence of pollutants. From this function dependency is possible to obtain values of concentrations of the pollutant in water stream. In generally, this dependency has exponential status. Its transformation to logarithmical coordinate system is equivalent to linear status that allows working with model easier and more simply to determine parameters of linear status. Prediction of nitrogen concentration in water stream was performed in Laborec River (eastern Slovakia).

## SDEWES2021.0516

# Life Cycle Assesment of Four Residential Buildings in Slovakia and Comparative Analysis

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## Abstract

Statistics shows that building industry causes largest amount of greenhouse gas (GHG) emissions among all other industries. With current urge of fulfilling our aimed goal to achieve temperature rise below 2°C a year from Paris agreement and then below 1.5°C a year, we need to analyse our building stock. Because of population growth and connected demand for new accommodation we focused on residential buildings. The main aim of this paper is analyses of residential buildings located in Slovakia using eToolLCD software. Boundaries are set for cradle to grave analysis. Chosen functional unit is 1 $m^2$ of the total floor area, which represents base to which the inputs and outputs of modelling the benchmark system relate. Length of the referential period is set to 60 years, Assessed environmental impacts are global warming potential (GWP), ozone depletion (OP), acidification potential (AP), eutrophication potential (EP), photochemical ozone creation potential (POCP), abiotic depletion potential of elements (ADPE), abiotic depletion potential of fossil fuels (ADPF) and also use of primary energy resources (PENERT). Analysed buildings represent current building trend in Slovakia using current energy efficient standards, along with widely used alternative of retrofitted precast panel building. Final results are compared and analysed. This approach is selected to bring needed information about current state of construction trend used in Slovakia, to set a starting point for further critical reviews of different strategies and also to inform, what is the impact of current selection of building materials and approaches as well as technologies related to building operation on environmental impacts and climate change.

## SDEWES2021.0830

# Biochar's Effect on the Ecosystem Services Provided by Sandy-Textured and Contaminated Sandy Soils: a Systematic Review Protocol

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## Abstract

Goal and background: Biochar is a relatively new soil amendment method in agricultural practices that can improve the ecosystem services of soils. Biochar has commonly been applied to soils that are less fertile, such as sandy–textured soils, or heavy metal polluted, such as sandy-textured and contaminated sandy soils, to improve their properties. Yet, not all sandy-textured and contaminated sandy soils respond to biochar applications positively, evidenced by some studies indicating no or a negative biochar effect. So, there is a lack of consensus regarding biochar's positive impact on soil ecosystem services, specifically biomass production, water cycle, nutrient cycle, and climate regulation. Therefore, the present study's objective is to review studies systematically to identify the impact of biochar amendments on the ecosystem services of sandy-textured and contaminated sandy soils.

Methods: This review follows the guideline of the Collaboration for Environmental Evidence and corresponds with the ROSES (RepOrting standards for Systematic Evidence Synthesis) reporting standard. A comprehensive search strategy will be employed to cover peer-reviewed, and gray literature through bibliographic databases, organizational and institutional websites, and web-searches. The search results will be screened first by their title and abstract, and then by their full text. Two reviewers will do this, based on inclusion criteria. A validity assessment will be conducted to critically appraise and assess the validity of studies using the most common framework. Data will be extracted from the studies that are found valid for the review. Narrative synthesis and meta-analysis are planned to be employed to synthesize the review results. Through targeted meta-analysis, we intend to see the impact of biochar on soil ecosystem services, which later can be exploited by policymakers.

## SDEWES2021.1057

# Streamflow Components and Climate Change: Lessons Learnt After Modelling Experiences in Mediterranean Catchments

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## Abstract

Sustainable water management in the near future needs to take into account the plausible impacts of climate change, and hydrological models can help in this task. Studies that analyse their impacts on water availability are numerous. Most of these studies, however, focus on the variability on the water balance components, the streamflow patterns or the aquifer recharge, being a lack of studies analysing the impacts of climate change on the streamflow components.

We have compiled the outcomes of three previous experience of climate change scenarios simulations in Mediterranean climate catchments (the Ompólveda River and the Salado River catchments in Spain and the Guadalupe River catchment in Mexico) addressed with SWAT. Then, the impacts of climate change on streamflow components distribution have been assessed.

Results show that in the Spanish catchments, where groundwater contribution is the main streamflow component in the baseline conditions, simulations predict a noticeable decrease of this component (up to -74% in both catchments in the most pessimistic scenario). Thus, lateral flow, despite slightly decreasing, becomes the main streamflow component. In the Guadalupe River catchment, the most arid one, where lateral flow is already in the baseline the main component (69%), this component will experience the largest absolute decreases across climate change scenarios, but the highest relative decrease might be experience by groundwater flow, up to -92%. Absolute variations in surface component are small and the different ways of simulate the climate change scenarios in the three cases of study might hinder their interpretation.

## Green economy and better governance 1

## SDEWES2021.0039

# Technological Change, Consumption Patterns and Income Distribution: Strategies for a Low-Carbon EU Transition

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## Abstract

The emergency of climate change has placed efforts to mitigate its effects and limit its sources at the international forefront.In this context, the European Commission has set the fight against climate change as one of its main priorities, supporting, among other international initiatives the Paris Agreement, which sets sustainable economic growth in a context of poverty reduction in the political agenda for the next decades.

The environmental impacts of economic activity has been extensively analysed in the economic and environmental literature. However, nowadays, in a context of high globalization and production fragmentation, consumption and production patterns cannot be considered in isolation, being necessary models that integrate both perspectives for the formulation of comprehensive measures of progress towards low-carbon economies. Moreover, disparities in income distribution and lifestyles between and within each country also modulate the effectivity of those measures. These policies are called upon to coexist and be complemented with technological changes that accelerate the processes of diffusion and adoption of clean technologies in an increasing number of countries and sectors. In this broad context, this work develops a dynamic multiregional and multisectoral computable general equilibrium (CGE) model, covering consumption and production behaviour for all the European Union countries in its design. We extend this model to the different income groups for each country, taking into account the potential inequality reduction.

On the basis of this model, we design a range of scenarios to make environmental and inequality reduction goals compatible. We use the evolution of consumption patterns and production structures of each country, to design strategies to go toward a more sustainable and just economy for 2050. Besides of these sustainable and more equally trajectories, we use the evolution of diffusion patterns of innovation, clean technology and carbon intensity in key sectors. Therefore, this model is intended to be the base for the development of empirical applications and the generation of scenarios of technological, environmental and consumption pathways.

## SDEWES2021.0098

# The Influence of Regulation, Taxes and Charges on the Energy Supply of Buildings

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## Abstract

Nowadays, many technologies to supply buildings with heat, cold, and electricity exist as well as technologies for energy storage. The motivation of this research work is on the one hand to investigate the influence of current German regulation, taxes and charges on energy carriers on building energy systems. Furthermore, the aim is to show which regulatory approaches represent the most cost-effective solutions for energy supply that lead to CO2 neutrality and also to the use of energy storage systems. A mixed-integer linear programming is used to optimise the supply components taking into account variable electricity tariffs. The variable electricity tariffs are calculated according to the "merit order" rule, taking into account government forecasts and scenarios as well as various concepts for the taxation of energy sources. A new method for the precise estimation of investment costs between 2015 and 2050 is developed and applied. The paper shows how an optimal house energy supply would look like under current and changed legal framework conditions as well as different tax burdens and reliefs. Initially, the optimal energy supply constellations for three different types of buildings (new low energy house, modernised building, old unrefurbished building) were identified and analysed under current conditions. In the next step twelve different taxation concepts were defined and their influence on the energy supply of residential buildings is analysed.

The results show that in order to decarbonize the heating sector, the taxes on electricity, natural gas and oil should be aligned as soon as possible. In this case, the attractiveness of fossil fuels will be replaced by (renewable) electricity-based heating systems in the whole observation period. When electricity and gas prices are too low, the inefficient direct heating system is used instead of the efficient heat pump technology. Thus, a certain level of energy prices is of major relevance for the penetration of high efficiency solutions. A huge price difference between natural gas and electricity leads to the effect that thermal storage tanks remain unattractive.

## SDEWES2021.0482

# Effect of Recycled Content and Other Policies on Plastic Packaging Industry – an Analytical Economics Approach

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## Abstract

Expended product responsibility schemes have effectively increased the separately collected plastic waste. However, due to the structure of the recycling industry, these mechanisms cannot increase recycling rates up to the objective levels.

Additional policy instruments to increase recycling rates such as recycled content targets, bonus green dot fees for recycled contents, recycling targets and tax on non-recycled plastic packaging have been discussed on a political level in the last years. However, the effectiveness of these policy interventions has not been quantitively studied yet.

This paper examines the effectiveness of the implementation of these policy instruments to increase recycling rates and the impact on different stakeholders of the value chain: plastic producers, consumers, collectors, and recyclers using a partial equilibrium model. Results show that a mix of direct interventions and economic interventions would effectively decouple recycling markets from oil markets and provide incentives for technological development.

## SDEWES2021.0766

# Second-Life EV Batteries for Stationary Energy Storage Applications in Local Energy Communities

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## Abstract

Alongside the concern on environmental sustainability, the concept of Circular economy, term for an economic system designed to regenerate itself, has gained momentum. Local Energy Communities (LEC), a fairly modern concept where collectivity and circularity find full expression, are based on an approach centred on sustainable development, self-production and circular economy. In particular, Energy Communities are an innovative model according to which local energy needs are met independently, through the choice of shared solutions for energy production from renewable sources. The matter of including batteries in early experimental configurations of energy communities is controversial, mainly because of their high up-front cost, often not yet economically sustainable. Erstwhile the use of stationary energy storage systems for self-consumption optimization, load management, peak shaving, back-up power and, not least, for the provision of ancillary services, would foster the value of these communities. In this paper, we design a techno-economic analysis to assess the impact of usage of the second life of batteries for increasing energy self-independence of LECs. For the study, we will consider cost minimization with technical constraints for the analysis. Hourly annual load profile data for consumption and other inputs related to prices and PV generation profile will be used. This paper assesses the benefits of using battery systems for load shifting and grid balancing needs, while addressing the problem of high costs through the exploitation of 2nd-life batteries, adding an extra layer or circularity. Scenarios related to maximizing self-consumption of PV with storage from the second life of batteries and demand-side management will be designed. The economic impact of the second life of batteries on the LECs energy usage will be studied while considering the technical aspects of the proposed system.

## SDEWES2021.0792

# Interdisciplinary Research on the Solar Energy Implementation in the Context of the Circular Economy

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## Abstract

The interdisciplinary research conducted in this paper covers all processes from the moment of production of photovoltaic panels, through the processes of transformation of solar energy into electricity, to the decomposition of all used materials, or parts, in the context of circular economy. The goal was to use all materials or parts that remain as excess in the process of producing electricity from solar, as a resource in another process at the right time, and to reuse them to the level of zero waste. In this way, new, increased costs of electricity production from solar panels are achieved. The author calculated and named them as environmental protection costs and sustainability costs. The costs are expressed in €c/kWh. Environmental protection cost and sustainability cost should be added to technology costs in all optimizing analysis. Environmental protection costs include all costs arising from all mitigation measures of direct environmental impact in the process of electricity production from solar energy. What is called sustainable costs in this paper includes all the additional costs of decomposing all used materials and reusing them to the level of zero wastes. The electric power system of Serbia was a case study to which the previous principles were tested and calculated, giving a comparison of technology, environmental and sustainability cost.

## SDEWES2021.0805

# Contribution to Strategic Project Management for Dams Towards Sustainability

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## Abstract

Dams are one of the most important strategic structures. The main goal of this manuscript is to research interdisciplinary and to improve the project management for dams. Although dams are constructed for production of renewable clean hydro energy, from circular economy point of view, there are still pending problems for solving and improving present stage. For example: the question of dam removal is not analyzed in the context of holistic approach to sustainable solution research, within a project management for dams. The aim of this paper is to present the complexity of one hydro power plant removal project and its total cost in comparison with the total cost of dam construction. There is also a discussion on question when this additional cost has to be included in a strategic project management and who should bear the expenses of the removal project. Recommended answers to a decision maker are offered. The project of simulation of dam removal has been done on case study of gravity dam and hydropower plant Paunci on the Drina River.

## SDEWES2021.1088

# The Importance and Potential of Photovoltaics in the Context of Low-Carbon Development in Poland

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## Abstract

The main topic of the publication is the development of photovoltaic systems in Poland, and its main goal is to characterize the current situation and development prospects in a given subject area in the context of the growing importance of the low-carbon economy in Poland. The article uses both secondary and primary (Foresight) data. The development of photovoltaic micro-installations in Poland, recorded in recent years, was possible thanks to the state support. Unnecessary administrative barriers have been removed, legal provisions have been simplified and adapted to small, distributed systems. However, there is a risk of a slowdown in the high dynamics of rates on the analysed market in Poland due to changes in legal solutions planned by the state.

This study was conducted and financed in the framework of the research project “Economic aspects of low carbon development in the countries of the Visegrad Group”, grant No. 2018/31/B/HS4/00485, granted by the National Science Centre, Poland, program OPUS.

## Green economy and better governance 2

## SDEWES2021.0209

# Green Measures in Urban Areas

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## Abstract

Natural water retention measures are multi-functional measures that aim to protect water resources using natural means and processes. Those measures can contribute to reducing the risk of floods and water scarcity and drought while also improving the status of surface and ground water bodies. They can support the achievement of the goals of a range of EU policies, including those for surface water, groundwater and coastal management, nature conservation, agriculture, forestry, urban, green growth and climate change mitigation and adaptation. Rainwater harvesting involves collecting and storing rainwater at source for subsequent use, for example, using water butts or larger storage tanks. Tanks can be specifically designed and managed to accommodate storm water volumes, which is likely to be more effective when applied at a larger scale than individual properties. In general, however, rainwater harvesting should be considered only as a source-control component in a sustainable drainage system; where, in combination with other measures, they will contribute to effective and sustainable water management. If collecting systems and rainwater infiltration, cannot cope with high rainfall intensity, this can be done by municipalities or by the services of water supply and sanitation, storage pools volumes of water. These volumes are stored for a short time after being pumped into sewers or drainage. These tanks can be positioned in park areas, parking areas, shops, etc. Existing experiences can be sources of inspiration for your own organization, planning process and geographic area and are presented in the paper.

## SDEWES2021.0264

# The Evolution of the Post-Consumer Plastic Packaging Waste System in Flanders

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## Abstract

The use of plastic packaging has known a sharp increase in the last decades. As most of this packaging material is destined for single use, a large amount of plastic packaging waste has emerged. To minimize the environmental cost of this waste, various waste management strategies have been introduced in different regions. In this study, post-consumer plastic packaging waste management in Flanders (Belgium) was analyzed by performing a dynamic material flow analysis, covering a time period from 1985 to 2018. The considered waste management system starts from the consumer plastic packaging put on the market. The considered system ends with the production of secondary raw materials or when the materials end up in their final destinations, for example as emissions to the environment or as landfilled materials. In addition, a potential future scenario was included in which the current plastic packaging collection system will be extended towards new plastic packaging materials. Recycling rates were calculated for the different years in order to analyze the historical and expected future trend. The recycling rate of post-consumer plastic packaging has known the largest increase when installing the separate collection of the plastic, metal and beverage carton packaging in the typical blue bags at the end of the 90's. However, a large amount of post-consumer plastic packaging waste is still destined to end up with the residual waste from which only energy is recovered. In the future scenario, the recycling rate will increase, however, the fraction ending up in energy applications remains prominent. One of the reasons for this observation is that the required purity in the sorting process of the additional fractions leads to a relatively high residue stream. Strategies to improve the recycling rate could focus on increasing the collection rate in selective collection or introducing a sorting step after the residual collection. An increased recycling rate of post-consumer plastic packaging is important in the transition towards a circular economy, where it can lead to a reduced requirement of raw materials and can cause a reduction in landfilled and incinerated materials.

## SDEWES2021.0360

# Sustainability Framework for Assessment of Mergers and Acquisitions in Enegy Sector

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## Abstract

According to Thomson Reuters DataStream database, 22.458 merger and acquisition (M&A) transaction in deal value that exceeds 7.016 billion Euros have occurred in the energy worldwide sector during 1995-2020. Uncertainties and shockwaves sent by COVID-19 to the global economy does not exclude the M&A market. A significant number of announced deals were either postponed, amended or cancelled, many planned M&A have been deferred during 2020. However, multinational and emerging market enterprises are still keen to utilize international M&A as means of springboard for strategic resources. International M&A enables promotion of sustainable competitive advantages, accelerates industry developments, and helps to promote sustainable social and economic development. COVID-19 has accentuated the centrality of sustainability for business resilience. Any resilience and sustainability discussion was contended with health, safety and wellbeing. Moreover, the pandemic has clearly exalted the role of partnerships in current world.

M&A enable the involved companies not only to maintain, but also to strengthen their competitiveness in the market. In the short run, pursuing M&A in the search of external growth opportunities and strategies for company's value enhancement have an impact to both the acquiring and acquired companies involved as well as to the industry itself. In the long run, M&A are important in pursuance of environmental-, social-, economic sustainability and innovation in the energy sector.

This research aims to systemize empirical studies which would allow assessing relationship between M&A transactions and the principles of sustainable development in the energy sector. To do so, SALSA methodology containing search, appraisal, synthesis, and analysis with additional snowballing technique is conducted.

Current research contributes to existing knowledge by providing an extensive systematic literature review of the academic publications on sustainable development and M&A deals. This paper may be insightful for practitioners and scholars because it highlights the most relevant lines of research on the topic and provides a synthesis of the interdisciplinary literature. Practical contributions of this paper come from synthesis of interconnections between sustainable development and M&A deals, which enables holistic understanding of sustainable development and M&A deals.

## SDEWES2021.0397

# Shadow Pricing of Energy-Related Carbon Emission in Agriculture: an Adaptive Approach

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## Abstract

The agricultural sector is important in regards to resource consumption and food provision. The public support programmes implemented worldwide allow stimulating the transition towards sustainable energy use in agriculture among other objectives. This paper seeks to disentangle the major patterns in energy-related GHG emission performance in the selected European Union countries. The country-level data are used to construct the environmental production technology by means of the data envelopment analysis. The different directional output distance functions (aggregate, unit and radial) are used to quantify the shadow prices and construct the marginal abatement cost curves. The results indicate spatial and temporal variation in the environmental performance that can be addressed by adjusting the support programmers.

## SDEWES2021.0894

# A Decision Support System to Analyze the Forest Circular Bioeconomy

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## Abstract

In recent years, the growing anthropogenic pressure on environment has forced the international policy community to adopt strategies and policies to reduce the negative impacts on natural resources. In this context, the circular bioeconomy is an important opportunity to connect socio-economic and technical processes with environmental sustainability. In particular, forest resource plays a key role with a relevant reference to the potential of bioenergy production.

The main objective of this work is to describe the development and the application of a Decision Support System (DSS) integrated into GIS Grass software in order to analyze the level of sustainability of the forest supply chain in a context of circular bioeconomy. The DSS – named r.forcircular – includes a graphical interface that allows to import a series of geodatabases and to set parameters related to the study area boundaries, morphology, forest stand characteristics as-well-as technical and economic variables. The model identifies forest areas potentially exploitable from both technical (according to mechanization, logistic and geomorphological variables) and economic (through the estimation of stumpage value) point of view. Subsequently, the use of indicators belonging to the 4R framework of the circular economy (Reduce, Reuse, Recycle, Recover) allows to evaluate the level of circularity of the forestry supply chain. Finally, the application of multicriteria procedure (compromise programming) permits to identify the potential of forest areas to be sustainably managed for the production of traditional wood assortments and bioenergy. The model facilitates geographical analysis of production process and user-friendly quantification of each economic and bioeconomic indicator.

The DSS r.forcircular has been tested in the area of the Municipalities Union Valdarno and Valdisieve (Tuscany region, Italy) demonstrating the usefulness of accountability applied by scenario and sensitivity analysis in the forest circular bioeconomy framework.

## SDEWES2021.0991

# Modeling of Integrated Organic Waste Management System Based on the Principles of Sustainable Circular Economy

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## Abstract

Inadequate organic waste management known by the concept of linear economy leads to the generation of new amounts of waste and immobilization of nutrients and chemical energy which, by being excluded from the natural processes of matter circulation, become inaccessible for reuse. The application of the concept of circular economy (CE) in an integrated organic waste management system on one territory enables the return of nutrients to nature and energy utilization with minimal generation of new quantities of organic waste. Within this research, the analysis of the possibility of including the maximum quantities of organic raw materials generated in one territory in the organic waste management system according to the principles of circular economy, as well as the model development for integrated organic waste management. Various CE indicators will be developed to assess the efficiency of the implementation and application of the circular economy.

## Hybrid and electric vehicles

### SDEWES2021.0449

# Efficiency Comparison of Different Powertrain Structures Intended for a Hybrid Skidder

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## Abstract

Hybrid powertrain presents a viable solution for reducing fuel consumption achieved by a powertrain electrification while maintaining the independence from the electric grid or a charging station. Due to the fact that skidders belong to the class of forestry machinery which is intended for field use, this operating independence is very important. A simple backward-looking model of a series hybrid powertrain skidder is developed and presented in this paper. The model is then simulated over a number of previously-defined operating missions which include realistic track slopes and variable loads. The results are compared with the results of conventional and parallel hybrid powertrains proposed in previous works. Simulation results show that 17% fuel efficiency improvement is obtainable with the proposed series configuration over the conventional skidder in skid trail driving. Finally, the return of investment period of series hybrid and parallel-hybrid configurations are compared, and their respective advantages and disadvantages are listed and discussed.

## SDEWES2021.0450

# Comparison of Two Battery Charging Control System Designs Without and with Soc Estimator

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## Abstract

This paper presents two designs of constant-current/constant voltage battery charging control systems in the form of a cascade control system arrangement with the superimposed proportional-integral (PI) controller commanding the battery charging current reference to the inner PI controller-based current control loop. The superimposed control level can be realized as: (i) battery terminal voltage limiting control loop, or (ii) battery state-of-charge (SoC) control loop based on SoC estimation using an extended Kalman filter (EKF), augmented by the aforementioned battery terminal voltage controller for preventing battery over-voltages. The control system design is based on the suitable control-oriented model of the battery charging process and utilization of damping optimum criterion. The effectiveness of the proposed battery charging control system has been verified by means of simulations using the readily available model of a lithium-iron-phosphate ($LiFePO_4$) battery cell.

## SDEWES2021.0457

# Potential Use of Novel Efficient Direct Driven Electro-Hydraulic System for Skidders

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## Abstract

Nowadays there are increasing demands in terms of reducing the cost of running forestry machines along with the regulatory pressures for lower exhaust emissions to improve the ecological indices and reduction of acoustic noise in order to comply with increasingly more stringent industry ergonomic guidelines. Therefore, the producers of forestry equipment are increasingly interested to make such heavy machinery more efficient, which can already be seen with the emergence of certain hybrid and electric powertrain-based forestry vehicles. However, many tools and accessories used by these heavy vehicles are still powered by hydraulics systems. For example, articulated forestry tractor known as skidder uses hydraulic steering, hydraulic lifting for front pushing plate or rear protection plate, and also uses a hydraulic double-drum winch. Having this in mind, this paper investigates the possible use of direct driven electro-hydraulic system instead of the classical one in order to increase the skidder's operating efficiency. Both the classical and direct driven electro-hydraulic systems are modeled, simulated and experimentally verified for the purpose of comparative analysis of their efficiency. Experiments are carried out under laboratory conditions and experimental results are obtained both for the unloaded cylinder and different payloads. The obtained results are used to gain insights about the possible advantages of the directly driven electro-hydraulic system.

## SDEWES2021.0461

# Design of a Starting and Torque Boosting System for and Internal Combustion Engine Using a 48V Starter Motor/generator Within a P0 Mild Hybrid Vehicle Configuration

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## Abstract

Gradually stricter demands on CO2 emissions reduction imposed by the European Union have proved as an efficient motivator for automobile manufacturers to develop novel technologies in order to electrify their respective fleets. Starting from 2020, the average emissions target for a manufacturer's fleet is set below 95 g CO2/km, which corresponds to 27% reduction compared to the former target of 130 g CO2/km. In order to meet the new emissions regulation, road vehicles require additional technologies aimed at the reduction of energy demands from the internal combustion engine (ICE). Favorable solution from the standpoint of costs and simplicity of integration is a 48V electrical architecture utilizing a low-power induction machine, which operates both as a starter and a generator, and is coupled via a timing belt with the crankshaft of an ICE, widely known as the BSG (belt starter generator). BSG is a component of a compounded system named FEAD (front end accessory drive), an integral part of a P0 mild hybrid power-train, used for starting-up and boosting of the ICE power output, as well as recuperating energy used for the vehicle deceleration. The aim of this work was to design a vibration damping system for the belt transmission system within the FEAD which couples the BSG pulley with the ICE crankshaft pulley and to test the aforementioned system by means of simulations for realistic operating regimes of the P0 mild hybrid power-train.

## SDEWES2021.0670

# Prospects for the Electrification of Road Transport: Battery Electric Vehicles vs. Fuel Cell Vehicles

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## Abstract

The electrification of the transport sector is considered as an important means to cope with the continuously increasing greenhouse gas emissions caused by different transport modes, especially by road transport. It combines energy efficient automotive powertrain systems, such as battery electric- and fuel cell vehicles, with the possibility to increase the use of renewable energy in the transport sector. Depending on the type of alternative vehicles as well as primary energy sources used for electricity and hydrogen production, the contribution of electrification could have very different magnitude. Currently, electric passenger cars are widely supported with different monetary- and non-monetary measures. However, since the transport electrification closely interacts with economic systems, market penetration of electric vehicles is still relatively low, mostly due to higher costs and shorter driving range in comparison to conventional vehicles.

The core objective of this paper is to analyse perspective of electrification of road transport considering different vehicle types, such as cars, buses and trucks. We investigate the pros and cons of electrification of these vehicle categories, focusing on cost-benefit analysis. Finally, the future prospects and most favourable applications for battery- and fuel cell vehicles are identified.

Our method of approach is based on economic and environmental assessment of electric vehicles in comparison to the corresponding conventional fossil-fuelled vehicles. The economic assessment covers total costs of mobility per kilometre driven. The environmental assessment has a major focus on the impact of electricity- and hydrogen production. Furthermore, the effect of different policies applied in most successful countries in electrification of the transport sector, will be discussed in the context of their social, economic and environmental impacts.

From the current perspective, hydrogen-powered electric vehicles are more suitable for larger distances and more powerful vehicles, such as rural public bus-systems and heavy long-distance-driving trucks. Battery electric vehicles are suitable for passenger car mobility, as well as for the public transport in urban areas. However, the majority of electric transport applications in cities are grid-connected public transport facilities.

The major conclusion is that battery electric- and fuel cell vehicles are inevitable in the transformation of the transport system. Selecting the most favourable technologies from an energy economic point of view, as well as appropriate policy measures is of very high relevance in this transition.

## SDEWES2021.0675

# Solar-Powered Small Autonomous Boat for Environmental Measurements

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## Abstract

Nowadays, the usage of small autonomous boats has been increasing in popularity. Their main tasks are to perform environmental measurements, data acquisition, and processing, garbage collection, as well as water hazards detection. Autonomous boat platforms can be also adapted to a variety of other applications, such as aquatic animal population control, contamination detection, and shore control. This paper shows the development of the novel construction of a small autonomous boat engineered by the AGH Solar Boat Team at the AGH UST in Krakow. The presented construction of the autonomous boat is based on a hull specially designed for this purpose. The geometry and internal construction of the hull have been modeled using CFD methods. The high strength and rigidity of the hull are ensured by the use of composite materials of ecological origin (flax fibers and bio-based resin). On the top of the boat, there is a flat deck, dedicated to mounting custom ultra-light photovoltaic panels. The PV panels are the main power source for the boat, which allows providing self-sufficient operation in suitable weather conditions (as was shown during dynamic simulations). The design of the propulsion and steering systems of the boat was optimized in terms of minimizing energy consumption. The developed unit was equipped with sensors for environmental measurements, including e.g. pH, turbidity, oxygen content in water, and water purity sensors. Simulations conducted using TRNSYS software allowed the comparison of different operating scenarios and select these, which were connected with an autonomous boat operation.

## SDEWES2021.0976

# A User Perspective on Current Drivers and Barriers for Electric Vehicle Usage in Austria

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## Abstract

The global electric vehicle market is rapidly growing, which is an important step, as electro-mobility is an essential driver for achieving climate targets. However, acceptance of electric vehicles is still lacking among potential users. To overcome their skepticism, it is necessary to understand the decisive factors for the consumers' decision-making process. Therefore, this work investigates essential drivers and barriers to electric vehicle adoption derived from international literature. Electric vehicle users from the electro-mobility-club Austria were interviewed by means of an online survey. Importance-performance analysis was conducted to analyze the data. Interpretations are supported by means of receiver operating characteristic analysis. The results show that the environmental performance of electric vehicles is a key motivator for participants and that this is already perceived as satisfying. Major barriers governments and manufactures should address are acquisition cost, range and time consumption associated with the usage of electric vehicles.

## SDEWES2021.1036

# Energy Consumption Analysis Modelling of a Mid-Size Bev

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## Abstract

Increasing environmental concerns and stricter emission legislations imposed by governments worldwide are generating market demand for electrified powertrains and we are currently experiencing an automotive paradigm shift. In addition to traditional powertrains, manufacturers must produce electrified powertrains of various degrees, ranging from mild hybrids to pure electric drive vehicles, putting most of them into a position where they can no longer rely on past experience and standardized workflows.

Due to the (still) limited range of xEVs, efficient integration and control of vehicle systems is essential. An efficient way to tackle this system complexity is by virtualizing the development process with the help of system simulation tools. Using them, engineers can design and optimize individual vehicle systems and integrate them into a common simulation model to investigate the interdependencies between them and consequently optimize them to maximize the efficiency of the vehicle. This approach is also more time and cost-effective, as many design decisions can be made early in the development process, this way reducing the need for prototyping and testing.

The paper demonstrates a state-of-the-art modelling approach used in the development of battery electric vehicles. The model comprises sub-models of the driveline, electric motor, high voltage battery, thermal models of the battery and the electric motor, as well as the air conditioning system and vehicle cabin and enables simulation of transient drive cycles. The model's fidelity level makes it suitable for energy consumption studies due to the closed causal chain between the operating load of the powertrain and the energy consumption.

Key results of the model include the power of the electric machine and the battery, the power required for cooling/heating the vehicle and its components and the temperatures of the coolant and cabin air and have been validated against a comparable benchmark vehicle available in-house.

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## SDEWES2021.0175

# Influence of Waste-to-Energy Plant Integration on Local Imission Load

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## Abstract

Landfilling is still the most common municipal waste treatment method in around half of the EU countries. It has been shown that diverting some of the waste to energy recovery makes it possible to reduce emissions of various pollutants, especially if the waste replaces lower quality fossil fuels in heating plants. A methodology is, therefore, presented for assessing the influence of a Waste-to-Energy plant integration into an existing district heating system on the local immission load. The change in emission production is estimated using a previously developed optimisation tool. The parameters of the existing heating plant, such as the fuels used, the boiler output range, etc., are considered. A Gaussian scatter model is then utilised to determine the local immission loads of individual pollutants. This strategy is presented via a case study involving real-world data.

## SDEWES2021.0401

# Experimental and Mechanism Study on the NOx Formation and Control During the Self-Sustaining Incineration Process of N-Containing VOCs (Dimethylformamide)

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## Abstract

Dimethylformamide (DMF) is widely used in electronic industry, it is released in large quantities during the production of Copper Clad Laminate (CCL, the basis of printed circuit board), and mixed with air to form the extremely low equivalent ratio of lean combustion conditions. Preheating the mixture to a high temperature (~600 °C) to keep a self-sustaining combustion is now the most widely-used low-cost processing mode. In this paper, electronic industrial DMF-air mixture incineration process is taken as an object. Based on the jet stirred reaction system, the products from thermal decomposition and oxidation in fuel-lean condition of dimethylformamide were investigated in the temperature range of 450-900 °C. Experiments with different residence time were conducted for pyrolysis and equivalent ratio was changed from 0.05 to 0.20 in oxidation experiment. At last the SNCR denitration experimental study was performed at the typical oxidation condition in a temperature range of 825-975 °C. The results show that fully thermal decomposition of DMF at high temperature mainly produces $H_2$, CO, HCN, $CO_2$ and $CH_4$, as well as a part of $C_2Hx$ and a small amount of N+. The significant species formation after a residence time of 3 seconds' pyrolysis mostly begin from 450-650 °C. During the fuel-lean oxidation period of 3 seconds, the fuel nitrogen conversion form of DMF-air varies greatly in the range of 600-900 °C. HCN and $N_2O$ reach the highest values at 650 °C and 750 °C respectively, while $N_2$ and NO increase and become the main final nitrogen conversion products with temperature above 800 °C. The denitration efficiency of SNCR is about 30%-50%, and the increase during temperature rise is not significant, which is related to the participation of $N_2O$. This study provides experimental data on the oxidation and pyrolysis mechanism of DMF, as well as an important reference for the efficient and clean combustion of industrial DMF-air mixture.

## SDEWES2021.0403

# Experimental Study on Emission Characteristics of a Pre-Combustion Low NOx Burner in an Industrial Boiler

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## Abstract

The increasingly stringent emission standards in China lead to lower emission requirements on the coal-fired industrial boilers, and it is difficult for the existing industrial boiler to meet the emission standards without the selective catalytic reduction (SCR) technology. This paper presents a new type of low-$NO_x$ coal-fired industrial burner. The effects of primary air ratio, secondary air ratio, swirl vane angle, FGR ratio and OFA ratio on the $NO_x$ emission. The results show that the $NO_x$ concentration gradually increases as the primary air ratio increases from 7.8% to 8.5%. As the inner secondary air ratio increases from 0.67 to 1.32, the $NO_x$ concentration gradually increases. The amount of $NO_x$ concentration decreases first and then increases with the angle of swirl vane increases from 30 ° to 60 °. The OFA ratio has a feeble influence on $NO_x$, and the overall trend is to decrease first and then increase with increasing OFA ratio. The $NO_x$ concentration decreases and and the extent of decrease slows down as the FGR ratio increases from 0 to 13.3%. The $NO_x$ emission is 175 mg/m$^3$ (9% $O_2$) while the carbon in fly ash is 14.94 % and the boiler thermal efficiency is 91.7%.

## SDEWES2021.0428

# Numerical Assessment of NOx Formation and Control in Pressurized Oxy-Ammonia Combustion

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## Abstract

Pressurized oxy-combustion is an emerging technology and has a high efficiency compared to atmospheric combustion for carbon capture, utilization, and sequestration (CCUS). NOx is one of the significant conventional pollutants produced by pressurized oxy-combustion, which has not only a disastrous effect on the environment but also aggravate the corrosion in the CCUS system. Ammonia is one of the primary gaseous precursors for NOx generation in solid fuel combustion; however, it can also reduce the NOx in the post combustion process. Moreover, today, ammonia is an emerging and one of the most attractive carbon-free fuels to combat greenhouse gas emissions. Nonetheless, the evolution of NOx in pressurized ammonia combustion is still very rarely studied, especially in the oxy-environment. Therefore, it is imperative to study the NOx formation and its control by ammonia oxidation in pressurized oxy-combustion. In this study, first, the formation of NOx from pressurized ammonia oxy-combustion is kinetically evaluated. The effect of different parameters is investigated at high pressure i.e., by comparing the effects of oxy and the air environment, temperature, $H_2O$, and $SO_2$ concentration, on NOx formation. After that, the SNCR process is analyzed at high pressure to control the NOx using the actual post oxy-combustion conditions. The results show that the ammonia oxidation temperature decreases significantly as the pressure rises from 1 atm to 10 atm. Pressures larger than 10 atm have no effect on the oxidation of $NH_3$. The NO concentration continuously decreases with increasing the pressure, which means that higher pressure has a beneficial effect on NOx reduction efficiency. The NO formation in the air is significantly higher than in the oxy environment, which may be due to the significant thermal NOx formation in an air environment. The water vapour enhances the NO formation in the oxy environment significantly at 1 atm; however, this effect is suppressed by elevated pressure. There is no effect of $SO_2$ on $NH_3$ oxidation and NO formation at both atmospheric and elevated pressure. The concentration of NOx formation decreases from 180 ppm to 40 ppm, increasing the pressure from 1 atm to 15 atm, respectively. Further, the optimum temperature window for $NH_3$ oxidation shifts very significantly toward the lower temperature, increasing the pressure. In addition, the de-NOx efficiency by the SNCR process is enhanced by 2 to 3% with an increase in pressure from 1 atm to 15 atm. Moreover, the width of the optimum temperature window for maximum De-NOx is broadened from 1250K to 1450K with increasing the pressure from 1 atm to 10 atm. The benefit of the temperature window expansion is that it offers flexibility in the position of the injection system, and NOx control could be attainable over a vast boiler operating range. This study can guide the assessment of NOx formation and its control in pressurized oxy-combustion processes.

SDEWES2021.0429

# Study on Preheating Decarburization Process and Combustion Characteristics of Fine Slag in Coal Gasification

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## Abstract

Coal chemical gasification process produces a large number of gasification coarse slag and gasification fine slag. The gasification coarse slag is directly discharged from the bottom of the furnace, which is similar to the boiler ash slag in composition and has low carbon content, and it can be used as raw materials for road building or backfill treatment. Due to its high carbon content and large burning loss, gasification fine slag does not meet the national and industrial standards of building materials. The gasification fine slag has high water content, high carbon content and extremely low volatile content. The landfill and stacking treatment occupies a large amount of land resources, which not only wastes resources, but also causes serious environmental pollution. At present, low proportion mixing into the furnace combustion is the main way of large-scale absorption, but the treatment capacity is relatively small, and the long-term continuous mixing combustion on the stability of the system, boiler combustion efficiency of the negative impact needs to be verified. The internal combustion process of constant temperature preheating and decarburization unit for low volatile and low calorific value fuel can be simulated by using thermogravimetric experiment platform for constant temperature thermogravimetric experiment, which can provide the data under the different preheating temperature and combustion atmosphere size grading gasification for the comparison and analysis of combustion properties of fine slag. It was found that the gasification fine slag samples began to oxidize rapidly when oxygen was introduced, and the burnout time was between 6.6-9.4 min at 900 °C and 10% $O_2$, and 3.7-5.6 min at 900 °C and 21% $O_2$. Under the condition of controlling the NOx value within the specified range, the oxygen concentration in the combustion zone could be appropriately increased to shorten the burnout time. With the increase of preheating temperature, the average weight loss rate of gasified fine slag samples with the same particle size grading increases regularly, while the burnout time decreases regularly. The increase of preheating temperature can improve the burnout characteristics of gasified fine slag, and the combustion zone temperature can be appropriately raised to achieve faster burnout under the safe operation of the equipment. Under different combustion atmosphere and preheating temperature, with the increase of particle size of gasification fine slag, the weight loss and the burnout time increases regularly, and the average weight loss rate decreases regularly. Therefore, the preheating and decarburization device needs to reasonably adjust the residence time of materials according to the particle size of materials in order to achieve full burnout.

## SDEWES2021.0464

# Modeling Char Evolution for Bituminous Coal During Pyrolysis at High Pressure

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## Abstract

Global warming has aroused the attention of countries all over the world. Different laws, policies, and technologies have been promoted in recent years to abate greenhouse gas emissions. Pressurized oxy-coal combustion is one of the most promising technologies to realize the carbon capture in large-scale power plant in the future. While the ambient pressure could significantly influence the coal pyrolysis behavior, including the volatile releasing, char evolution and fragmentation. In this study, Yulin coal was used for the pyrolysis experiment in a pressurized drop tube furnace. The produced char was analyzed by the scanning electron microscope (SEM). A single bubble model was used to simulate the char evolution process during pyrolysis at elevated pressure, where the volatile releasing rate and yield by residence time can be obtained from the CPD (chemical percolation devolatilization) model. It shows that the revised single bubble model could be suitable for predicting the char evolution over a wide range of pressure and heating rate. An optimum pressure is present around 10-15 atm, where the swelling ratio and porosity reach to the maximum value. This model can predict the two regimes of coal swelling in varied heating rates, which is more obvious at high pressure. The variation trend of porosity is similar with the swelling ratio.

## Modelling for pollution avoidance and energy efficiency 2

### SDEWES2021.0081

# Quantifying the Transmission of Outdoor Pollutants into the Indoor Environment and Vice-Versa – Methodologies, Challenges and Future Direction

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## Abstract

Air pollution is a global cause of concern with its widespread nature and health impacts. Numerous epidemiological studies have shown a strong relationship between poor air quality and deteriorating health, demanding urgent remedial measures. Specifically, indoor pollution is more critical as it is widely reported that people spent about 80% of their time indoors. Moreover, the current pandemic has forced people to spend a significant portion of their time indoors. Outdoor pollutants significantly contribute towards indoor pollution, its strength depending on various parameters including ventilation strategy, meteorology, building design, outdoor strength etc. Thus, quantifying the transmission of outdoor pollutants into the indoor environment and vice-versa remains a priority for environmental planning. Experimental studies have shown a wide range of values of the indoor to outdoor pollution ratio, varying from 0.02 to values greater than 20. Similarly, modelling studies have also reported a wide range of values for different relationships. This study analyses the various factors which have been reported to influence the transmission of pollutants between the two environments. The report critically reviews the studies which have investigated the inter environment variability and transmission, providing an overview of various factors and its impacts, based on the analysis of over 200 recently published works, covering both experimental and modelling studies. The analyses briefly describe the methodologies used in the studies of pollution transmission, its shortcomings and concludes with a discussion on improving the air quality by adjusting these factors. The analyses reveal, that while these studies have certainly helped to quantify the long-term personal exposure to pollutants and assess their health impact, they have not paid special attention to the mechanism of transmission of pollutants from outdoor to the indoor environment and vice versa. Partly due to the complex interaction between indoor and outdoor environment, and partly due to the dynamic nature of building occupation and use. Nevertheless, the quantification of infiltration is essential to determine the contribution of ambient pollutants in indoor air quality. Only after indexing these mechanisms and its relative strength, can designers make an intervention in buildings and urban environment to counter the effects of infiltration. Finally, the direction for future research is outlined.

## SDEWES2021.0144

# Investigation of the Impact of Outdoor Pollutants on the Indoor Air Quality of Naturally Ventilated Buildings in Urban Canyons

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## Abstract

The transition to remote working due to the pandemic has accentuated the importance of clean indoor air, as people spend a significant portion of their time indoors. Amongst the various determinants of indoor air quality, outdoor pollutants remain a significant contributor. This study aims to evaluate the transmission of outdoor pollutants into the indoor environment by using 3D Computational Fluid Dynamics modelling. The validated model can predict the indoor pollution levels for various building and urban configurations. Naturally ventilated buildings next to an urban canyon were modelled in ANSYS Fluent and validated using experimental data. The model consisted of two buildings with different window opening strategies, on either side of a pollution emitting road. Results indicate that for a canyon with an aspect ratio of 1, indoor spaces in the upstream building are usually less polluted than downstream ones. Although within the canyon, pollution is 2~3 times higher near the upstream building. Cross ventilation can minimise or prevent infiltration of roadside pollutants into indoor spaces, while also assisting in the dispersion of ambient pollutants. The critical configuration, in terms of air quality, is single-sided ventilation from the canyon. This significantly increases indoor pollutant concentration regardless of the building location. The study reveals that multiple factors determine the indoor-outdoor links, and thorough indexing and understanding of the processes can help designers and urban planners in regulating urban configuration and geometries for improved indoor air quality. Future works should look at investigating the influence of indoor emission and the effects of different seasons.

## SDEWES2021.0365

# Estimation of Mercury Emissions and Releases in Air, Water, Soil and Waste Using UNEP Toolkit in Albania

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## Abstract

Albania is a signatory country of Minamata Convention and is preparing for the ratification process, which comes with obligations for phasing out/down mercury-added products and better management of mercury emissions and releases from various sectors. This paper summarizes the results of the first national mercury inventory in Albania. Total mercury input, releases, distribution into different phase media, as well as major contributing source categories are discussed here. The development of mercury national profile for Albania was made mainly using UNEP Toolkit Level 1. The total mercury input in Albania is estimated to be 4,340 kg Hg/y. The total mercury release in Albania is 5,530 kg Hg/y, from which 2,370 kg Hg/y are released in the air. The largest mercury contributing source sub-categories to the atmosphere are open fire waste burning, thermometers, informal dumping of waste, cement production and electrical switches and relays. Estimated mercury releases are 1,220 kg Hg/y in water and 1,020 kg Hg/y to general waste. 790 kg of mercury is released to land in Albania on an annual basis. UNEP Toolkit 2 level was used only for the calculations related to mercury amalgam fillings. Data gaps and uncertainties are also summarized here.

## SDEWES2021.0474

# An Impact of 3D Printing Conditions on Emissions of Ultrafine Particles

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## Abstract

This paper presents a complex and extensive experimental evaluation of fine particle emission released by an FDM 3D printer for four of the most common printing materials (ABS, PLA, PET-G, and TPU). These thermoplastic filaments were examined at three printing temperatures within their recommended range. In addition, the measurements were extended by the use of various types of printing nozzles, which influenced the emissions considerably. This research is based on more than a hundred individual measurements for which a standardized printing method was developed. The study presents information about differences between particular printing conditions in terms of the amount of emitted fine particles as well as the particle size distributions during printing periods. This expands existing knowledge about the emission of ultrafine particles during 3D printing and can help to reduce the emission of these devices to achieve cleaner and safer operation of 3D printers.

## SDEWES2021.0612

# Prediction of Hg Distribution During the Process of Lignite Combustion in Fluidized Boiler and Flue Gas Cleanup with Use of Regression Models and Neural Networks

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## Abstract

The aim of this reaserch to determine the distribution of Hg in the process of lignite combustion in a fluidized bed reactor and assess the impact of the post-treatment on speciation and emissions of Hg into air. The results of the research will be used to develop regression models and artificial neural networks models, which will give the ability to continuously monitor the concentrations of Hg in the flue gases leaving the installation, based on the information about the fuel and combustion conditions. In the case of Hg emission limits exceedance, this tool will allow taking actions to recover the desired concentration levels of Hg in gases emitted into the atmosphere. Additional methods of post-treatment (dedicated only for Hg) can be used optionally, but not as a continuous unit. To verify the targets, an database for mercury (data regarding the distribution of Hg between the various coal combustion products, the content of Hg in lignites and their chemical composition, the influence of flue gas cleaning methods on the Hg speciation) has been used. The measurements was taken on demonstration installation in Czech Rapublic and in Polish power plants operating on lignite and supplemented with denitrification systems, dust collection and flue gas desulfurization.

## Modelling for pollution avoidance and energy efficiency 3

## SDEWES2021.0644

# Granulometric and Adsorption Studies of Four Albanian Natural Clays Toward Pesticides

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## Abstract

The use of natural soil components, such as clays has recently gained increasing interest for their promising properties as adsorbents and pesticide carriers. Four natural Albanian clays (Brari, Currila, Dardha, Prrenjasi) were characterized by granulometric analysis and powder X-ray diffraction. The granulometric analysis performed by Andreasen pipette and Torsion balance techniques were employed to categorize the samples based on their particle sizes and to correlate these parameters to their adsorption behavior toward selected pesticides. Currila and Dardha clays reveal finer textures, consisting mostly of particles with a mean diameter of 2.6 µm. Brari and Prrenjasi clays have a higher percentage of particles with mean diameters varying between 8 and 14 µm. Differential distribution charts show that Andreasen Pipette method reveals better distribution results, especially on the determination of the largest size of particles, which are clearly disregarded by Torsion balance method. The particle size distribution and their content strongly influence the adsorptive capacities of these clays towards selected pesticides.

The adsorption behavior and the adsorption capacity of each clay employed were studied for pesticide concentrations varying below their solubility limit in water. The overall adsorption process in each case is studied by the adsorption isotherm based on Freundlich, Langmuir, Temkin and Dubinin-Radushkevich models for a selected concentration and a variable time as well as for a selected time against variable pesticide concentrations. Aspects of the adsorption kinetics and intra-particle diffusion mechanisms are considered for the elucidation of the adsorption mechanisms.

## SDEWES2021.0789

# Effect of Length, Location and Angle of Inserting Internal Spiral Fins on the Micro Combustor Performance for Thermophotovoltaic Systems

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## Abstract

The temperature value and uniformity of combustor outer wall are significant to the energy conversion efficiency and energy output of combustion-based thermophotovoltaic systems. Therefore, the spiral fins are introduced into the micro combustor to improve the thermal performance. In this work, the three-dimensional models with detailed hydrogen/air reaction mechanisms, consisting of 13 species and 19 reactions, are employed. The influences of length, location, and angle of the inserting internal spiral fins on the flame and thermal performance of the micro combustor are systematically investigated. The distance between inlet and spiral fins of 7 mm and 9 mm exhibit more uniform outer wall temperature distribution and high outer wall temperature. The increase of internal spiral fins angle and length can improve the average outer wall temperature, but with higher pressure drop and worse temperature uniformity. From the viewpoint of engineering applications, the micro combustor with internal spiral fins is a simple and practical way to improve the low output power of the combustion-based micro thermophotovoltaic system.

## SDEWES2021.0795

# Experimental and Numerical Study of Ammonia/Methane/Air Laboratory Burner

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## Abstract

The object of the present work is numerical study of various turbulence models on the ammonia combustion under practical industrial conditions. San Diego chemical kinetics mechanism was selected based on our previous study for the analysis. Sensitivity analysis included k-ε model with turbulence chemistry interaction, k-ζ-f model and LES model, all three under different equivalence ratios. Simulation results showed only minor influence of turbulence on the results, with LES model producing more accurate results beyond equivalence ratio of 1. On the other hand, it required increased computational efforts, so k-ζ-f model could be considered optimum when compromise between computational intensity and model accuracy is considered. It is expected that this study will contribute to enhance the current knowledge by providing new insights in ammonia burning conditions closely resembling those in industrial applications and consequently help to design real industrial burning systems.

## SDEWES2021.0854

# Optimal Control of Reflux Ratio in Batch Distillation of Non-Ideal Binary Mixtures

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## Abstract

Distillation is the most widely applied technology for liquid mixtures separation and is solely responsible for approximately 40 % of energy use in process industries. Despite widespread adoption, its separation efficiency is quite low resulting in wasteful energy use, especially in batch mode which is particularly suitable for flexible small-scale production in specialty-chemical, biochemical, and pharmaceutical industries. Additionally, flexibility and inherent dynamic nature of batch distillation processes pose challenging design, modelling and operational problems. Various control modes of batch distillation can be utilized to produce the product of the same quality. Constant reflux ratio mode, which is most commonly used, consists of the start-up total reflux phase until steady state is achieved, followed by the product removal phase at constant reflux ratio. In this work, start-up and production phases of the batch distillation of non-ideal binary mixture are modelled by a system of differential and algebraic equations, which are embedded in the optimal control problem. Control problems are formulated with the goal of product maximization in prescribed time and minimization of time and energy for producing required yield by varying time dependent reflux ratio. Pontryagin maximum principle-based method is used to obtain optimal reflux ratio trajectories. Case study of ethanol-water mixture batch distillation for a batch size of 2 260 kg using a 500 kW reboiler is conducted. Results show that significant time and energy savings up to 23 % can be achieved by using optimal variable reflux ratio compared to conventional constant reflux ratio profile. Results confirm that total reflux ratio is optimal for start-up phase, albeit optimal transition to production phase occurs well before steady-state composition is achieved. Industrial application of optimized variable reflux ratio control mode potentially can significantly improve batch distillation process sustainability.

## SDEWES2021.0954

# A Comparison of Calibration and Uncertainty Analysis Algorithms for Altınapa Reservoir Watershed Hydrologic Model

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## Abstract

Hydrological models can be used for representing hydrological processes and analysing water quantity and quality at the watershed scale. Calibration and uncertainty analyses of these models are important for obtaining reliable results. Various calibration and uncertainty analysis algorithms are available in the literature. In this study, we compared four algorithms to calibrate a SWAT model developed for the Altınapa Reservoir Watershed in Turkey. The techniques selected include Sequential Uncertainty Fitting (SUFI-2), Parameter Solution (ParaSol), Generalized Likelihood Uncertainty Estimation (GLUE), and Particle Swarm Optimization (PSO) and they are available in the SWAT-CUP software developed for calibration and uncertainty analysis of SWAT models. The outcomes from different techniques were compared based on Nash-Sutcliffe Efficiency (NSE), determination coefficient ($R^2$), p-factor and r-factor. The results showed that SUFI2, Parasol, GLUE, and PSO provided NSE values in the range of 0.55-0.57 and $R^2$ values in the range of 0.56-0.61 during model calibration. NSE values were in the range of 0.37-0.55 and $R^2$ values were in the range of 0.50-0.60 during model validation. p-factor values ranged between 70% and 79% in calibration and 60% and 70% during validation. r-factors were between 0.69-1.32 and 0.55-2.17 during calibration and validation, respectively. In general, SUFI2 provided satisfactory results during both model calibration and validation. SUFI-2 calculation was accepted as a feasible technique; even though it requires more work and extra requirements for adjusting parameter ranges.

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## SDEWES2021.1000

# A New Non-Iterative Calculation Method for Cross-Flow Tube Heat Exchangers with Complicated Flow Arrangements

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## Abstract

A new method for thermal performance calculations of cross-flow tube heat exchangers was proposed. The method may be used to determine the temperature of hot and cool fluid along their flow path and the wall temperature. The heat exchanger is divided into segments, in which outlet fluid temperatures are calculated by analytical formulas in a non-iterative way. An example of the use of the method for the calculation of a two-pass cross-co-current superheater was presented. An analytical model was also developed for the superheater to estimate the accuracy of the proposed method. The results of the superheater calculation using the presented method are in good agreement with the results obtained by the exact analytical model. A mathematical model of an automotive radiator was also elaborated using the developed method. The results of the radiator calculations using the developed method were compared with the experimental results. The proposed method can be used to calculate heat exchangers with a complicated flow system in which the physical properties of fluids depend on temperature. The computation time of heat exchangers using the developed method is very short.

# Nano and micro technologies and science for sustainable development of energy, water, and environment systems

## SDEWES2021.0353

## Effect of Plasma Actuation on Film Cooling Performance

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### Abstract

In order to improve film cooling effectiveness, plasma actuator is arranged on blade surface in this research. As one novel device based on active flow control, plasma actuators have many advantages, such as fast response, small volume and low power consumption. Due to plasma aerodynamic actuation, the blade temperature decreases significantly. This paper investigated an effect of arrangements of plasma actuators on film cooling performance. Results show that the film cooling effectiveness is improved significantly when the plasma is applied to the wall surface. It is found that the maximum increment of the average wall film cooling effectiveness is 11.7% at low blowing ratios compared with plasma off (PA-off), when the actuator is arranged near the outlet of the film cooling hole (PA-up). Compared with the PA-off case, the average wall film cooling effectivenesses of the PA-down case and PA-both cases increase by 138.3% and 122.9% respectively.

## SDEWES2021.0650

# Condensation Pressure Drop Characteristics of Propane in Helically Coiled Tube-In-Tube Heat Exchanger

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## Abstract

This paper presents experimental study on condensation pressure drop characteristics of propane (R290) flowing through an annular passage of helically coiled tube-in-tube heat exchanger.

Experimental rig is compression refrigerant cycle that consists of compressor, condenser, expansion valve and evaporator. Compression cycle is equipped with internal heat exchanger that can be bypassed to see the effect of the component on the pressure drop in condenser. The test section (condenser) is made of two copper tubes that are coaxially oriented. Inner tube of the condenser is grooved on its outside surface. Diameter of inner tube is 19.7 mm and the nominal outer diameter is 22.2 mm. Inner diameter of outer tube is 35.0 mm. The coil diameter is 280 mm and the coil pitch is 42 mm. The coil axis is oriented vertically, so the pressure drop is affected by gravitational force.

Pressure drops are determined at different saturation temperatures 30 °C, 35 °C, 40 °C and 45 °C, and at different heat fluxes 21 kW/m$^2$, 26 kW/m$^2$ and 35 kW/m$^2$. Experimental results are compared to the existing pressure drop correlations found in open literature. The pressure drop results show a satisfactory agreement between the Lockhart-Martinelli correlation and experimental data. It is also noticed that the internal heat exchanger in compression cycle has significant effect on pressure drop due to its effect on thermophysical properties of refrigerant.

## SDEWES2021.0698

# Heat Transfer Effectiveness Characteristics Maps for Additively Manufactured Triply Periodic Minimal Surfaces Compact Heat Exchangers

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## Abstract

Increased power density in modern miniaturized electronics caused difficulty to keep electronic performance effectively. This challenge leads to the search for high-performance compact heat exchanger as one of the thermal management solutions. Conventionally manufactured heat exchangers had limitations that thwart the development of geometrically complex heat exchangers which are capable of exploiting topological aspects to enhance thermal performance. Subsequently, additive manufacturing (AM) is proposed as a powerful fabrication technique for compact heat exchanger based on the mathematically-known triply periodic minimal surfaces (TPMS). In this work, we present 3D compact crossflow heat exchanger computational fluid dynamics (CFD) modelling of geometrically complex structures based on TPMS using STARCCM+ CFD platform. Moreover, (CFD modelling is used to obtain new Characteristics Maps that relates Heat Transfer Effectiveness (Ɛ) and Number of Transfer Units (NTU) for the proposed heat exchanger. The convection heat transfer coefficient, pressure drop, and inlet and outlet fluid temperature are all examined.

## SDEWES2021.0831

# Detection of Microplastics Pollution in Dubai Coastal Water Using Senitel-2 Imagery and Regression Analysis

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## Abstract

The use of plastics in massive quantities has led to its accumulation on land and in turn to its transport to water. This accumulation has been attributed to the plastics non-biodegradable nature and poor waste management practices. When in water, plastics are disintegrated into smaller pieces known as micro-plastics and are transported by wind and currents through the oceans. This paper presents the outcomes of a study aimed at the evaluation of micro-plastic contamination along the Dubai coast using remote sensing techniques. Water samples with micro-plastics created in the laboratory were analysed to identify the spectral reflectance of micro-plastics. The tested water samples showed an evident spectral reflectance in the range 900-1200nm. In addition, beach water samples were collected from ten beaches in Dubai and analysed in the laboratory for microplastics. When analysed for microplastics, the beach water samples found to contain average of 0.324mg/L and 5.3items/L, which indicates high microplastics pollution. The spectral reflectance curves of the beach water samples were obtained using a handheld spectrometer used at the time of sampling. Band 9 (central wavelength: 945.1nm) of a Senitel-2 image acquired on the sampling was used to obtain s spectral model. Using the microplastics concentration (in mg/L) of seven of the beach water samples and the corresponding spectral reflectance values, a linear model was developed and was also validated using three of the total ten samples. Moreover, the R-squared value was determined as 0.85, which shows the closeness of the data to the fitted regression line. The authors believe that Senitel-2 images (Band 9) and the developed spectral model can be used in similar coastal areas to detect microplastics pollution.

## SDEWES2021.0943

# Modification of Commercial Ro and Nf Membranes with Zwitterionic L-DOPA and TiO2

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## Abstract

Surface modification of membranes is one of the recommended techniques to prevent membrane fouling, increase flux, and reduce energy costs. Membrane modification is applied to increase the selectivity and permeability performances of commercially used RO and NF membranes. It is known that hydrophilic, smooth and neutral membrane surfaces are more resistant to fouling. Zwitterionic materials such as L-DOPA are known to be promising in membrane surface modification. The aim of this study is to increase the hydrophilicity and flux value by modifying the surfaces of nanofiltration (NF270) and reverse osmosis (BW30-XFR) membranes with zwitterionic L-DOPA and TiO2. The modification of membrane surfaces was performed by L-DOPA (2 g/L) and TiO2 (0.1% and 1% w/w) in Tris-aminomethane buffer solution. The achievement of modification was evaluated based on SEM images of the modified BW30-XFR membranes, FTIR analysis, permeate fluxes and contact angle values. The modifications of membrane surfaces successfully were achieved based on SEM images and FTIR analysis. The contact angle of the modified BW30-XFR membrane was 60±3.05° with an increase of 7% compared to the unmodified BW30-XFR membrane. On the other hand, the contact angle of the modified NF270 membrane was decreased by 12% to 34±1.67° compared to the unmodified NF270 membrane. While L-DOPA+TiO2 decreased hydrophilicity in RO membrane, the hydrophilicity of NF membrane was increased after modification. Permeate flux testes were monitored at 20 bar constant pressure for RO membranes and 10 bar constant pressure for NF membranes. The pure water flux value of the modified BW30-XFR membrane was 94.3 L/m2h with 17% flux increase compared to the unmodified BW30-XFR membrane. Similarly, the pure water flux increased with 31% to 177.8 L/m2h for modified NF270 membrane comparing unmodified membrane. As a result, L-DOPA and TiO2 enhanced the performance of commercial RO and NF membranes in terms of water flux. Moreover, modification with L-DOPA and TiO2 was much more effective in improving the performance of the NF membrane than RO membrane.

## SDEWES2021.0977

# Effects of Leonardite Humic Acid as an Eco-Efficient Superplasticizer on Setting and Hydration of Portland Cement

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## Abstract

Commonly used water reducing chemical admixtures are poly-naphthalene sulfonate (PNS), poly-melamine sulfonate (PMS) and polycarboxylic acid (PCA) based. In this study, the effects of humic acid extracted from leonardite (LHA), which was developed as an eco-efficient alternative to PNS- and PMS-based commercial superplasticizers (SPs) on the setting and hydration properties of Portland cement were investigated. First, the plasticizing performance of LHA as flow of fresh mortars was compared with other SPs (PNS and PMS). Isothermal calorimetry tests were carried out on the prepared cement pastes. The effects of LHA addition and other SPs on hydration rate and total heat of hydration of the cement paste were determined. In addition, thermal analysis (TGA) experiments were carried out on the hardened cement pastes on the 3, 7, 28 and 90 days to evaluate the hydration mechanism. Finally, the effect of LHA on setting time was compared with other SPs. Experimental results showed that LHA has comparable performance to PNS, PMS, and LHA has a considerable potential as an eco-efficient plasticizing agent for cementitious systems.

## SDEWES2021.0978

# The Use of Nanofertilizers to Increase Precision in Rice Production

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## Abstract

Rice cultivation (Oryza sativa L.) has a widespread use of fertilizers and pesticides since it is necessary to produce larger quantities and also prevent the effect of pests, diseases and weeds, in order to fulfil the food demands of a growing world population.

For the use of phosphorus, the limit set by Bertolami & Francisco (2020), at the Planetary Boundaries, has already been exceeded, causing marked disturbances in the earth system, meaning that its delivery, although indispensable, must be carried out precisely and in forms that can be easily assimilated by crops. The scarcity of phosphorus and the consequent increase in its price in recent years also impose the urgency of new forms of application. Nanofertilizers can provide a precise and more sustainable way of application, as the amount of raw material is reduced. Likewise, the pressure on aquatic ecosystems is reduced, since rice is grown in flooded beds and therefore losses to water bodies have to be reduced.

The aim of this work is to develop phosphorous nanofertilizer pellets, which use slow release technology to ensure the precise and efficient application of phosphorus to rice crops along the cycle, and to verify their possible effect as a biostimulant. The use of suitable and sustainable supports for nanofertilizers is extremely important as the main challenge for their use is the amount of support required to successfully deliver the active substance (Ekebafe et al., 2011). The proposed pellets will consist of poly-beta-amino-esters (PBAE), graphene oxide (GO), chitosan, poly lactic-co-glycolic acid (PLGA) and the active substance. Development of the pellets will comprise component integration and design, followed by kinetic tests to assess its stability under different conditions. Ecotoxicology tests, at different trophic levels, will be performed to ensure that there are no ecotoxicity effects from the use of any component and/or combination of components. Finally, when all the preparatory tests are concluded, feedback will be given to the development stage and improvements will be made to optimize the pellets. When the optimization process is complete, the pellets will be tested in pilot rice assays where conventional fertilizer will be used as control. If the pellets prove to be effective and without any harmful effect, its use can be spread to other fertilizer and other crops towards a more sustainable production.

## Regional planning and cooperation

### SDEWES2021.0177

# Local Adaptation Plans in Mediterranean Europe: How Cities and Regions are Responding to the Climate Crisis?

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## Abstract

European cities across the Mediterranean region face common climatic threats. Urbanised areas are highly vulnerable to the adverse effects of climate change, including climate variability and climate extremes. Cities concentrate population and assets, and losses and damages as a result of climate change impacts such as heat waves, droughts, wildfires, landslides, coastal hazards are likely. So far, however, there is no systematic understanding how cities in the Mediterranean Europe are preparing to adapt to these impacts, nor of how they aim to increase their resilience and adaptive capacity. Understanding how cities plan to manage climatic risks will help to identify action gaps, allocate resources and provides better-informed climate policy, at local, regional national and international scale. This research gathered and analysed adaptation planning documents in a representative sample of 73 cities across 9 Mediterranean European countries (France, Italy, Spain, Greece, Portugal, Croatia, Slovenia, Cyprus and Malta) in the context of their national policies. The results and this paper shed important light on the progress of adaptation planning, by focusing on identified impacts and proposed adaptation measures.

## SDEWES2021.0691

# Participatory Process Protocol Towards Energy Transition Planning on Touristic Islands

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## Abstract

EU islands face a vast challenge to cope with climate targets while handling complex stakeholders' networks. This study aims to propose a Participatory Process Protocol (PPP) to enhance the output of energy transition planning, through the effective engagement of local stakeholders. The proposed protocol stems from a successful experience deployed in 18 Mediterranean port cities and is transferred into the framework of SECAP development, for the planning context of islands. First, a K-means clustering is carried for inhabited EU islands. The 4 resulting clusters serve as the base for the calculation of energy transition KPIs according to information received from 70 EU islands. Then, the PPP is arranged to complement the SECAP methodology, whereas its implementation is revised based on the experience of three port cities case studies. The different approaches that islands from each cluster might establish to adopt the PPP are discussed, especially regarding their potential to become carbon neutral by 2030.

## SDEWES2021.0927

# Urban Energy Transition Indicator Selection. A Multicriteria Decision-Making Tool for City Stakeholders

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## Abstract

The importance of cities towards energy transition and sustainability objectives is nowadays widely known. To overcome this challenge, city stakeholders must develop mitigation and adaptation measures. Cities and urban planning are complex systems. Thus, several guidelines to support cities in this transformation are available in the existing literature. However, the literature review highlights the lack of an efficient and easy procedure to assess urban energy transition. Indeed, studies focus either on a narrow part of energy transition or are too complete and detailed to be used efficiently by city stakeholders. The purpose of this paper is to provide a state-of-the-art of indicator-based methodologies to assess urban energy transition that can suit the need of each city. This assessment results in a configurable tool providing the best indicators for a given city. The aim is to provide an indicator framework to assess city specificities while keeping a broad scope to compare them with other European city initiatives. The first version of the tool stands on 123 indicators evaluation through defined criteria rated using Likert scales and weighted following the analytic hierarchy process (AHP) multicriteria decision-making methodology. The application of the proposed tool intends to support the development of strategies and plans for energy transition at the city level. The main challenges to overcome are providing an efficient list of indicators covering all the aspects of energy transition while finding a solution to optimize their evaluation with a quantitative analysis.

## SDEWES2021.0933

# Supporting Local Authorities to Plan Energy Efficiency in Public Buildings – the Case of Teruel Province: from Local Needs to Regional Planning

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## Abstract

The support offered to local authorities in the PrioritEE project consisted of technical, economic and planning training on the integration of energy efficiency measures as well as the development of tools (guidelines, a decision support tool, databases and a visualization platform) that allow local authorities to prepare their building renovation plans. These tools have been found very useful for local authorities, particularly in the case of Teruel province, characterised by many small municipalities whose local governments do not have the technical staff to undertake this type of planning. As a result of PrioritEE, an energy action plan was elaborated for the implementation of 96 energy efficiency measures in public buildings of Teruel province. The execution of this plan would allow energy savings of 1,3 MWh/year and 245 tons$_{CO2e}$/year of $CO_2$ emission reductions, involving an investment of 1.2 M€. The close collaboration with public authorities made it possible to assess the strengths and weaknesses of using the developed tools. One of the barriers found is the availability of accurate building data (e.g. regarding envelope features) necessary for the decision support tool.

## SDEWES2021.0958

# Energy System Modeling Analysis for Regional Planning and Policy Making – a Case Study of Groningen Province in the North of the Netherlands

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## Abstract

Regional planners do not adequately consider potentials and limitations of spatially-dependent renewables within the context of an integrated energy system. Similarly, energy system analysts create models without properly recognizing restrictions related to land use planning. In this paper, a regionalized energy system modeling framework was developed in an attempt to bridge this gap. The regionalized model is formulated from an existing national energy system model called Options Portfolio for Emission Reduction Assessment or OPERA. Spatial parameters relevant for regional analysis were identified and integrated into the model. Since renewables are expected to play a major role in the future energy system, particularly of a densely populated country such as the Netherlands, the focus of the modeling framework was renewables. The case study was Groningen Province located in the northern region of the Netherlands. Results showed significant potential contribution from offshore wind energy in the regionalized model compared to the model without regional segregation (617 PJ difference). Results highlight the need for following area-specific approach when planning future energy system and setting various renewable potential targets.

## Renewable electricity generation systems 1

## SDEWES2021.0381

# Low Pressure Calcination of Limestone to Boost Thermochemical Energy Storage Based on the Calcium Looping Process

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## Abstract

The Calcium-Looping (CaL) process based on the multicyclic calcination-carbonation of $CaCO_3$/CaO is a promising Thermochemical Energy Storage (TCES) technique to be integrated into solar thermal plants. As a novelty, this work proposes a CaL integration that considers low-pressure calcination under pure CO2 at reduced temperature. Low-pressure calcination (0.01 bar) provides a suitable solution to reduce CaO sintering and its consequent loss of reactivity in the carbonation stage. Since calcination temperature is reduced (from 950ºC at ambient pressure to 765ºC), energy losses at the receiver are lowered. In addition, a reduced calcination temperature allows using metallic receivers already tested at the MW scale, which notably increases the CSP-CaL integration reliability. Moreover, the multicycle CaO reactivity in short residence times is promoted, requiring a simpler reactor design. The proposed plant proposes a smooth integration of the CaL process in CSP plants, with a moderate storage level and supported by a natural gas back-up system (solar share higher than 50%). Results show that solar thermal-to electric efficiency is above 30%, which shows potential integration potential.

## SDEWES2021.0528

# Energy Performance Evaluation for a Floating Photovoltaic System Located on the Reservoir of a Hydro Power Plant Under the Mediterranean Climate Conditions

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## Abstract

Deployment of photovoltaic systems on water bodies unlocks enormous areas in populated regions. Also, their utilization will create the possibility to increase the share of photovoltaics systems related to the energy transition. There is little information regarding the available data for floating photovoltaic systems (FPVS). The positive effect of water on cooling the photovoltaic modules should be considered, also. This study is performed by utilizing experimental data from a field test located in a region having Mediterranean Climate Conditions. It is a newly installed FPVS with an installed capacity of 0.5 $MW_p$ DC. Results include the energy yield, final yield, performance ratio, capacity factor, and system efficiency. They refer to a daily period during sunny and cloudy days and offer a clear view regarding the system operation.

SDEWES2021.0618

# Efficiency Increase of Photovoltaic Systems by Means of Evaporative Cooling

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## Abstract

Today`s solar cells generate electricity from about 20% of the incoming solar energy. The remaining amount is reflected or absorbed and thus converted into heat. This significantly increases the temperature of the individual cells compared to the temperature of the Standard Test Conditions (STC), which is relevant for the nominal efficiency. This temperature increase causes a reduction in efficiency by 0.5% relative per degree Celsius temperature increase. For example, a surface temperature of 55 °C results in an efficiency of 17%, i.e., a decrease in total power output of 15%. Furthermore, it is currently being discussed whether a degradation of solar cells could also be caused by temperature peaks.

To increase the efficiency of solar cells and to avoid degradation by extreme temperature events we cool the solar cells using water droplet evaporation from a nozzle spray in a chimney-like channel attached to the back of the solar cell.

Challenges in the development are the combination of an optimal relation between high cooling capacity and minimal energy and water consumption as well as a maintenance-free and universally applicable design of the system.

The aim of this paper is to carry out parameter studies varying the nozzle position and number in the cooling channel as well as varying the nozzle inlet pressure and the resulting water consumption. The criteria for selecting suitable nozzles are briefly discussed in this context and a suitable preselection is made.

The parameter studies take place in a specially designed testing rig, which mimics the heating of the solar cell by a 1x1 m² surface heating element and thus generates a defined and reproducible heat flow. The cooling channel is designed transparently and thus allows not only temperature measurement at the heater but also the application of laser-optical measurement methods like PIV and spray analysis to characterize the resulting flow. The nozzle inlet pressure is varied in the range of 1 – 6 bar resulting in a water consumption between 5 – 25 l/h.

The results of these parameter studies show that the used water both evaporates and settles as a water film on the back of the solar cell and in the duct, and that the film that is formed also contributes to cooling. Newly arising problems regarding the excess water are addressed and corresponding solution approaches for further use in separate circuits are presented. In addition, the approach presented here is compared to other cooling concepts for PV systems.

## SDEWES2021.0662

# Exergy Analysis of Solar-Geothermal Based Power Plant Integrated with Boiling and Reverse Osmosis Water Purification

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## Abstract

The emphasis on renewable energy sources is increasing due to the exhaustiveness of fossil fuels and their effect on the environment. Non- conventional energies are naturally available but exclusively cannot provide consistent power output. Organic Reheat Rankine cycle is applicable to combine it with diverse energy source types for multi-purpose and better efficiency that works at a low temperature with specifically selected suitable working fluid. In this work the designed, solar and geothermal renewable energies have been integrated with the Organic Reheat Rankine cycle having a medium of the thermocline energy storage. The objectives of the designed plant are power generation, boiling, and advanced water treatment through different stages of filtration. Aspen plus V11 software has been used for the design of the system configuration. Parameters that have more impact on the system has been optimized like the dead state temperature, geothermal high pressure turbine outlet and inlet pressure, ambient temperature, geothermal injection well fluid flow rate, production well pressure, production well temperature, and geothermal low pressure turbine outlet pressure. Exergy analysis of each component has been carried out on EES and the components of higher exergy destruction associated with energy conversion have been identified. For the Organic Reheat Rankine cycle, an appropriate working fluid biphenyl/diphenyl oxide has been selected and characterized based on the criteria of stability, environment, temperature, and toxicity has been considered. The RO water treatment process has been analyzed on GPS-X hydromantis software. The RO system is efficient and effective method of water treatment, by considering permeate pump and energy recovery unit in the design, the energy consumption has reduced. The running cost of the filtration and RO water treatment system is 6149.11 $/yr and 3.35KW/m$^3$ power is required to run the booster pump that pressurize the untreated water through semipermeable membrane. The geothermal well operating condition parameters have been estimated from the existing well source data and the newly under construction Aluto Langano power plant. In the end, the power output which can serve the case study area households and industry, at high exergetic efficiency of 51.64 % for the night time system and 49.25% for the daytime operating system with the 100 m$^3$/day of treated water as a supplement to the municipal filtered water. As a conclusion the designed system can perfectly achieves the objectives and the thermal disinfection process consumes 13.36% of the total exergy that sterilize the water from contaminants by boiling water exposing to waste heat beyond the boiling point temperature which is estimated 135$^o$C. To increase the life span of RO system, the water has filtered in the clarifiers that removes large size industry and household wastes thrown in the lake.

SDEWES2021.0764

# Multiple Impacts of Low-Carbon Technologies and Their Role in the Decision-Making for Small Investors

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## Abstract

Renewable energy sources (RES) are seen as one of the main drivers to the carbon neutrality transition, especially in the power energy sector. Even though their share has increased substantially in the last decade, substantial development of RES is still needed. Besides GHG emissions decrease, RES implementation brings other indirect impacts (socio-economic, environmental, health, and other), the so-called multiple impacts. These multiple impacts can play an important role in investment decisions, especially by households. Conversely to the general perception in business investors, the relation between RES share and non-financial drivers has been perceived as strong among small (residential) investors. However, empirical evidence to support this claim has so far been scarce, even though it suggests that the multiple impacts can tip the scale in the investor attitude to renewable technologies and ultimate decision making.

Our paper, therefore, provides this empirical evidence showing how multiple impacts are perceived and included in residential decision-making on photovoltaics investment. To do so, we utilize a mixed-method approach. Following a thorough understanding of the process of PV purchasing, we carried out in-depth structured interviews with 10 representatives of each stakeholder group involved in the investor decision. Results of these interviews helped to identify 25 key factors of decision making. These factors were then incorporated in a survey among residential decision-makers, with responses from 128 respondents.

Results of our sample, which has been proved to be sufficiently statistically representative, show that (1) non-financial, divided to personal and social, benefits are significant for household PV investors, mainly represented by environmental (74 % respondents) and energy security (80 % respondents) concerns; (2) these non-financial benefits are considered to the same extent as financial benefits; (3) investors are less concerned about the amount of the current investment in relation to future cost savings and (4) investors are more willing to become active customers and participate in their energy consumption and production. Further results show that 60% of respondents install PV system together with other energy savings investments, the internet was the main source (90%) of information and the opinion of the surroundings was not the statistically significant driver. The results can feed in the better design and promotion of PV support policy.

## SDEWES2021.0855

# Distributed Generation and Solar Photovoltaic Energy: the Case of Brazil

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## Abstract

The expansion of distributed generation (DG) in recent years has been observed in many countries. In Brazil, the DG has gained notoriety and has been expanding significantly in recent years. The existing Brazilian regulations had been periodically revised and updated trying to induce the growth of DG in Brazil. Photovoltaic solar is the DG technology predominantly used in Brazil, thus which contributes to avoid GEE emissions. The current regulations are partially adequate to support the growth of DG in Brazil. A review of the current legislation is under discussion, but the revision of the legislation planned may lead to setbacks in terms of benefits for consumer-producers (prosumers) and future prosumers and legal uncertainty in the market. There is divergence of interests between energy consumers and energy distribution companies and the distribution companies' lobby acts to reduce DG benefits and transfer costs (taxes and electricity power usage) to consumers.

This work presents the panorama of GD in Brazil, analyses and compares the numbers of this current market. It analyses the legislation and presents proposals regarding the revision of the legal framework, considering the divergences between the interests of the prosumers and the energy distribution companies. Possible scenarios for the updating of GD legislation have been elaborated and analysed.

The methodologies used in this article were an exploratory research and a general analysis of the DG in Brazil, subsidizing its contextualization and subsequent critical evaluation. The hypotheses presented by the authors are: (i) the existence of a great expansion potential to be explored by DG; (ii) the current national regulations are functional, but can be improved; (iii) the existence of divergences between the interests of consumers and prosumers and distribution companies; (iv) the existence of risks related to the pressures generated by the indebtedness and “judicialization” of the BES associated with the distribution companies' lobby or prosumers. In this way, analyses were made of the Brazilian context and findings of the impact of the legislation adopted in recent years. Comments and criticisms are also made about the possible changes from the updating of legislation for the year 2020 in Brazil.

The results verified were: GD grew from 2012 and there is a much greater potential for growth; more than 90% of the GD is photovoltaic; energy distribution companies are alarmed by the exponential growth of GD and the possibility of economic and financial imbalance, but it is also interested in exploiting it; among the scenarios obtained, there is only one scenario where the consumer-producer maintains the current benefits of DG, and there are setbacks in the others.

## SDEWES2021.0903

# Investigation of Cost Saving Potential for Biopower Generation by Fuel Switching in Northern Thailand

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## Abstract

In this work, a cost optimization model considering biomass and transportation as main parts of total cost was applied to a case study of a 9.4 $MW_e$ Phrae power plant in northern Thailand. Objective of this work was to evaluate if fuel switching would result in cost reduction. Originally, the biopower plant uses rice straws and husks solely as fuel. Several potential agricultural residues in northern Thailand within 70 km radius of the plant were considered for full or partial substitution of the current biomass fuel used. Linear programing was applied to a number of supplies in calculating the cost to the demand point, with transportation by 10 wheel-trucks. From the simulation, it was revealed that more than 50% of the power generated could come from corn residues while the rest was from rice straws. Total cost saving of almost 44% or about 1.11 million USD a year was potentially possible.

## SDEWES2021.1031

# Water-Energy NEXUS in African Power Pools – the Dispa-Set Africa Model

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## Abstract

In this study, a detailed power system modelling framework is presented for the African continent and applied to assess the induced water stress. The proposed model is an open-source unit commitment and power dispatch model with one node per African country. All large-scale operating generation units are reviewed and parametrized using different data sources. The modelling framework is then calibrated with historical data from 2018. Two scenarios are defined to assess the effects of the short-term expansion of the African power grid in the five African power pools. Insights regarding the importance of weather variability are obtained simulating 39 different annual climatic conditions.

The results indicate that the system adequacy is insufficient in many countries: significant amounts of load shedding are required in several isolated or poorly interconnected countries in the five power pools. Interestingly, increasing the interconnection capacities reveals to be an effective solution, bringing the load shedding to almost zero. Increased interconnections also reduce VRES curtailment, thus increasing the overall flexibility of the system, and the marginal prices. Congestion in several major cross-border lines is however observed in all scenarios, because of the limited transfer capacities from North to South, East to West and vice versa.

The analysis of the water-energy nexus indicators reveals that that the water stress induced by power generation activities is problematic in some power pools. The influence of water temperatures on water availability for power plant operation is not considered. However, the dispatch of traditional generation is influenced by their profitability, as computed by the optimal dispatch model. Water consumption from power plants exceeds 0.2 times the water availability in several countries. A particularly vulnerable country is Sudan, with water withdrawals up to 6.4 times the water availability and total water consumption of 0.52 times the water availability. Highest freshwater abstraction among all analysed climate years of 160.1 $m^3$/MWh is recorded in Sudan, a country with excessive dependency on external freshwater resources from the Nile River. Despite this, the current exploitation of water resources for power generation remains acceptable in the majority of African countries. It is important to note that Africa is currently undergoing a rapid growth in electricity demand, which will most likely impact the previous conclusion.

## Renewable electricity generation systems 2

### SDEWES2021.0859

# Case Study of the Distributed Generation Photovoltaic System Installation Connected to Electrical Grid in a Rest Home: Technical Economic Analysis of Coast and Benefit

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## Abstract

The world energy matrix is diversified, but there is still a predominance of non-renewable fuels. However, due to population growth and technological and industrial development, there will consequently be an increase in energy demand and, as a result of sustainable challenges (Global warming, climate changes, CO2 emission reduction, etc.) and environmental regulation, the search for alternative energy sources will be necessary. Among renewable energy sources, the photovoltaic solar energy stands out, as it allows the generation of a clean and decentralized form. Brazil is located in the intertropical zone, registering high rates of solar irradiation throughout the year, compared to countries that use this technology, which makes it a suitable place for its use.

This study aimed to analyze the technical and economic viability of the installation of a photovoltaic solar distributed generation system connected to the electrical grid, classified as micro-generation, of the order of 20 kWp of energy under net metering regime, as an alternative to reduce costs and energy diversification in an rest home.

The methodology used was: a case study; literature review; definition of reference photovoltaic project specifications; market research for companies for the elaboration and implementation of the photovoltaic project and selection criteria definition; and cost-benefit analysis of the implemented project; analysis of the perspectives of regulatory framework changes.

As results obtained were: identification and comparison of 5 projects from different companies to choose the winner project; verification that the photovoltaic system have economic and financial feasibility in terms of simple payback and payback discounted by electricity bill; The cost-benefit relation is favourable for conditions of current regulatory framework . However, depending on the possible regulatory framework changes proposed by the electricity sector regulator agent, the discount of electricity bill can be reduced by 28%, 34%, 42%, 50% or 62%, significantly undermining the planned payback.

## SDEWES2021.0899

# Assessment of Industry 4.0 Readiness for Hydropower Generation Industry in Laos

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## Abstract

For Energy and Power Industry, a Major Topic To Be Investigated in This Field Is the Emerging of the Fourth Industrial Revolution or Industry 4.0 Concept Which Represents the Relation Between Industrial Production and Information Technology. It Appears That This Concept Has Great Potential in Improving Generation and Operation Systems in the Energy and Power Sector by Increasing Energy Efficiency, Flexibility of Operation, Lifespan, and Reducing Costs of Installation, Operation and Maintenance. For the Global Hydropower Industry, Many Generators Have Achieved High Levels of Technological Maturity. Nonetheless, There Remain Some, Especially Those in Developing Countries, That Are Still at Low Level of Industry 4.0 Maturity. Many Hydroelectricity Producers Have Struggled With the Pathway on How to Start Introducing and Implementing the Concepts and to Grasp Its Full Value. Another Obstacle Is That They Misunderstand How Difficult It Is to Face Its Challenges. Lao PDR, a Country With Full Potential of Renewable Energy Generation, Is Coping With These Challenges. Thus, by Identifying the Existing Maturity Models of Industry 4.0 and the Application of Multiple-Criteria Decision-Making Method, This Study Has Proposed a Novel Framework Integrating the Set of Metrics on Industry 4.0 Readiness for Hydropower Plants in Laos Which Concern the Fundamentals of Strategy and Organizational Structure, Information Systems, Smart Operations, Human Resources and Organizational Culture Towards Innovation Perspective.

## SDEWES2021.0921

# A New Numerical Tool for the Techno-Economic Analysis of Small Hydropower Plants

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## Abstract

Many projects (such as SMART) address to important barriers for the expansion of small-scale hydro-electricity production in Europe. One of the main barriers is the lack of suitable methodology and tools (computer programs) able to create a clear view of the small hydropower plants (SHPs) potential in the given territory, as well as a complete techno-economic analysis for certain location. Although, in the world there are a certain number of computer programs for this purpose, but they are not able to take into account all the specifics of watercourses. Due to, a new original numerical tool (software) for the techno-economic analysis of SHPs is developed and will be presented in this paper. In the software the latest knowledges and technical developments in the field of SHPs are incorporated (e.g. the newest types of water turbines for SHPs). Also, the interface of the software is also designed to allow user friendly application. The software is very useful for experts in the field of SHPs, but also much wider, for decision-makers, potential investors and stakeholders. It will improve water resources management, disseminate opportunities to investors and increase the interest of stakeholders to invest in SHPs, resulting in their wider use.

## SDEWES2021.0922

# Effect of Working Fluid on Characteristics of Organic Rankine Cycle with Medium Temperature Geothermal Water

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## Abstract

Over the past 45 years, worldwide electricity production based on geothermal sources has increased significantly: the installed generating capacity has grown from 1300 MW in 1975 to almost 21,500 MW in 2020. In 1998 the Energy Institute "Hrvoje Požar" prepared a Program of Geothermal Energy Usage in the Republic of Croatia, which shows that in the Republic of Croatia there are some medium temperature geothermal sources (geothermal water) in the range from 90 to 170 °C, by means of which it is possible to produce electricity in binary plants, either with the Organic Rankine Cycle (ORC) or with the Kalina cycle. However concrete initiatives for the construction of geothermal power plants have only recently been started. In accordance with this authors in previous papers have presented result of an energy-exergy analysis of geothermal resources Velika Ciglena (170 °C), Lunjkovec-Kutnjak (140 °C), Babina Greda (125 °C) and Rečica (120 °C), in order to determine which cycle is better for the conditions in Croatia. On the basis of analysis results that the ORC is thermodynamically better from the Kalina cycle for temperatures of all cited geothermal sources and cooling air, and considering the problems that all the new technologies encounter in their early phase of application, authors propose the application of binary plants using ORC cycle for all medium temperature geothermal sources in the Republic of Croatia. Researches related to the application of the ORC generally deals with the selection of the working fluid, optimization of the ORC unit and the whole plant and analysis of possible modifications with aim to increase its thermodynamic efficiency or net mechanical power output. Although in the available literature, there are a large number of published research results on the selection of the working fluid, however, every geothermal source is a case for itself with respect to the temperature of geothermal water and the cooling fluid on location (water or air). Therefore, in this paper will be presented the results of analysis of the working fluids effect on thermodynamic and techno–economic characteristics of binary plant with ORC - case study of Geothermal Power Plant Lunjkovec-Kutnjak with temperature of geothermal water 140 °C. As the working fluid the next refrigerants and hydrocarbons will be analyzed: isopentane ($C_5H_{12}$), isobutene ($C_4H_{10}$), isohexane ($C_6H_{14}$), R114 ($C_2Cl_2F_4$), R141B ($C_2H_3Cl_2F$) and R142B ($C_2H_3Cl_2F_2$), etc.

## SDEWES2021.0935

# Effect of Tube Size on Alternative Material Heat Exchangers for Geothermal Applications by Numerical Model

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## Abstract

The geothermal energy is widely diffused for high-size thermoelectric applications by using high temperature sources. The low-medium temperature reservoirs are basically used for direct balneotherapy scopes despite the low temperature fields are more present worldwide than high one. Geothermal fluids at medium and low temperature could be mainly used by considering the installation of small size power plant for power only or for heat and power by using Organic Ranking Cycles technology or in alternative for direct heating and cooling application. The optimization of system parameters in geothermal plant can be a good strategy for cost reduction mitigating the economy of scale. The use of small deep sites in low-medium enthalpy could be favourited by the cost's reduction and by the exploitation of small-size plant for energy communities solving geothermal social acceptability issue. A high cost in the geothermal plant regards the heat exchanger evaporator enables the thermal heat exchange between the working fluid (which is commonly an organic fluid for an Organic Rankine Cycle) and the geothermal fluid (supplied by the aquifer). The high cost depends on aggressivity of geothermal fluid that leads to the corrosion of steel traditionally used in the heat exchangers. The maintenance of steel heat exchangers or in alternative the investment cost of anticorrosion metal (such as titanium) influence the diffusion of geothermal small plant. This paper analyses an alternative to metallic heat exchanger for thermoelectric geothermal use. Plastic materials usage was simulated for evaporator installed in an Organic Rankine Cycle plant in order to overcome the problems of corrosion/cost and the increase of heat exchanger thermal resistance due to the fouling effect. The design and performance investigation of optimum operating configurations for the evaporator is realized by considering titanium, steel and polymers taking into account both pressure drops and economic aspects. A mathematical approach via one-dimentional model is performed by using the correlation referred to in the literature about heat transfer in single-phase and two-phase fluids. A sensitivity analysis will be conducted on the tubes dimensions to minimize the plastic footprint. The outcomes provide the heat transfer area for the shell and tube heat exchanger with a fixed electric power size of thermoelectric plant. The results have demonstrated that the best combination of fluid, layout and polymer leads to a cost saving of evaporator of 70% with respect to titanium on the basis of the same life cycle time.

## SDEWES2021.0959

# Electrical Interconnection of a Solar Roof-Tile System: System Topology and Microconverter

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## Abstract

This paper qualifies the flexible electrical interconnection concept of a new type of solar roof tiles. On the one hand string connected roof tiles with multiple strings in parallel are regarded as well as systems including roof tiles with MPP trackers being integrated. Latter avoids mismatching being expected, since the roof tile systems should also be realized in urban existing buildings showing dormers etc.

The new roof tile system with integrated photovoltaic cells, which is characterized in particular by an rear ventilation channel for air-cooling, is presented, especially with regard to the electrical data. The quarters of 6" solar cells used for optimum area utilization of the roof tile lead to comparatively high voltages and reduced currents of the string of roof tiles (@STC: 14.5Wp,MPP; ISC=2.8A; UOC=4.5V). Suitable parallel connections of strings of different lengths are proposed in the paper, resulting in configurations that cover a very wide range of roof tile configurations for common grid-connected PV inverters.

Optional microconverters are realized based on customized buck converters in the roof tiles junction box. Buck converters are feasible due to the increased string voltages. The DC-DC converters are also presented in detail in terms of design and efficiency. The control challenge, i.e. the interaction between the MPP tracker of the microinverter and the control behavior of the grid-connected PV inverter could be solved and will be presented.

By means of the electronics in the roof tiles junction box, the feature "voltage-free DC line in case of fire" can be realized. In the final paper, a mimic is presented for this purpose, which modulates a high-frequency AC signal onto the DC line which is recognized by the roof tiles as a release signal.

## SDEWES2021.0990

# Long-Term Pathways for Carbon-Neutrality from Chile: Variability in Absorption CO2

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## Abstract

Currently, climate change and global warming are among the main problems facing society. Emissions of $CO_2$ and other greenhouse gases (GHG) play a crucial role in this context. Therefore, to limit the global temperature increase to 1.5°C above pre-industrial levels, several countries, including Chile, have developed targets to decarbonize highly polluting systems and adapt to the Paris agreement. Within these targets is the Nationally Determined Contribution (NDC). The NDCs aim to reduce emissions, particularly in the energy and transport sectors. Chile updated its NDC in 2020, proposing the goal of being a carbon-neutral country by 2050. To meet this goal, energy systems are being transformed with a higher proportion of renewable energy such as solar and wind. Additionally, Chile describes that neutrality will be achieved through carbon sequestration by the forestry sector. However, depending on the forestry sector to achieve carbon neutrality presents a significant challenge and risk for Chile. This is because climate change mainly contributes to variability in moisture conditions causing drought and extreme fire risk increasing the emissions associated with these events. In this context, biomass can be one of the transition routes for the decarbonization of the energy sector because it is considered a carbon capture and storage (CCS) technology. However, due to the country's risks from global warming (drought and forest fires), there is also uncertainty in this CCS potential (biomass). Therefore, this study considers different challenges associated with neutrality. We use a detailed Latin American representation of the Global Change Analysis Model (GCAM-LA) as a sensitivity analysis for different sequestration levels. We also develop the use of chance constraint to deal with uncertainty at different carbon budget levels. Moreover, we model distributions to the year 2050 for different $CO_2$ limits, which are then used to mathematically represent the probability that Chile will exceed emission generation levels that cannot be subsequently captured. We propose alternative pathways for deep decarbonization that diverge from the Chilean ministry's strategies to reduce dependence on $CO_2$ sequestration from land use and achieve carbon neutrality by 2050. The results show that stringent policies reduce $CO_2$ emissions by increasing green penetration and electrification of different energy demand sectors.

## SDEWES2021.1032

# Influence of the Thermal Storage Type on the Concentrated Solar Power Plant with Electric Heater

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## Abstract

One of the most appealing features of concentrated solar power plants (CSP) is its compatibility with thermal energy storage (TES). In such plant solar energy is transformed into the heat in solar collectors and either immediately used for electricity production in the steam cycle or directly stored in the TES and later transformed into the electricity. Number of energy transformations in such system is kept to minimum, enabling efficient and cost-effective electricity storage. By itself CSP with TES is able to provide electricity during the whole night, given large enough energy storage and collector field. In a system with high share of renewable energy sources and periods of surplus energy, electricity heater can be used for storage charging. Installation costs of such heater are minimal. Storing electricity as heat implies significant transformation losses, but with limited storage alternatives it can be attractive solution. In this paper influence of the storage technology on the electricity storage efficiency and plant efficiency is investigated. Detailed quasi-stationary model of the parabolic trough CSP with different TES technologies is defined and validated. Overall plant efficiency over period of one year is simulated with different boundary conditions: energy demand and energy prices. It is show that storage technology choice does not affect only amount of energy that can be stored from the grid but can also lead to improvement of overall plant efficiency.

## Renewable energy resources 1

## SDEWES2021.0059

# A Novel Control Strategy for Wind- and Sea-Induced Vibratory Loads Alleviation on Floating Offshore Wind Turbines

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## Abstract

Among the renewable energy technologies, offshore wind energy is expected to provide a significant contribution for the achievement of the European RE targets for the next future. Currently, almost all of the EU offshore wind farms are installed as bottom-fixed structures, mainly in the North Sea, at water depths below 50 m, which is the current technological limit. In the development of floating offshore wind turbine (FOWT) applications, one of the main concerns consists of motion and load perturbations arising for sea-wave/platform interactions and wind-gust effects yielding time-variant generated power and structural fatigue. Indeed, these affect the maximum extractable power in the operating region 3 (limited by structural and electrical reasons), and at the same time the levelized cost of energy (LCOE). This paper deals with the definition of a control strategy aimed at increasing wind turbine lifetime reducing vibratory blade and hub loads. Two controllers are introduced an superimposed to the standard collective pitch and torque controller aimed at power regulation. A resonant controller, based on collective blade pitch actuation, is applied for the rejection of the vibratory loads induced by sea waves, whereas a Proportional-Integral (PI) controller, fed by measured cyclic blade-root bending moments, provides the blade cyclic pitch to be actuated for the reduction of blade root loads. The proposed control strategy is validated by computational investigations that examine the NREL 5MW wind turbine, supported by a spar buoy platform. These show that significant reductions of the blade root bending moments at the revolu- tion frequency and at the sea perturbation frequencies are achievable, thus demonstrating the good potential performance of the controller introduced. Important issues like the required control effort, the influence of the controller on platform motion, and the impact on the fatigue life of the blades are also examined and discussed.

## SDEWES2021.0142

# A Non-Gaussian Multivariate Statistical Monitoring of Spatio-Temporal Wind Speed Frequency Towards Renewable Energy Quality Improvement in South Korea

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## Abstract

In accordance with climate change mitigation, the South Korean government has announced an “Implementation Plan for the 3020 Renewable Energy” to increase the renewable energy penetration, especially wind energy, to 20 % of power generation by 2030. Evaluation of wind energy characteristics and potential is a primary and important step for the wind energy development because similar wind turbines installed at two locations with similar average wind speed may typically generate different power because of the differences in the non-Gaussian characteristics of wind speed. Hence, identification of the probability distribution of wind speed data is crucial to assess the wind energy potential in a particular location. However, a detailed study of suitable probability distribution models of wind speed data to maximize the wind power regarding the transition of renewable energy roadmap is scarce in Korea.

This study aims to propose a wind power quality control guideline for the optimal design of wind turbines, by conducting the spatio-temporal analysis and non-Gaussian monitoring of regional wind speed frequencies in South Korea. First, the anemometer data was collected at 17 different Korean sites. The annual data was measured in an hourly resolution, and the collected dataset was standardized at a similar height of 10 m following the ASCE 7-10 standardization methods to obviate the altitude effect on wind speed. The spatial and temporal characteristics of the measured wind data were analyzed, and then the corresponding probability density function (PDF) was determined among more than 100 candidated continuous PDFs using the Chi-square test at each region. From the best-fitted PDFs, the distribution parameters were estimated that could provide the properties and shape of wind speed frequency, and a non-Gaussian statistical quality control was employed using Hotelling $T^2$ control chart and to monitor by the estimated parameters. The statistical monitoring of weed speed was linked to the assessment of wind power quality in each region through Betz law. Comparing the Gaussian-based power quality approach, this power quality control based on the non-Gaussian assessment of the wind turbines can provide the optimal specification of wind turbine deign in each region including the cut-in and cut-out wind speed to maximize the generated wind electricity, while neglecting the harnessed power operation by extreme wind conditions.

Acknowledgments: This work was supported by a National Research Foundation (NRF) grant funded by the Korea government (MSIT) (No. 2021R1A2C2007838), and the Korea Ministry of Environment (MOE) as Graduate school specialized in Climate Change.

## SDEWES2021.0275

# Life Cycle Assessment of Fixed and Single-Axis Tracking System for Photovoltaic Power Plants: a Case Study for Multi-Crystalline Silicon (Multi-Si) Photovoltaic Modules in Northeast Brazil

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## Abstract

In a situation in which the global economy is advancing towards a low-carbon future, replacing fossil fuels with solar photovoltaics (PV) systems has been a promising pathway not only because of the reduction of greenhouse gas (GHG) emissions but also thanks to the solar resource availability and inexhaustibility. In Brazil, solar PV is a crucial component in the power supply expansion since it has grown dramatically in the last years. Although the power generation from solar PV systems is often considered carbon-free by society, this technology can have significant environmental impacts during other stages of its value chain. In this context, this paper aims at assessing the environmental impacts of fixed and single-axis tracking systems (SATS) from a solar PV power plant composed of multi-crystalline silicon (multi-Si) PV modules and situated in Northeast Brazil. For this purpose, our analysis explores the environmental performance of these solar PV systems from a life cycle perspective, which includes the production of solar PV modules, transport activities, and the construction, operation, maintenance, and decommissioning of the solar PV power plant, using the ReCiPe Midpoint method. According to the results, the most environmentally sound system is the fixed one, which is associated with lower environmental impacts per kilowatt-hour (kWh) generated when compared to the SATS. The latter one shows a better environmental performance only on four from 17 impacts categories considered. Furthermore, our findings provide relevant environmental information for decision-makers to select the most suitable solar PV system for addressing issues related to the pursuit of sustainable development.

SDEWES2021.0369

# Analysis of Residential Rooftop PV Diffusion in India Through a Bass Model Approach

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## Abstract

National Solar Mission in India aims to achieve 100 GW of solar by 2022 in which 40GW of installation will be from rooftop PV. There has been a slow growth in the residential rooftop PV in India, owing to higher upfront costs and ambiguous conditions of the policies for the residential consumer. In this paper, the analysis of the diffusion of PV markets is performed using the Bass model. The historical data of installed rooftop PV is not enough for the model, as the installation of PV was almost non-existent, hence data of solar water heaters is utilized to calculate the parameters for the model. The model used for the study is based on a Bass model developed for Brazil. The trajectory of growth for solar water heaters in the market presents a congruence for the growth of solar PV due to inherent similarities in the technologies and its application. The study is significant as it forecasts the diffusion of PV in the market, which is essential for achieving India's Intended Nationally Determined Contributions (INDC) goals and Renewable Energy (RE) targets. The results indicate that residential rooftop PV diffusion will tend to present a slower pace in India than in other markets if no additional policies are implemented to foster this market.

## SDEWES2021.0384

# Economic, Environmental and Social Analysis of the Biomass Exploitation and Application to a Spanish Region

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## Abstract

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The Aragón region (47,720 km2) is the fourth largest in Spain, with a relevant forestry surface (34.3%) and a thriving agricultural sector (36.6% of the total surface). As a consequence, it has an important biomass potential from forestry and agriculture residues. The analysis of strategies to use these biomass resources is of great interest from the economic and environmental points of view. Furthermore, the region has a severe depopulation problem. In most of its rural areas, the risk of depopulation is very high; the population density in the Teruel province (approximately 30% of the Aragón territory) is around 9 inhab./km² (less than 12,5 being a demographic desert, according to EU parameters) Therefore, besides the economic and environmental impact of the biomass use, the main motivation for this study is to assess how the exploitation of biomass can contribute to mitigate this problem through job creation in depopulated rural areas. The methodology developed in this work can be applied to other territories since the decline of rural communities is a challenge not only for Aragón, but also for other parts of Spain, Europe and worldwide.

The objective of this work has been the economic, environmental and social analysis of pellet production using the forestry and agricultural residues of the Aragón region. To do this, we have developed a methodology based on GIS techniques. Initially, we have calculated the potential of biomass residues. Then, we have configured two potential strategies for the pellet production: small-size pellet factories (< 100,000 t/year) distributed across the territory, and large factories (> 200,000 t/year). Finally, we have determined the costs, $CO_2$ emissions, and job creation in depopulated areas for the three strategies for pellet manufacturing.

The market value of the pellet production using the biomass residues in Aragón is around €120 million. From the economic and environmental point of view, both strategies provide similar performances; we find that small-size factories are penalized by the scale economies/efficiencies of the plant; and, the large factories have the disadvantage of the higher transport distances, resulting in higher transport costs and higher emissions. The total job creation is around 3,500 full equivalent jobs in both strategies; generating around 1,500 full eq. jobs in depopulated areas.

## SDEWES2021.0388

# Deconvolution Techniques for the Kinetic Modeling of the Brewer's Spent Grain Pyrolysis

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## Abstract

Within the presented paper, a deconvolution technique for overlapped differential thermogravimetry (DTG) profiles for brewer's spent grain conversion for bioactive recovery are presented. BSG samples were collected from local brewery Alternatywa, Ruda Śląska, Poland, and its fuel properties are presented and discussed. Thermoanalytical measurements were carried out at heating rates of 1, 2, and 4 K/min, under a nitrogen atmosphere. Deconvolution procedure was implemented using Matlab, and Excel Solver, for the root Gaussian function, and three pre-assumed elementary kinetic steps, ascribed to hemicellulose, cellulose, and bulk lignin-extractives independent decomposition. Deconvoluted profiles, which sum resembled total BSG conversion profiles, of hemicellulose, cellulose, and lignin/extractives. Deconvoluted kinetic parameters (activation energy E, pre-exponential factor A, and reaction model n) are E=161.8±0.46 kJ/mol, $A=4.14\cdot10^{16}\pm5.13\cdot10^{14}$ $min^{-1}$, n=1.37±0.09 for p-hemicellulose, E=204.08±3.45 kJ/mol, $A=2.30\cdot10^{19}\pm6.81\cdot10^{18}$ $min^{-1}$, n=1.37±0.18 for cellulose, and E=26.23±2.23 kJ/mol, A=88.81-841.47 $min^{-1}$, n=1.09±0.02 for lignin/extractives respectively. Gaussian deconvolution techniques resulted in kinetic modelling of the BSG pyrolysis profiles with a standard error of the estimate $\sigma_{est.}$=0.02-0.1 %/min of the estimated conversion profiles.

## Renewable energy resources 2

## SDEWES2021.0585

# Wind Energy Opportunities in Central Asia

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## Abstract

Central Asia has an enormous prospective in green energy sector and particularly in renewables. On top of that there are several problems in energy generation in a whole region. Therefore, renewable energy sources, particularly wind energy, have been significantly promoting for future developing. The purpose of this work is to present technical and economical perspectives of wind energy development in Central Asia.

The paper includes energy generation analysis using Weibull distribution approach. It covers analysing of wind speed data, extrapolation of wind speeds and calculations of electricity production. Further, the work has discussions on potential losses and better positions solutions. Finally, several wind turbine of different manufacturers have been compared and the better one was considered.

Feasibility study involves discussions on today's economic situation in region, covering topics like legislation and stimulation from Government's side. Selected methodology also includes calculations on possible costs and, moreover, involves research in main financial parameters, future risks and profits. Finally, sensitivities have been provided on different aspects and were discussed, as well as possible future changes, problems and uncertainties were covered and final decision was provided

## SDEWES2021.0604

# Biomass Devolatilization Process Parametric Analysis by Varying the Ratio of the Components H2O/CO2, Co/CO2 and (CH4,c2H4)/CO2

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## Abstract

Devolatilization is a process of volatile components formation that takes place immediately after the drying process and precedes combustion or gasification. The paper presents the procedure for determining the composition of devolatilization products on the taken biomass sample. The following components were considered as devolatilization products: $CO$, $CO_2$, $H_2$, $H_2O$, $H_2S$, $NH_3$, $C_2H_4$, $CH_4$, and tar. The procedure relies on two independent models that adopt two distinct principles. The first model, the model of energy and mass balance, does not consider the analysis of the influence of temperature, and therefore the system is indeterminate. The second model is based on determining the equilibrium composition of gaseous components of the devolatilization process by applying the principle of minimum Gibbs function. This model gives the gas-phase composition of the $H_2O/CO_2$, $CO/CO_2$ and $(CH_4,C_2H_4)/CO_2$ systems. Combining these two models using an iterative procedure leads to an exact solution, i.e. the composition of the devolatilization product, which includes tar as a condensed product. Analysis of gaseous components composition of the selected biomass sample devolatilization in the temperature range of 700-950 K, is presented. The proposed procedure has shown satisfactory accuracy, which has been verified by setting mass and energy balances. The results can be used with adequate reliability in this type of analysis and further research.

## SDEWES2021.0606

# Performance Analysis of Gravitational Water Vortex Turbine Using Openfoam

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## Abstract

A Gravitational Water Vortex Turbine is a new development that extracts power from an artificially formed water vortex when the water from an open flow channel is directed tangentially to a round basin and discharges through the hole provided at the bottom of the basin. This can harness hydro power in the application range of low to ultralow head and median to low flows and has the unique feature of leaving a positive environmental impact through the aeration of water as it passes through the turbine. However, the presence of free-surface vortex in the flow field complicates its design from conventional impulse and reaction turbines perspective due to vortex-blade interaction.

Recent investigations have indicated that curved blade profiles are more efficient to harness the kinetic energy of the vortex. However, a little amount of work has been done on the optimization of a suitable runner for the free surface vortex profile considering the vortex-blade interaction, the ratio of runner diameter to basin diameter (blade area), and its effect on torque and power generation.

In this study, the performance of the Gravitational Water Vortex Turbine has been investigated numerically using OpenFOAM. The effect of design parameters such as vortex-blade interaction, the ratio of runner diameter to basin diameter on the performance parameters such as effective head, torque, power, and efficiency has been characterized. As a result, it is found out that a small blade size runner has higher rotational speed due to the strength of vortex was higher in the vicinity of air-core but produces less torque. However, a large blade size runner has less rotational speed and high torque due to the nature of the vortex tangential velocity field decrease with increasing radius and large blade area respectively. Also, this work identified extending the size of runner blades to the far-field region resulting in the reduction of power output. Therefore, the outcomes from this study will be helpful to design and establish performance analysis for the Gravitational Water Vortex Power Plant for a given flow and head of a particular hydropower site. Moreover, it can also be used as a pointer for the future generations of Gravitational Water Vortex Turbine technology.

## SDEWES2021.0677

# Power Generation from Landfill Methane: Weather-Related Volatility Analysis to Include it in the Colombian Power Portfolio

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## Abstract

The Colombian power market is hydro-dominated, since 67% of power produced comes from hydro power sources. In addition it has thermal power from natural gas and coal, and in the last years alternative energy sources such as wind and solar have been introduced, although so far their share is not significant. Due to this condition, the Colombian power market is very volatile and depends on weather conditions, normally in rainy seasons prices are low and power is available, while in dry seasons prices are high and power can be scarce. Although there are large landfills from urban areas, so far there are no power plants that use it. In order to introduce power generation from landfill methane in Colombia, this paper analizes the volatility of power generation from landfill biogas in specific geographic locations in the country. The Scholl Canyon Model is used to estimate the gas generation rate, the main variables identified are site precipitation and waste type. Then Levelized Cost of Energy is calculated in order to compare it with historical data from other resources, and facilitate a portfolio analysis with other resources in the energy mix. When correlating hydro vs methane resources in the four main cities, results show that there is a positive correlation between hydro and methane-from- landfill power resources for three sites (Cundinamarca, Valle and Atlántico) while there is a negative correlation with Antioquia site.

## SDEWES2021.0681

# Reversible Solid Oxide Cell Coupled with Auxiliary and Desalination Systems: the Applied Case of an Offshore Wind Turbine

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## Abstract

The wind farms technical advances reached in recent years are outstanding. Offshore solutions are broadening their deployment horizon and, considering both floating platforms and fixed foundation engineering, the foreseen farm projects are constantly increasing contributing to strengthening their leading role. The new global energy model will be based on integrated systems where several technologies, including storages and management solutions, will operate in synergy. In this optic, hydrogen and its related technologies are a flexible and innovative solutions able to ensure flexibility and sector coupling while processing large volumes of energy. For these reasons, the coupling of electrolysers and offshore wind turbines is being investigated to evaluate the possible mutual benefits in terms of energy management systems at wind turbine level.

Until now the most studied arrangement involved Alkaline or Proton Exchange Membrane electrolysers, while in this study the novel concept of coupling wind energy with a unitized reversible Solid Oxide Cell (rSOC) will be presented. The installation of a rSOC, a compact poly-generation system integrating fuel cell and electrolyser in the same device, can ensure multiple advantages such as low consumption during hydrogen production and combined heat and power production (CHP) from stored hydrogen. In this latter condition the rSOC can supply the auxiliary systems which are fed by batteries or backed from the mainland connection cable during production outages, leading to challenges in terms of maintenance, safety, and electric connections. Additionally, working at sea the water availability for hydrogen production is not a limit, therefore it must be treated via desalination systems which are typically electric-feed solutions but now the thermal energy availability can be exploited to reduce this consumption. Considering such a framework, in this study a new control algorithm has been developed to manage the rSOC operation related to the wind resource aiming to implement a local $H_2$ storage with a triple function: i) assure power supply to the wind turbine auxiliary services during power shortages, ii) efficient hydrogen production to be stored and successively used onsite or sold according to its availability iii) valorise the high-grade heat produced to decrease the desalinization system electric consumption, enhancing the overall system efficiency compared to low temperature electrolysers as the ones studied until now

## SDEWES2021.0682

# Analysis of Operational Characteristics of Bio-Oxy Cfbc with Indirect S-CO2 Turbine

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## Abstract

Many countries around the world are putting a lot of effort into renewable energy technologies using waste resources to solve climate change and environmental pollution problems. Biowastes, such as cow manure (CM), waste paper (WP), and wood waste (WW), are recognized as an essential source of renewable energy, and their importance increased significantly over time. However, research on high-efficiency power generation processes using biowaste is insufficient. The oxy- CFB combustion with indirect supercritical carbon dioxide (S-$CO_2$

) cycle is a technology that can easily capture the emitted carbon and reuse it to generate power. This process eliminates the need for a separate facility for $CO_2$

capture, so environmental facilities can be reduced, less compression work is consumed through recompression in the S-$CO_2$

cycle. In this study, we proposed oxy-circulating fluidized bed (CFB) combustion technology with indirect S-$CO_2$

cycle using biowaste generated in Korea as a raw material. The process was composed of four main parts: ASU, oxy-CFB combustion boiler, S-$CO_2$

cycle, and $CO_2$

compression and purification unit (CPU), and the process was simulated by Aspen Plus. In the 20MWe Bio-oxy CFBC model, 200 tons/day of biomass fuels, such as domestic WP, WW, and CM were injected into CFB combustor in order to generate supercritical $CO_2$

. The CFB combustor was operated at 850°C, and the operating conditions of the S-$CO_2$

turbine were applied at 760°C and 300bar. Despite the high volatility of the biomass components, it achieved 38.4, 37.8, and 38.2% net efficiencies for WW, WP, and CM, respectively. In this study, high efficiency was achieved by omitting additional factors such as FD fan, power consumption of the pump to discharge water from the CPU, and heat loss generated in the S-$CO_2$

cycle. However, the energy penalty due to the high power consumption of ASU and CPU can be minimized by applying the S-$CO_2$

turbine.

## Renewable energy resources 3

### SDEWES2021.0706

# Wave Power Forecasting Using an Effective Decomposition-Based Bi-Directional Deep Learning Model: a Case Study of Mediterranean Sea, Favignana Island

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## Abstract

Ocean wave power is a promising renewable energy source, with an expected potential of around 337~GW worldwide.

Wave energy forecasting is imperative for the economic dispatch and handling of the power systems and the integration of wave energy into power grids. However, forecasting wave power is challenging because wave resources are stochastic, intermittent and non-stationary. This paper proposes a novel multi-step forecasting model, consisting of an adaptive decomposition-based method and Bi-directional long short-term memory (Bi-LSTM) model to forecast the wave energy flux. Furthermore, we evaluate the importance of the decomposition technique in order to increase the accuracy of the forecasting model in predicting the wave energy flux. The time-scale of the forecasting period is 6~h.

To evaluate the performance of the proposed hybrid deep learning model, we use the real collected wave data at a buoy that is positioned off Favignana Island in the Mediterranean Sea. Finally, the proposed model is compared with five well-known forecasting methods. The obtained results show that the proposed model significantly outperforms others over extended time periods.

## SDEWES2021.0717

# Preliminary Analysis of Energy Yield of Wind Farms in the Context of Seasonal Changes

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## Abstract

With the increasing use of renewable sources, with particular emphasis on wind energy, detailed wind potential analyses have been added. The aim of this paper is to investigate the seasonal variation of the wind characteristics in term of wind energy potential using the wind speed data collected for one year in Kosovo, namely Koznica, in three different altitudes. The study takes into account the months in which each season begins, i.e., March, June, September and December. Long-term, seasonal, and diurnal variations of the wind speed in 2015–2016 are analysed for a homogeneous wind data set from Koznica. The results show that the spring and winter season have the greatest potential in terms of wind speed, with an intensity near of 6,732 m/s. Interannual variations of the annual mean wind speed are mostly ± 0.61 m/s from the overall average (6.12 m/s). Seasonal variations of the monthly mean wind speed have the near same level. Wind speed histograms and wind speed rose shows that the wind speed directions are south, north and south – east. While there is almost no dependence of the wind speed on the measurement time in winter and in autumn except days when anemometer was frozen, there is a large daily cycle in spring and summer with values deviating by ±0.43 m/s from the average.

## SDEWES2021.0718

# Energy Analysis and Advantages of Using Solar Thin-Film PV Panels in Kosovo Climate Circumstances

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## Abstract

The use of photovoltaic (PV) panels has developed rapidly in recent years as a result of the potential for transformation from fossil fuel-based economies to economies based predominantly on renewable energy. The production of solar photovoltaic (PV) energy has already become a real potential for taking a more significant share in energy systems and will be even more tremendous potential for energy production in the near future thanks to the recent development of PV technologies and significant reduction of costs involved. One of the most promising and relatively inexpensive technologies is the technology of thin-film PV modules. High-efficiency, low-cost thin-film solar cells have been an exciting option for photovoltaic technology for relatively high-efficiency electricity generation since 1995. Thin-film solar cells are a promising approach to terrestrial photovoltaic units and offer a wide range of device design and construction choices. This paper aims to give a clearer picture of the energy analysis of such devices in specific circumstances, which means from which type of solar film PV panels we get more energy during use in Kosovo. The analysis provides guidance on which type is more favorable and appropriate and has more significant advantages for Kosovo climate and weather conditions. The work also analyzes the limiting factors for greater penetration of renewable energy technologies in the energy system.

## SDEWES2021.0744

# Assessing the Energy-Saving Potential of Ground Source Multiple-Chillers in Simple and Hybrid Configurations

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## Abstract

Air conditioning in residential and tertiary sectors accounts for a large share of energy usage. To reduce the environmental impacts of meeting such demands, the adoption of renewable energy technologies is highly advisable. Among them, the possibility of using the soil as a thermal source for heating and cooling systems has been widely investigated. In this regard, this paper evaluates the energy benefits achievable using the soil as a thermal sink for the air conditioning of an office in Southern Italy. A multiple-chiller system coupled with a borehole heat exchanger is investigated and compared to conventional air-cooled and water-cooled systems. Detailed modeling of all components is carried out to depict the thermodynamic interaction in the plants and obtain more robust energy results. Besides this, a new approach is proposed to calculate the thermal resistance of the borehole. Results show that the seasonal energy efficiency ratio of ground-coupled multiple chiller systems increases up to 6.14 compared to 3.69 and 5.73 of conventional air-cooled and water-cooled systems respectively. The integration of a borehole heat exchanger with a cooling tower also allows water savings of approximately 25% compared to a conventional water-cooled system. Finally, a further increase in the borehole depth from 150 m to 200 m results in no further benefits due to geothermal gradient effects.

## SDEWES2021.0772

# Incorporating Concentrating Solar Power (CSP) Technologies in a Bottom-up Planning Model: Freshwater Consumption and Greenhouse Gas Emissions Under a Life Cycle Perspective

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## Abstract

Since Brazil belongs to the developing countries group that has been leading the global electricity supply growth, the national energy policy forecasts an increase in the share of alternative and renewable energy sources (excluding medium and large hydropower plants) in its electricity mix. Today, these sources exceed the 80% mark and will reach 87% in the ten-year horizon. Although solar photovoltaic proves to be central to meet rising electricity demand in Brazil, its rich solar resource can also be exploited to further diversify the national electricity mix by introducing other solar energy sources, such as concentrating solar power (CSP).

This paper aims to contribute with the incorporation of CSP generation in the bottom-up model MATRIZ considering three different technologies: (1) solar thermal parabolic trough (STPT) without thermal storage system (TSS) with air cooling; (2) STPT with a TSS of 6 hours with air cooling; and (3) solar tower power (STP) with a TSS of 7.5 hours with air cooling. MATRIZ model was developed for long-term energy policies' analysis and validated using the MARKAL model, developed by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (IEA). Inserting a new energy technology in the MATRIZ model requires its technical and financial information. Environmental aspects can also be incorporated into the model's decision-making by considering the costs of its greenhouse gas (GHG) emissions and its freshwater consumption.

In this sense, the present paper focuses on obtaining freshwater consumption and GHG emissions associated with these three CSP options under a life cycle perspective. This analysis was performed with the software SimaPro, adapting data from the Ecoinvent database and using the ReCiPe 2016 method, along with information provided by the System Advisory Model (SAM), by the National Renewable Energy Laboratory (NREL) and other criteria found in the literature.

According to the results, the most environmentally sound CSP option is the STP system, which is associated with lower GHG emissions and water consumption per kWh generated when compared to the two STPT systems. In general, including socio-environmental aspects in long-term planning models proves to be a way to recognize the benefits of renewable energy sources that are not yet economically viable, such as CSP technologies, paving the way for their implementation.

## SDEWES2021.0857

# A SWOT Analysis of Renewable Energy in Kyrgyzstan: Assessment and Outlook for Fostering the Kyrgyz Renewable Sector

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## Abstract

Kyrgyzstan is well known for its unique geographic location as it is situated at a high elevation and covered by the long range of the Tien-Shan mountains. The exceptional geographic condition placed Kyrgyzstan as one of the cold climatic countries in Central Asia. The cold climate results in long and harsh winters in the country. Hence, it is obvious that domestic space heating is the key and primary need for Kyrgyz people.

For domestic heat supply, there is a provision of district heating networks in Kyrgyzstan which can be considered as a modern energy service. However, district heating networks only connect the households situated in the capital city (Bishkek) and neighbouring urban areas. The rural areas are less likely to connect with such modern energy services because of their isolated location. The least developed energy infrastructure force rural communities to use locally available non-sustainable solid fuels (i.e. charcoal, firewood, cow-dung), which have a comparatively low calorific value and high ash content. Household non-sustainable solid fuel consumption is one of the key contributors to atmospheric air pollution. Further to this, the heavy reliance on firewood turns out as negative impacts on Kyrgyzstan's riparian forest and increase the stress on the forest cover. The non-sustainable way to meet the energy demand, is placed Kyrgyzstan as one of the most vulnerable to climate change in Central Asia.

On the contrary, Kyrgyzstan is endowed with alternative energy resources such as hydro energy, solar energy, wind energy, and bioenergy. However, the renewable energy (RE) sector in Kyrgyzstan is mostly untapped because of the lack of scientific knowledge, current energy policies, and lack of infrastructure. The available RE resources can be potentially used to supply sustainable energy in Kyrgyzstan, especially in rural areas.

The literature related to renewable energy resources is rather very limited in the context of Kyrgyzstan. Up to so far, only scant information available on the thematic knowledge about available renewable energy resources in Kyrgyzstan. To foster the development of the RE sector in Kyrgyzstan, there is a need to evaluate the suitability of each RE source with its pros and cons. In that response, this paper attempted to display a detailed strength, weakness, opportunities, and threats (SWOT) analysis of available renewable energy resources in Kyrgyzstan. The presented SWOT analysis considered socio-economic, judicial, technical, and environmental dimensions. Further to this, it also characterised the dynamics of the RE source of Kyrgyzstan. In summary, the performed SWOT analysis is concluded the paradigm that are strongly linked to the RE sector development.

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## SDEWES2021.0882

# Exploratory Study About Wind-Solar Hybrid Power Plants in Brazil

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## Abstract

The power generation abundant and sustainable to ensure the present and future evolution and prosperity of populations is a challenge that many countries around the world are seeking to solve. Considering this, the renewable energy development is a key factor for the transition from current global energy and electrical matrices, still based on fossil fuels, to new and diversified matrices based on sources with lower environmental impacts.

Among types of renewable energy, wind and solar sources have stood out significantly in recent years in terms of investments, research and expansion of installed capacity in the world. In many cases, there is an energetic complementarity between wind and solar sources. In this circumstance, the combination of wind and photovoltaic (PV) technologies for centralized electricity generation via hybrid plants is a possibility. However, centralized generation through hybrid plants is a very recent issue in the world.

Brazil, despite having a very clean energy and electrical matrix compared to the world context, also has the need to expand and diversify the national electric matrix in favor of supply security, maintenance of a clean matrix and compliance with COP targets 21. The Brazilian potentials for wind and solar energy are high and there is a great deal of complementarity between them, especially in the Northeast region. In this context, the combination of wind and solar photovoltaic (PV) technologies for centralized power generation by hybrid power plants is a possibility of contributing to the Brazilian Electricity Sector (BES) to meet part of its needs.

Thus, the objectives of this exploratory study in Brazil are to: (i) study the combined centralized wind and solar PV generation in the context of the SEB; (ii) envision possible scenarios and perspectives for hybrid plants; (iii) identify examples of hybrid plants or previous studies.

The results obtained were: (i) Combined centralized generation via wind-solar hybrid plants is an interesting opportunity for Brazil; (ii) Although there is still no specific regulation on combined generation in Brazil, there are three possible scenarios in relation to centralized combined wind and solar PV generation via hybrid projects at SEB: a) maintenance of the current regulatory framework; b) hybridization of existing wind or solar PV projects, c) hiring of hybrid projects from the original project. (iii) There are a total of 6 cases of wind-solar hybrid power plants were identified: 2 projects implemented and 4 future projects.

The conclusion reached is that combined generation via wind-solar hybrid plants is potentially an interesting opportunity to help SEB increase its share of renewable energy and meet part of its needs.

## SDEWES2021.0883

# A GIS Based Integrated Participatory Approach for Wind-Farm Siting

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## Abstract

Wind energy plays a vital role to meet growing energy needs and to replace non-renewable energy sources to reduce greenhouse gas emissions. Sweden has set the goal of 100% renewable electricity by 2040 with a major share coming from wind energy. In this context, Sweden has a national strategy for sustainable wind power development, with suggested development shares for each region. However, wind energy development also faces a multitude of ecological and societal impacts that needs consideration. Therefore, wind power planning face major challenges and there is a need for systematic planning support, integrating scientific knowledge and stakeholder valuation. The REWIND project aims to develop GIS-based methods based on multi-criteria analysis (MCA) for sustainable wind power planning.

In the case study of the County of Västernorrland, stakeholders are engaged in the main MCA steps, the design step with factor selection, treatment and aggregation, as well as weighting, and the evaluation step. Preparing this, to gain credibility, we analyse not only scientific literature but also existing planning documents and legal judgments in order to find relevant factors and their treatment and valuation. For the MCA process, we built the REWIND–GIS toolbox in Python for ArcGIS where factor parameters can be easily altered and conflicts in terms of different criteria can be aggregated and scrutinized. Through this a wide array of uncertainties can be tested, such as graded safety distances or conflict areas in varying degrees. Weights of factors from stakeholders are integrated into the model to arrive at different scenarios for suitable sites which are evaluated.

The evaluation and ranking of alternatives can then use the original factors, weights and conflicts while adding also new emerging factors, spatial or non-spatial. In this stage different methods of evaluation are also compared and tested. Through the systematic and transparent approach, planners have various options to choose from the decision space with improved understanding about the trade-offs in a quantified manner. REWIND bridges the knowledge gap in treatment of diverse factors and their performances spatially, through development of the transferable REWIND-GIS tool. This planning support tool will enable sustainable wind power planning on regional level, considering main sustainability aspects and diversified perspectives.

## SDEWES2021.0890

# Harnessing the Economic Potential of Ocean Thermal Energy Conversion in Upscaling Scenarios: Methodological Progress Illustrated for Indonesia

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## Abstract

Ocean thermal energy conversion (OTEC) is still at an early development stage despite a gigantic global theoretical potential. In this paper, practically suitable OTEC sites are mapped in Indonesia and the economic potential is determined considering technological learning and upscaling. More than 1,700 practically suitable sites for OTEC are detected in Indonesia. The economic potential is 6–41 $GW_{net}$. The scenario with the highest aggregated net present value of US$(2018) 24 billion could cover more than 8% of national electricity demand being covered in 2050. OTEC could be cost-competitive against any other energy technology in Indonesia. Notwithstanding these promising results, this work also shows OTEC's challenges. Cost optimisation is essential and learning effects must be strong and continuous. To which extent this is possible in practice is still unclear, but this paper shows that further development of OTEC is worthwhile, not only for Indonesia, but for many other countries worldwide.

## SDEWES2021.0905

# Sulfur-Free Supported Carbide Catalysts for the Hydrotreatment of Gasoil and Co-Processing with Rapeseed Oil

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## Abstract

The European Union directives related to the use of renewable energy established an overall target of 32 % for renewable energy sources consumption by 2030. The co-processing of petroleum fuels with vegetable oils in hydrotreating units is a promising route for high-quality biofuel production to fulfil those Directive demands.

The commercial catalysts for hydrotreating in refineries are supported by a transition-metal-based catalyst (Co-Mo/$Al_2O_3$ or Ni-Mo/$Al_2O_3$). However, the co-processing of high amounts of vegetable oils reduces its hydrodesulfurization (HDS) and hydrodenitrogenation (HDN) efficiency by leaching sulfur from the catalyst's active sites. This is a significant obstacle to consider for the final implementation of co-processing on an industrial scale. Therefore, Sulfur-free supported carbide catalysts could be regarded as promising alternatives to conventional hydrotreatment catalysts based on their capacity to absorb/activate $H_2$ and transfer it to the reactant molecules.

This work describes an extensive study on the use of sulfur-free supported ($Al_2O_3$ and $TiO_2$) carbide catalysts (MoCx, Co-MoCx, Ni-MoCx, P-MoCx) for the hydrotreatment of atmospheric gasoil (AGO) and co-processing with rapeseed oil (RSO). The tests were performed in a fixed bed reactor unit at industrial operating conditions (330-350 °C, 5.5 MPa, Weight hourly space velocity - WHSV: 1-2 $h^{-1}$) and AGO/RSO of 100/0, 95/5, 90/10 and 75/25 wt.%).

Analogous to conventional hydrotreatment catalysts, higher reaction temperatures and lower WHSV's positively affected catalyst activity and product quality. In the same way, the addition of a promotor such a Co/Ni, or P as dopant, significantly increased the HDS and HDN efficiency. Furthermore, all the tested catalysts promoted the hydrodeoxygenation pathway instead of (hydro)decarboxylation/decarbonylation routes during co-processing. Overall, our results suggest that bi-metallic carbide catalysts (Co-Mo or Ni-Mo) supported on $Al_2O_3$ are the most promising materials, showing high activity (up to 80 wt.% of HDS at 350 °C) and no significant negative effects due to RSO co-processing.

## SDEWES2021.0914

# Evaluating Heat Energy Potential of a Flooded Underground Mine– a Case Study

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## Abstract

In recent decades, the use of mine water from abandoned mines, especially underground mines, has become a topical issue. The range of options is quite wide and depends on many factors, including natural factors such as mine water quality, technical and socio-economic factors. Among possible options we could mention using accumulated mine water for water supply, separation of metals from mine water, using a mechanical energy of pumped mine water, and finally using mine water geothermal energy, etc.

This paper aims to present the possibilities of exploiting the geothermal potential of a flooded underground mine based on a case study from a flooded former uranium underground mine Olsi (Czech Republic). The practical application would have many obstacles like mine water aggressivity, overall quality of mine water (water management), a proximity of end-users, etc. An important idea behind this plan is the large volume of accumulated mine water underground. The system can be understood as a specific type of aquifer thermal energy storage (ATES) in the mining-disturbed pseudo-karst rock environment which could be used for heating as well as cooling purposes.

In this study, we use FEFLOW (Finite Element subsurface FLOW system) code (DHI group) for modelling a coupled flow and heat transport processes with aiming at evaluating energy potential of flooded mine using open-loop geothermal system (pumped mine water recharged back to deposit). The case study is based on a realistic configuration of principal mine workings (shafts and galleries) and mined-out areas, although decades after flooding, even in crystalline rocks, collapse can occur, and estimating the hydraulic properties of preferential pathways is very challenging and unfortunately unverifiable. Therefore, the study will be focused on sensitivity analysis and underlying assumptions testing to assess the geothermal energy balance. At this moment we do not have the ambition to fully assess the technical and economical viability of the project.

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### SDEWES2021.0946

# Sediment Heat Energy Production Expected to Use the Climate Change Effect to its Advantage

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## Abstract

This paper looks to examine the advantages of the climate change effect in seabed sediment heat energy for the city of Vaasa in western Finland, which has a unique land uplift effect that has been going on for centuries. Preliminary forecast data analysis for water and air temperature data were conducted, and correlations established between them and sediment temperature data, using SAS software for analysis. The major result of the provisional forecast shows that air and water temperatures show incremental increases through time, and that sediment temperature has positive correlations with water temperature with a 2-month lag. Therefore, sediment heat energy is also expected to increase in the future. Factor analysis validations show that the data has normal variations and no particular outliers. As a conclusion, this study reveals that sediment heat energy production uses climate change for its advantage, at least in summer time.

## SDEWES2021.0992

# Overview of the Exploration and Exploitation Activities of the Geothermal Brine Reservoirs in the Republic of Croatia

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## Abstract

Geothermal exploration in the Republic of Croatia was mostly associated with oil and gas industry exploration. Most of the currently known geothermal potential locations in Croatia's Panonnian Basin were discovered during the oil and gas exploration and exploitation from the mid 20$^{th}$ century onward. The Pannonian Basin, partly located in Croatia, is well known for its higher than average geothermal gradient with good potential for geothermal energy exploitation. Unfortunately, the geothermal energy utilization in Croatia, which began in the late 80s, developed very slowly and sporadically. Most of the projects and use are linked to balneology and numerous thermal spas. In the last decade there is a rise in using low temperature geothermal sources in agriculture, namely in greenhouses. However, with the change of legal framework in 2018, the market saw an uprise in number of geothermal exploration blocks. With Croatia's first geothermal ORC power plant Velika Ciglena in operation from 2019 and the legislature change, the interest in developing geothermal projects are seen in 13 exploration and 6 production licences given in the last three years, with focus on deep geothermal potential. Planned use of these granted licences vary from electricity production to agricultural use. Aside from classic geothermal brine production, there is also good potential of geothermal brine exploitation from bottom aquifers. Many hydrocarbon reservoirs in Croatia consists of oil and gas in the upper part of the reservoir and aquifer in the bottom part. During initial depletion drive exploitation, pressure in the reservoir declines causing brine from aquifer to slowly invade oil zone. While reservoir is in its last stages of production some waterflooded peripheral wells could be turned into geothermal ones, even if oil is still produced or after the field is abandoned. So far several locations with relatively high temperatures of the bottom aquifer were identifies as good potential for deep geothermal energy exploration and exploitation. This work gives an overview of the current state of the geothermal energy utilization in Croatia and future prospects.

## SDEWES2021.1004

# Environmental and Economic Sustainability of Energy from Forest Residues in Turkey

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## Abstract

Forest residues as the cheap and abundant option of biomass can replace current fossil energy sources, subsequently reducing greenhouse gas emissions (GHGs) and improving energy security. Given 27% of total lands covered with forests, Turkey has a remarkable potential of forest residues from harvesting and industrial activities. Thus, this study sets out to assess the environmental and economic sustainability of heat and power generation from forest residues in Turkey and aims to identify the sustainable options. Two different forms of biomass, wood chips and wood pellets, are considered for energy conversion via various technologies including direct combustion (for heat-only, power-only, and cogenerated heat and power (CHP)), gasification (for CHP) and co-firing with lignite. The environmental impacts and costs per MWh of heat and power are estimated using life cycle assessment (LCA) and life cycle costing and compared to the grid mix and natural gas boiler.

Results suggest that the direct combustion of wood chips through co-generation systems has the lowest life cycle environmental impacts and costs. Forest residues in the form of wood chips are more preferable for both aspects of sustainability because of the less energy intense processing of residues. Moreover, all biomass-only systems reveal great reductions (>80%) in climate change and fossil, water and ozone depletion potentials compared to reference energy systems, although some trade-offs exist. With regards to costs, all systems have lower levelised costs than reference systems except gasification. Furthermore, all technologies except pellet boiler are profitable and pay back in their lifetime. However, subsidies for biomass power and the heat recovery are found essential for the feasibility of relevant technologies. It is estimated that if 5.7 Mt of annual forest and forest industry residues in Turkey are utilised for the energy supply, it could potentially reduce 7.3 Mt $CO_2$ eq. (or 1.5% of annual GHGs) and save 5% of total energy import ($0.5 bn/a).

## SDEWES2021.1011

# Efficiency of Solar Energy Use for Domestic Hot-Water Systems in the Northern Regions

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## Abstract

The nature of the northern territories is extremely sensitive to different pollutants and appropriate treatment from these pollutions much longer than in the southern regions. The use of renewable energy resources in the northern territories reduces the amount of nonrenewable fossil fuels and

This paper studies the problems of improving the efficiency of solar power generation, storage and utilization in domestic hot water systems. Investigated systems are equipped with a gas-fired boiler as an additional source of thermal energy. Circulating pumps are supplied with electrical energy produced by the solar thermal power systems.

The paper presents the implemented methods and methods requiring scientific substantiation for improving the performance of solar hot water systems during the year. It is shown that even beyond the Arctic Circle, it is possible to implement solar hot water systems in residential buildings, thereby replacing at least 50% of natural gas with solar energy for water heating.

The ways are determined to obtain the maximum potential solar power generation for hot-water systems at the different solar intensities with minimum consumed electricity by a circulating pump, produced by photovoltaic panels. The paper proposes two operation scenarios of a circulating pump operation.

The first scenario suggests acquiring the data on saving electric energy via a dual control for the circulating pump operation (working or idle) throughout the day. The electricity consumption is measured approximately, i.e., operating hours, without start-up increase in the electricity consumption. The pump switches on and off automatically when the average temperature of the heating agent in solar collectors is, respectively, 10 and 1 °C higher than the water temperature at the bottom of the storage tank. The minimum consumed electricity by the circulating pump is 26.06 ± 0.64 % on sunny days, while its maximum reaches 36.40 % at low cloudiness and 57.02 % at continuous cloudiness.

The second scenario suggests the control for the pump engine speed (variable-frequency control) depending on the signal intensity generated by a solar activity detector. The results of theoretical studies concerning the possibility and efficiency of such control are given herein. In this paper, the process and instrumentation diagram was proposed to implement the optimal controller based on a programmable logic controller.

## SDEWES2021.1015

# Small Hydropower Plants for Sustainable Development

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## Abstract

Energy crisis caused by the reduction of fossil fuel reserves, dramatic fluctuations of their price, frequently caused by geopolitics, as well as environmental issues because of their expedited consumption (increasing global warming caused by greenhouse gasses, air pollution caused by various pollutants, ozone layer damage, acid rains, etc.) are a challenge for the sustainable human development. Because of this, last few decades increased interest has been expressed for renewables such as solar, wind, hydropower, geothermal and biomass, in order to achieve the 50-50-50 goals. Hydropower is one of the most important kind of renewable energy. While large hydropower plants, frequently associated with the building of large dams, despite the fact that they created a major reliable power supply plus irrigation and flood control benefits, the dams necessarily flooded large areas of fertile land and displaced many thousands of local inhabitants. There are also numerous environmental problems that can result from such major intervention with river flows. On the contrary, small hydropower plants, units with a rated capacity mainly of 10 MW or something smaller or larger (many countries define their own classification to meet local needs), have minimal and ignorable environmental problems in comparison with those of large hydropower plants with large dams. The main objective of the paper is to demonstrate how the small hydropower plants can be, from the technology, application and socio-economic point of view, simultaneously renewable, environment friendly and sustainable. Today, this can be achieved by using sophisticated computer-based tools for small hydropower plant resource planning and development (design), state of the art in the design of small hydropower plants and small hydroturbines (e.g. very low head turbines which are fish friendly) and different measures that will minimize the impact on the environment (fish ladders, fish screening (e.g. bio acoustic fish fence), trash screens, cleaners, etc.). In the paper previously mentioned will be elaborated in detail and illustrated on the example of a pilot small hydropower plant.

## SDEWES2021.1040

# Ignition Behavior of Hydrotreated Pyrolysis Oil in a Combustion Research Unit

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## Abstract

Objective The goal of this work is to investigate the ignition and combustion characteristics of hydrotreated pyrolysis oil (HPO) derived from different biomass origins. Specifically, to use the biofuel as a component fuel and blend with commercially available fuel in the existing marine engine without major modification. Ideally, both the physical and combustion properties of blended fuel should be similar to diesel.

Experimental procedures In the first part of this investigation, both commercially available fuels (MGO, HVO, FAME, and EN590) and MTF fuels were tested at 30 bar chamber pressure and various chamber temperature (430~580°C) without EGR. Then, HPO fuels are blended with HVO from 0 vol% to 100 vol% in steps of 25% and tested under the same operating conditions. The viscosity of fuels was tested from 10 to 100°C in steps of 15°C. The equilibrium time of 15 minutes was used for each temperature, and after reaching an equilibrium state, the dynamic viscosity of the sample was consecutively measured 10 times with a time interval of 10 s, being averaged to obtain the final dynamic viscosity result. And the difference between the 10 consecutive measurement results, was negligible, hence the error bar was omitted in the results.

Conclusions Based on the operating conditions, the ignition delay time of tested fuels is ranked according to HPO>diesel-like fuels>HVO. It also reveals that the biomass origin of HPO will have a minor influence on the ignition delay. And this influence will decrease at high chamber temperature, which applies to both the absolute and relative ID. Moreover, it shows that post-treatment increases the ID of HPO fuels. HVO and HPO fuel blends show good stability. The viscosity of all tested fuels decreases as temperature increases as expected. The differences in viscosity among HVO, HPO, and EN590 are small. No clear correlation can be observed between the viscosity of HVO+HPO blends and the blend ratio. Blending the HPO with HVO can substantially increase the ignition delay time of HVO and is proportional to the ratio. Two combustion regimes are observed at different temperature ranges. They mainly depend on fuel reactivity. Up to a certain ID-EOI, PRR peak increases as the temperature increases due to the increase of the premixed combustion part in the classical diesel combustion. At a certain difference, the PRR peak decreases due to over-mixing when the mixture overall lean. At 75 vol% HVO blend ratio, HVO+75vol%HPO have an identical ignition delay time as EN590 nearly independent of the operating conditions. Even more, both the chamber pressure and PRR profiles are nearly identical as well. This indicates a fully $CO_2$-neutral biofuel can be created that behaves exactly the same in a compression ignition engine.

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## SDEWES2021.0016

# One-Dimensional Numerical Prediction of Syngas Components in a Bubbling Fluidized Bed Gasifyer

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## Abstract

This research is focused on the development of a one-dimensional mathematical model (with respect to the height of the reactor) of fluidized bed gasifier in a bubbling regime at atmospheric pressure, by means of simulation by numerical methods with the use of MATLAB, based on the Theory of the Two Phases (emulsion and bubble). The model developed through empirical equations proposed in several publications, allows the prediction of the energy quality (LHV) and the composition of the synthesis gas throughout the height of the reactor during the gasification process, by estimating the molar flows of the main volatile species produced ($CO$,$CO_2$,$H_2O$,$H_2$,$O_2$,$CH_4$,$N_2$ and char). In addition, the model has been validated and presented in a paper, where the values of the molar fractions of hydrogen ($H_2$), carbon monoxide ($CO$) and methane ($CH_4$) obtained experimentally from an investigation were used to be compared with the mathematical model, obtaining a good approximation with an average error of 29%.

The one-dimensional model was applied to a scale plant of a bubbling fluidized bed gasifier fed with sugarcane bagasse, to predict the quality of syngas by estimating the main gaseous compounds, obtaining a low heating value (LHV) of 5.93 MJ/Nm$^3$. Finally, the variation of the LHV with respect to the reactor operating temperature and the Equivalence Ratio (ER) is estimated.

## SDEWES2021.0034

# CFD-Based Air Feed System Development for a Bubbling Fluidized Bed Gasifier

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## Abstract

The optimal performance of a bubbling fluidized bed gasifier is based on its excellent fluidization, which depends on the monitoring and control physical conditions such as the minimum fluidization velocity, fluid surface velocity, the bed pressure drop as well as biomass and inert material types.

This work consists of the study of the fluid dynamic behavior of a bubbling fluidized bed development of an air feed system of a 70 kW Bubbling Fluidized Bed Gasifier Prototype, operating with alumina as inert material. For this end, it was necessary the application of a previously validated CFD model to study [1] of the fluid-dynamic behavior of a bubbling fluidized bed subjected to different gas inlet velocities starting from a fixed bed height of 0.2 m, in order to determine an optimal air inlet operating speed range and the pressure drop of the aforementioned gasifier according to the fixed bed height and the size of alumina and bauxite particles as inert material, at identical thermal operational condition of real gasification.

The CFD model implementation was validated through comparison with experimental results of a sand fluidized bed (Zhang, 2011). Then, the fluidization of the alumina bed was simulated with six different velocities, with the objective of identifying: the pressure drop of the fluidized bed, the bed characteristics for each velocity and the optimal range of operating velocities of a gasifier; and thus to estimate the bed behavior of the prototype gasifier bed in inert condition. Once the operating velocities were determined, simulations of modifications in the geometry of the UDEP gasifier feed system were carried out, by means of which the indicators related to the uniformity of the fluidization medium inlet in the gasifier cross section were improved.

## SDEWES2021.0122

# Waste Gas Utilization by Combining Operation with Syngas Conversion to Biomethane Technology

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## Abstract

In recent years, biomethane production from biomass waste is developed intensively in the world. This study proposes a combined innovative biomethane production concept that combines the integration of two different technologies. The subject of the study is a selected operating biogas plant through anaerobic digestion. This power plant produces biogas for heat and power production. This study analyzes the idea of changing the concept, where instead of direct combustion, biogas would be directed to the biomethane purification process producing a higher value product. In view of the growing demand for biomethane, it is proposed to integrate synthetic gas conversion technologies into the existing biogas plant. It will be particularly important for future energy systems in the production of green biofuel for transport vehicles. The integration of the technology into the existing power plant would not only increase the production of biomethane but would also help to utilize the waste gas generated after biogas purification. The problem is that the waste gas still contains 10 to 25% methane, which leads to ozone depletion. In order to use waste gases for heat and power production, an additional continuous supply of caloric gases is required to prevent the release of methane into the environment. For this purpose, it was investigated a complex of measures affecting the combustion stability of waste gas. It was established that the enrichment of waste gas with at least 25 vol.% syngas allows stable combustion closer to the burner surface with a supply of 21 vol.% oxygen.

## SDEWES2021.0253

# Analysis of Greenhouse Gas Emissions Reduction from Biogas Production Based on Agricultural Residues and Industrial by-Products

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## Abstract

Bioenergy, especially biogas produced through anaerobic digestion of renewable feedstocks, is considered to be one of the highly promising alternatives to fossil fuels. The number of European biogas plants has increased steadily over the past decade, due to supportive policy. However, some of these policies resulted in the expansion of food and feed crops dedicated to biogas production, which has caused concerns about the sustainability of biogas production.

Recovery of biogas from agricultural residues and livestock production, as well as from industrial by-products is an acknowledged greenhouse gas mitigation technology, for the cases when their utilization achieves a certain level of greenhouse gases savings, as reflected by the revised Renewable Energy Directive, which entered into force in December 2018.

The aim of this work is to perform an analysis of greenhouse gas emissions reduction for numerous residues from agricultural and livestock production, as well as industrial by-products. The results define the maximum distance for which biogas produces from considered feedstocks achieve greenhouse gas emissions savings of 80%, compared to fossil fuels. The obtained results can be used for defining sustainable alternatives which should replace currently dominant maize silage in biogas production.

## SDEWES2021.0343

# Numerical Simulation of Biochar Combustion in a Simulated Ironmaking Electric ARC Furnace

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## Abstract

Climate change is the biggest issue for the steel industry in the 21st century. The Electric Arc Furnace (EAF) is the second most common process in steelmaking and accounted for 29% of the total world production of crude steel in 2018. In modern EAFs, more than 40% of energy comes from chemical sources of fossil fuels: natural gas and coal. Reducing greenhouse gas emissions (GHG) in steelmaking requires the development of breakthrough technologies and operational strategies. In particular, about 60–70% of the direct GHG emissions in EAF steelmaking originate from the use of fossil carbon charge during the melting of steel scrap. In this paper, the use of biochar from torrefaction, slow pyrolysis and hydrothermal carbonisation (HTC) of biomass as a substitute for fossil coal in EAF was studied. A three-dimensional computational fluid dynamics (CFD) model for combustion and electrode radiation inside an EAF was developed by assuming particle surface and gas-phase reactions to predict injected biochar particle combustion. The effect of combustion reaction on the temperature distribution inside the EAF and the influence of intermediate gas release was analysed. Results showed that the use of biochars instead of fossil coal in the EAF steelmaking process did not involve significant negative differences and that CFD simulation can efficiently be used to develop and investigate EAF in the design phase.

## SDEWES2021.0441

# Electro-Mechanical Properties of High Dense Yttrium-Doped Barium Zirconate Electrolyte Materials for Fuel Cells

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## Abstract

In order to cope with the climate change environmental threat and the exhaustion of fossil fuel reserves, the development of sustainable, more effective and cleaner energy sources becomes in a major global challenge. Among the different solutions, solid oxide fuel cells (SOFCs) have stood out in the last years as one of the most promising alternatives for sustainable energy production. Nevertheless, the main limitation of SOFCs lies in their unsatisfactory durability and reliability due to the high operating temperatures and thermal cycling characteristic of these devices. An intense search is currently underway for materials for SOFCs with the objective of lowering the working temperature and then overcoming these limitations. Yttrium-doped Barium Zirconate is considered an attractive alternative to Yttria-Stabilised Zirconia electrolyte material in Solid Oxide Fuel Cells (SOFC), exhibiting an elevated electrical conductivity and an excellent chemical stability over a large range of temperatures and oxygen partial pressures. While numerous studies have dealt with the preparation of dense ceramics and with the study of influence of composition on proton conduction properties, the available data on mechanical properties of Yttrium-doped Barium Zirconate compounds still remain scarce. We have thus started an exhaustive study of the electro-mechanical properties of high density (> 95%) sintered $BaZr_{1-x}Y_xO_{3-x/2}$ compounds. Materials were prepared using known strategies to obtain dense compounds, having either micronic scale grain size in the case of solid state reactive sintering or submicronic grain size in the case of conventional sintering.

A new device was built to measure electro-mechanical properties of electrolytes in solid oxide fuel cell operating conditions. Compressive mechanical tests together with electrical measurements have been performed at 700 °C under hydrogen. The objective of this study was to evaluate the mechanical behaviour of Barium Zirconated in SOFCs working conditions and find the reasons why electrolyte conductivity diminishes with time in relationship with microstructural and structural evolution. This work provides a comprehensive insight into the electo-mechanical behaviour of cell components in operation conditions being of essential interest for the development of SOFCs.

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## SDEWES2021.0444

# Multiphase CFD Simulation and Experimental Validation of Spent Coffee Grounds Pyrolysis in a Bubbling Fluidized Bed Reactor

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## Abstract

Spent Coffee Waste (SCW) originated from brewing coffee powders has grown dramatically, hence suitable management of this solid biomass waste is imperative. The thermo-chemical conversion of SCW solid biomass is the most promising approach to extract valuable products in the form of biofuels and chemicals. Evaluating design and scale-up heuristics of bubbling fluidized bed using computational fluid dynamics (CFD) simulation is not only cheaper and easier but also provides key data for the whole reactor. A fast pyrolysis of SCW solid biomass in a bubbling fluidized bed were simulated using transient Eulerian-Eulerian multiphase model. Firstly, the developed model is validated against the experimental obtained hydrodynamic profile. Followed by a validated hydrodynamic model were coupled with a SCW solid biomass pyrolysis kinetic model for the prediction of product yields (gas, bio-oil, and char). The simulation results of this investigation show good agreement with the experimentally observed yield distribution. The influences of reactor operating conditions and reactor configuration on the products yield were discussed. Overall, this study provides important guidelines for possible reactor scale-up, intensification and optimization.

## SDEWES2021.0506

# The Stability of Mixed Oxide as a Catalyst for Transesterification of Vegetable Oil

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## Abstract

Triacylglycerides are one of possible renewable sources of energy and are used for fuels or as raw materials for other chemicals. Triacylglycerides are contained in the vegetable oils, animal fats or waste frying oils. One transformation way is a transesterification, which is a reaction between triacylglycerides and low molecular alcohols (methanol or ethanol). The products of transesterification are mixture of methyl esters and glycerol. The esters are usually used as a renewable source of energy (biodiesel). However, the esters can be also used as a raw material for other valuable chemicals, such as lubricants used in means of transport or epoxides for polymerization. The side product is glycerol, which has many applications in chemistry, food and pharmacy industry. The transesterification is usually catalysed by a basic homogeneous catalyst (not possible to reuse); however heterogeneous catalysis is also applicable. The disadvantage of heterogeneous catalyst is its stability and reusability.

This work is focused on the stability of mixed oxides (synthesized from hydrotalcites) as possible heterogeneous basic catalysts suitable for transesterification. Many papers dealing with various types mixed oxides as catalysts, but almost no papers are focused on the catalyst stability, which is the crucial parameter for application. The stability of Mg-Al mixed oxides was determined by leaching of metals (contained in the catalyst) to the liquid phase (the ester and glycerol phase) after transesterification. The solid catalyst was also characterised by various methods including determination of all metals. The main attention was focused on the basic matter, which remained after the catalyst synthesis and can increase the catalyst activity (ester yield). Moreover, it leaches to the liquid product as impurities. The reason of leaching will be described. The results of the catalyst analysis before and after transesterification are correlated with catalyst activity and metals (especially sodium) in the transesterification products. The issue of residual sodium in mixed oxides was not published yet.

The reason of leaching will be described, which would enable to synthesize a stable catalyst. Therefore, the formed ester and glycerol will contain less impurities, which is environmentally friendly (less energy is needed for further purification).

Acknowledgements

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## SDEWES2021.0614

# Fatty Acid Distribution of Chlorella Sorokiniana Grown with Crude Glycerol and Anaerobic Digestrate as an Alternative Source of Bio-Oil for Biodiesel Production

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## Abstract

The growth kinetics, the lipid and protein content of the microalgal species Chlorella sorokiniana grown heterotrophically in growth media containing glycerol and increasing amounts of anaerobic digestrate (AD) (0 %, 15 %, 30 % and 50 %) was studied. The effect of AD on the fatty acid (FA) distribution in the oil extracted and the fatty acid methyl ester (FAME) properties such as the saponification number (SN), the iodine value (IV), the cetane number (CN) and the higher heating value (HHV) was also examined and this novelty has not been reported before. The cultivation took place in orthogonal glass bioreactors at 30±1°C and pH=7±0.3. In all experiments the initial organic carbon and nitrogen concentrations were held constant and carbon concentration in the growth media was measured daily. Anaerobic digestrate (AD) from a local biogas plant was first filtered and then was centrifuged prior to sterilization. The AD was found to affect the rate of carbon uptake. The maximum carbon uptake rate occurs at about 30 % AD. As the % AD added to the growth media increased from 0% to 50%, protein and lipid content ranged from 32.3 - 38.4 % and 23.1% to 18.1% respectively. Fatty acid distribution ranged from C10 to C26. In all AD percentages the predominant fatty acids were the medium chain FA C16-C18 constituting up to about 89 % of the total fatty acids. Increasing the percentage of AD from 0 % to 50 % increased both the % of short chain FA (C10-C14) and the % of long chain FA (>C18). On the contrary, the medium chain FA (C16-C18) decreased from 88.6% to 53.9%. With respect to the saturation of the FA chains, increasing the percentage of AD from 0 % to 50 % increased the % of SFA and decreased the % of PUFA.

These changes in the FA distribution, as the % of AD varied from 0% to 50%, affected the FAME properties. As the % of AD increased, the cetane number (CN) of the FAME increased from 52.7 to 56.1 and the iodine value decreased from 93.1 to 74.5 g I/100 g FAME. Glycerin is a good substrate for the heterotrophic cultivation of Chlorella sorokiniana, as it is readily utilized for its growth while, AD from biogas plants can be used as an additional source of carbon and macro and micronutrients for the heterotrophic growth of microalgae and also to improve FAME properties. Further research is needed in order to determine the effect of other modes of cultivation using glycerol and AD in microalgal cultivation for biodiesel production such as semi-batch and mixotrophic cultivation and cultivation using other strains, especially genetically modified strains.

ACKNOWLEDGEMENT

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## SDEWES2021.0674

# Complex Aspects of Energy Crops and Policy Implications

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## Abstract

The paper focuses on the design of a methodology that links the modelling of biomass potential from agricultural land using geographic information systems (derivation of biomass yield according to soil, topographical and climatic characteristics) with the growing need to provide non-productive functions contributing to sustainable land use and with the economic viability of biomass from energy crops. According to the proposed methodology, perennial energy crops are prioritised for allocation where land risk index is highest. Land risk index is determined by assessing 5 basic characteristics - landscape connectivity, landscape heterogeneity, threat of the drought, threat of the water and the soil erosion. Another aspect of the allocation of energy crop plantations is the economic competitiveness of this biomass, which is modelled using the production price of energy biomass considering the competition between conventional agriculture and energy biomass. The application of the methodology is demonstrated using a case study of the Czech Republic. The results of this study show that when allocating SRC plantations to 15% of the arable land area and respecting the priority of allocating plantations to land with the highest land risk value, the biomass production from SRC plantations for marginal biomass prices of 6-12 EUR/GJ is reduced by 23-38% compared to a scenario where neither the aspect of non-productive functions nor competitiveness is considered.

## SDEWES2021.0719

# Canabis Sativa as Multi Purpose Energy Crop

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## Abstract

Biomass, and in particular the purposely grown energy crops, will play an increasing role in meeting the EU's goal of achieving climate neutrality. An effective strategy for the development of biomass cultivation on agricultural land requires the search for energy crops that would be suitable for the given climatic and soil conditions, but would also be beneficial for farmers from a business point of view. An important aspect here is not only the price of biomass produced in this way, but also the diversification of its possible use. Cannabis (Cannabis sativa) can be a suitable addition to the energy crop portfolio to reduce the business risk associated with perennial energy crops (eg high one-off costs of plant establishment) and linkages to one type of market (biomass production for energy). Biomass from cannabis is not only a suitable raw material for the production of solid biofuels, but has a number of other uses (eg material use in construction, food and cosmetics, etc.). An interesting possibility is its use for the production of biochar as a very valuable soil additive to improve the quality of intensively farmed land.

The aim of the article is to present the results of a comprehensive evaluation of the efficiency of cannabis cultivation with emphasis on energy use and biochar production. The article presents the results of field experiments with cannabis cultivation and with the use of biomass thus produced for biochar production. The experimental data obtained in this way were further used to create an economic model assessing the efficiency of cannabis cultivation for energy purposes and biochar production. At the same time, the economic model makes it possible to evaluate the advantage of growing cannabis in comparison with perennial energy crops, both from the point of view of one's own economic efficiency and from the point of view of various levels of business risk.

The results of the application of the methodology are demonstrated on the case example of the Czech Republic. Along with the economic evaluation, the result of the analysis of the area of agricultural land is presented, where the soil and climatic parameters meet the requirements for cannabis planting.

Preliminary modeling results show that in the conditions of the Czech Republic (as a representative of Central Europe) cannabis can be a suitable addition to the portfolio of energy crops, especially in terms of diversification of risks associated with the cultivation of energy crops.

SDEWES2021.0740

# Offshore Wind Speed Classification Using Merra-2 and Machine Learning Models of the Mediterranean Sea

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## Abstract

The Mediterranean Sea has favorable climatic conditions for the exploitation of Offshore Wind (OW) energy sources. Anyway, to accurately highlight the best areas for Offshore Wind Turbine Generators (OWTGs) installations, it is necessary to focus on the long-term OW potential assessment. A precise evaluation of wind parameters plays a crucial role in the OWTGs installation success, as demonstrated by many past projects in the Mediterranean Sea that did not follow due to a lack of initial OW sources assessment. In this regard, the long-term Modern-Era Retrospective analysis for Research and Applications version 2 (MERRA-2) re-analysis has been designed and developed by the National Aeronautics and Space Administration (NASA) to identify possible locations of the OWTGs installation. In particular, an OW classification based on the last 40-years period OW speeds highlighted the best areas for potential OWTGs installations in the Mediterranean basin. Preliminary results show that areas in the Aegean Sea, Gulf of Lyon, the Northern regions of Morocco and Tunisia have interesting OW potential for further studies. Secondly, a combined forecasting model based on wavelet decomposition method and long-term memory neural network has been developed to predict the short-term wind speed considering the last ten years of hourly data for three areas. According to the forecasting results, the proposed model accurately predicted wind speed in four regions. In addition, the results of the combined developed model have been compared with other single models (MLP and LSTM), highlighting a higher level of accuracy. Finally, three Weibull fitting algorithms have been provided to analyze the wind energy potential in different areas.

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## SDEWES2021.0363

# Technical and Environmental Issues on the Development of Offshore Wind Farms: the Mediterranean Sea Case Study

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## Abstract

**Energy can be considered the beating heart of the world's economic growth, which can inject fresh blood into the bodies of countries to maintain and expand human economic and social development. Wind energy is one of the most abundant, cleanest and safest renewable energy sources (RESs) globally. One of the research areas that can significantly impact the development and advancement of renewable energy worldwide is identifying the optimal use of various marine renewable resources, especially offshore wind farms (OWFs) installations. Offshore wind energy can be considered the strongest RESs in installed capacity and future facilities in offshore areas. This paper focused on the technical sources assessment and environmental issues on the development of the OWFs, such as wind speed assessment techniques (in situ measurements, remote sensing and reanalysis data from 1980-Jan - 2021-Jan), environmental factors, control strategies, and the impact of hybrid technologies on OWFs is discussed and analyzed. Technological advances allow higher capacity turbines to be installed in deeper waters, but not much is known about their effects on the environment yet. Therefore, the impact of each wind turbine base on the ecological areas used in OWFs has been investigated. The results show that the marine environment impact varies between the OWFs foundation used, which can vary depending on the installation and the volume occupied in the bases used in the seabed. Finally, we review lessons learned from recent literature and recommend future monitoring and evaluation as interest in marine wind energy grows worldwide.**

## SDEWES2021.1048

# Analysis of the Power Production from a Wind Turbine Installed in Urban Area of Prishtina

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## Abstract

Wind energy is one of the main sources of renewable energy resources. Wind turbines are usually located in areas with higher altitude and consequently the higher wind velocity. Due to transmission energy losses and many other reasons, studies have recently been conducted about the possibility of installing wind turbines in urban areas.

For a turbine previously installed in the urban area of Prishtina, more precisely at the rooftop of the Laboratories of Technical Faculties of the University of Prishtina, the data of electricity production for the year 2019 have been taken. The turbine is a horizontal axis wind turbine, has an installed capacity of 300 watts and has its own code S-300. For the year 2019, the characteristics of electricity production from the S-300 turbine have been analyzed. In addition, the curve of electricity production from this turbine in relation with the wind velocity is presented, including the total amount of power produced in relation with average wind velocity.

Considering the definition of wind turbines efficiency given by the scientist Albert Betz and the mathematical form of wind turbine power generation, the main and most interesting part of this presentation is the analysis of the Betz coefficient and theoritical and real power production for the installed turbine. The results of the real efficiency of the wind turbine in the end are compared with the theoretical efficiency calculated with mathematical equations.

## SDEWES2021.1060

# Using B15 in Vehicles on Real On-Road Circumstances - a Case Study

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## Abstract

The environmental imbalance that has been shown through unusual climate changes and amplified natural catastrophes is the mirror of extreme pollution, which the planet is no longer able to eradicate. Abusive use of petroleum comes from the energy dependence inherent in the dynamics that society adopts today, and this becomes a time bomb, both economically and environmentally. The transportation sector is one of the biggest consumerist on energy expenditures and polluting gas emissions, being urgent and imperative to act on this sector. The legislation about these emissions has been suffering constant updates, more and more incisive on this subject. Although the demanding polluting gas reductions, it also imposes the use of sustainable energy sources, where the biofuels are, outlining some raw materials as energy sources, as they might not be sustainable.

This research will present an overview of biodiesel use on vehicles running in on-road real circumstances. For this, through a completely practical strand, the present paperwork covers the analysis of the B15 use on car fleets. This study was based on car fleets follow-up, composed of cars and trucks, fuels with conventional diesel, and B15 on equivalent periods. Collecting data from consumptions and driving styles, allowed to conclude that excessive behaviors on the drivers' behalf can impact even more fuel consumption than the fuel itself. Towards all the analyzed car fleets, the 15% Biodiesel incorporation on fuel will imply some variations in fuel consumption, sometimes greater, sometimes lower, compared to the conventional fuel. Even considering a small mean raise in fuel consumption is verified, the increase in biodiesel blends can be confirmed as a positive contribution to the environment, due to all the advantages a renewable fuel offers, mainly on the $CO_2$ reduction emissions and decrease on fossil energy dependence.

## SDEWES2021.1069

# Experimental Study of Flame Variations of Biogas Enriched with Hydrogen

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## Abstract

Climate change caused by anthropogenic activity reinforces the necessity to find new energy systems to minimize greenhouse gas (GHG) emissions. The ambitious environmental targets are forcing a technological revolution to reduce human impact. Hence, renewable energy research is essential to fight against climate change and, specifically, this work is focused on renewable gases such as hydrogen, biomethane and biogas.

When we speak about renewable gases, hydrogen is probably the first gas that come to our minds. However, biogas is an alternative and sustainable solution. Biogas is produced by anaerobic digestion or fermentation of biodegradable waste, such as manure, wood, agricultural products, etc. Despite its renewable origin, biogas is a poor gas due to its high carbon dioxide content, and the strong fuel variabilities. As the implementation of the "hydrogen economy" seems to be far from now, the use of hydrogen as a transition element may be a key element to boost the energy transition. Hydrogen enrichment is a well know technique that enhance the combustion characteristics of conventional fuels. For example, hydrogen addition improves flame stability and reduces heat release oscillations. This also can implies a decrease of pollutant emissions.

The present study addresses a conventional combustion system behavior, consisting of a burner of 100 kW fed with biogas-hydrogen mixtures instead of natural gas. Flame behavior and ignition behavior were investigated. The tests were performed with three different mixtures of $CH_4$-$CO_2$ recreating three biogases; rich biogas 70:30 $CH_4$: $CO_2$ (BG70), standard biogas 60:40 $CH_4$: $CO_2$ (BG60) and poor biogas 50:50 $CH_4$: $CO_2$ (BG60). Finally, with the aim to encourage better flame stability, each biogas was enriched with hydrogen from 5% to 25%. Using a bentonce burner in the experimental setup designed to study the flame visually, the flame is produced. The flame is captured by means of a thermographic camera and a digital camera. The images obtained will be the base of the data processing. The data imagen processing was carried out with the Fiji Imajej software, applying colour histogram. The results will establish the operation conditions of conventional combustion systems when fed with renewable fuels and will determine flame variations when biogas is enriched with hydrogen.

## SDEWES2021.1073

# Spatio-Temporal Solar-Wind Complementarity Studies in the Provinces of Kalinga and Apayao, Philippines Using Canonical Correlation Analysis

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## Abstract

Increased utilization of renewable energy (RE) resources is critical in achieving key climate goals by 2050. Such energy transformation is perceived to alleviate the cost of energy and support sustainable development. However, the intermittent nature of RE, especially solar and wind, pose manageability and reliability concerns to the utility grid by making the demand curve more unpredictable. One way to address this intermittency problem is to harmonize the RE resources by measuring their spatio-temporal complementarity and locating the power plants in areas with good complementarity. Solar and wind power are complementary if one resource is high when the other is low, and vice versa, over a certain region. In this work, solar-wind complementarity was analyzed across the provinces of Kalinga and Apayao, Philippines, which are potential locations for harvesting renewables as suggested by the Competitive Renewable Energy Zone (CREZ) Report of the Philippine Department of Energy. The global horizontal solar irradiance (GHI) level and wind speed data sets were obtained from the NASA POWER database and then modelled using canonical correlation analysis (CCA). CCA is a multivariate statistical technique that can be used to analyze maximum correlations between any two sets of data. We modified the standard CCA to identify pairs of locations within the Kalinga-Apayao region where the degree of solar-wind complementarity is highest. Results show that the two RE resources do exhibit complementary peaks in the resulting locations. By identifying these locations, solar and wind resources in Kalinga and Apayao can be integrated optimally, leading to more stable power and increased reliability of the utility grid.

## SDEWES2021.1075

# Deep Borehole Heat Exchangers and Geoenergetics - Review Based on Polish Experiences and Research

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## Abstract

Deep boreholes join renewable energy sources. Until now, deep boreholes have mainly been associated with the global petroleum industry. The exploitation of crude oil and natural gas around the world is responsible for the drilling of tens of millions of boreholes. However, it is difficult to count them. Over 150 years of the oil industry's existence determined the development of drilling techniques and technologies. Currently, drilling experience allows for deep and very deep boreholes to be made also in the search for and exploitation of geothermal heat. One possible option are deep borehole heat exchangers. Moreover, it is possible to use boreholes already made and worn out, liquidated or intended for liquidation. A design can be used in these openings to obtain the Earth's heat where it is needed. However, a large proportion of the old openings are in places where heat is not needed. This applies, for example, to the Middle East, North Africa, Nigeria and Venezuela, as well as the southern US states.

In this case, the boreholes/wells can be used in many ways. They are covered by the general term geoenergetics, and in particular, borehole geoenergetics. They are included in the general concept of energy storage. The paper presents an overview of the possibilities in this regard.

## Renewable heat systems

### SDEWES2021.0035

# CFD Simulation of a Thermal and Fluidynamic Behavior of a Chimney Solar Dryer

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## Abstract

The present research aims to implement a computational fluid dynamics model to simulate the heat transfer phenomena and the fluid dynamics of the air circulating inside a solar chimney dryer. The design of the chimney solar dryer used in the modelling belongs to the University of California Davis, which is intended to be a low-cost collector for use in low-income areas. The Computational Fluid Dynamic (CFD) model is developed is a 2-D configuration, in which the Discrete Ordinates radiation model (DOM) was used to solve the radiant transport equation. Additionally, the Shear-Stress Transport k-ω model (SST) was used to model turbulence. The simulation has been validated by comparing data taken experimentally inside the dryer and the data obtained during the simulation. The numerical results shown that the main reason why the temperatures obtained in the simulations are quite far from the real temperatures is because of the variation of the magnitudes that quantify the environmental conditions over time, these variations are abrupt and common in the morning hours. The profile created for the simulation is composed of initial and hourly data on air temperature, soil temperature, external radiation temperature, convection heat transfer coefficient and solar radiation that are within the simulation interval. Having only hourly data of these conditions creates uncertainty about their behavior from one hour to the next.

## SDEWES2021.0438

# Abatement of Particulate Emissions from a Pellets Biomass Combustion

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## Abstract

The European Union's (EU) climate and energy framework sets the target of a 32% share of renewable energies in the final energy consumption by 2030. Biomass is the main renewable energy source in the EU, with a share of around 60%. Its primary energy supply accounted for 570 TWh in 2015 for domestic heating. High mortality rates associated with particulate emissions (PM) are a matter of concern worldwide. Small solid biomass combustion systems installed in households are among the main contributors to the global particulate emissions share. Preventive measures to reduce PM emissions include improving the fuel quality and operation practices, modifying the appliance design, reducing the energy demand or using a PM abatement system. The placement of inert porous materials to confine the combustion region is being recently explored as a possible mitigation system for this kind of pollution. However, due the complexity of the biomass thermochemical decomposition processes, it is challenging to justify the performance of these systems on the basis of a physicochemical understanding.

This work is aimed at evaluating how the use of inert porous foams in different operation conditions affects to the combustion process and alters the PM emissions production mechanisms in small solid biomass combustion systems. The results evidenced that the total air flow has a strong influence in the PM emission, leading to a reduction of 45 % in optimal conditions. The confinement of the flame with inert foams was observed to impact the temperature distribution in the combustion chamber substantially, improving the air-fuel mixture and favouring the thermal decomposition of the pellets, leading to a reduction in the particulate emissions above 60%. These results suggest that by using better operation practices and efficient abatement systems it is possible to mitigate the pollutants derived from domestic heating to comply with the recent and restrictive European regulations on particulate emissions.

## SDEWES2021.0762

# Improvement of Existing Ground Source Heat Pump System by Incorporating a Compressor Frequency Converter

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## Abstract

At a time of increasing electricity consumption and environmental pollution, high efficiency and environmental friendliness have placed heat pumps high on the list of priorities of local and regional energy strategies. Additional growth in the market share of heat pump systems is possible only with further advances in technology. The control subsystem is of great importance in the development of technology. One important aspect of regulation is maintaining the adequate refrigerant flow rate to precisely match the required heating/cooling capacity. This is possible by controlling the rotational speed of the compressor. Therefore, this paper investigates the impact of compressor frequency control on the reduction in energy required for heat pump operation. The inverter driven heat pump is compared to the base case of a single-stage heat pump. An experimental study was performed on an existing ground source heat pump with a 130 m deep borehole heat exchanger at the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, with single-stage system operation. The parameters of the system were monitored by heat and power meters and temperature and pressure sensors. The frequency converter was subsequently added, and the measurements were repeated. The obtained results were compared with the base case for temperature hysteresis of the storage tank set at 3, 6, and 9°C. The results of the research showed that advanced control and the increase in the storage temperature hysteresis prolongs the compressor working interval. An increase in evaporation temperature was also recorded, which has a positive effect on the coefficient of performance of the heat pump. In addition to increasing the COP by 6%, the frequency control reduces the stress during switching the compressor on, thus extending its service life.

## SDEWES2021.0872

# Levelized Costs and Economic Impact of Geothermal District Heating: a Decision-Path Analysis

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## Abstract

Geothermal district heating is one of the options to decarbonize the heating sector. While deploying geothermal district heating means making use of local and clean renewable resource, the high capital cost and uncertainties often make these systems less competitive. Our study aims to evaluate the competitiveness of geothermal district heating in the State of Geneva, Switzerland, and its impact on the domestic and overall economy by considering multiple decision paths to build geothermal district heating. We build a decision tree to generate 10,800 decision paths, each defined as a combination of ten decision parameters encountered while setting up geothermal district heating. For each decision path, four indicators are quantified. To evaluate competitiveness, levelized cost of geothermal district heating and levelized cost of the whole district heating system are quantified. To evaluate economic impact, economic impact multiplier and the share of the Swiss domestic impact are quantified. The last two indicators are calculated using input-output analysis. The influence of the ten decision parameters on the indicators is then analyzed and ranked using random forests regression.

We find a wide range of levelized cost of geothermal district heating (60–460 CHF/MWh) and levelized cost of the whole district heating system (50–220 CHF/MWh), reflecting how important are certain decision paths in impacting the competitiveness. The economic impact multiplier ranges from 1.7 to 5, meaning that for each monetary unit spent in developing geothermal district heating in Geneva, 1.7 to 5 monetary units are created in the overall economy. The share of the Swiss domestic impact ranges from 44% to 82%, reflecting the share of the created economic value that remains inside Switzerland. While the most influential decision parameters vary for each indicator, geothermal coverage in the total district heating supply (e.g., 40%, 70% or 100%) consistently strongly influences all four indicators. Linear heating density highly influences the competitiveness of geothermal district heating but not its economic impact. Our study shows the importance of integrating a combination of decision parameters to understand the competitiveness and the economic impacts of geothermal district heating. Although decision-makers are often challenged by many decision parameters, focusing on geothermal coverage and other most influential decision parameters will allow setting up economically meaningful strategies.

## SDEWES2021.0950

# Going Deeper in Shallow Geoexchange Heat Pump Systems – Is it Worth It?

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## Abstract

In the last decade, due to climate change concerns and new environmental regulations in EU, there is tremendous rise in installed heat pumps systems in new homes and buildings. Majority of these installed units is related to air-source heat pumps, as they offer good trade-off between capital and operating expenses. However, when analysing heating and cooling heat pumps systems from the primary energy consumption and ecological aspects, groundwater and shallow geothermal heat pump systems offer superior efficiency, comparing to all market available thermo-technical systems today. In the last decade, ground source systems have seen some technological improvement by employing new borehole heat exchanger designs, such are piping with internal fins and wider diameter (so called Turbocollector) to enhance heat transfer between fluid and rock, as well as to reduce pressure drop in system. Furthermore, process of drilling deeper offers higher ground temperatures and consequently higher seasonal performance factor in heating cycle, due to effect of geothermal gradient. Nevertheless, although deeper boreholes provide better heat extraction rates per meter during heat pump heating cycle, on the same time it reduces heat rejection rates during heat pump cooling cycle. This paper objective is to analyse and evaluate benefits and downsides of new approach in heat pump system design with deeper borehole heat exchangers up to 300 meters, comparing it to traditional design of double-loop exchangers with 100 meters in depth. Geothermal borehole grid design along with heat extraction and rejection simulation model is performed on numerous ground thermogeological variations, as well as at different heating/cooling building ratios on a yearly basis. Results of the sensitivity analysis will show what are benefits and downsides of deeper geothermal boreholes from the hydraulic and thermodynamic point of view, verified trough seasonal performance factor of the heat pump system.

## SDEWES2021.1078

# Directions of Geothermal Development in Poland on the Example of the Current Activity of Geotermia Uniejów Ltd. and the Commune Authorities

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## Abstract

Recently, the process of drilling geothermal wells in Poland has accelerated. The geological conditions in a large part of Poland's surface allow geothermal heat to be made available for heating purposes.

Since 2000, apartments and houses have been heated in Uniejów thanks to boreholes made in 1990-1991. Due to the low mineralization of water, the temperature reaching 70 ° C, high water production and local natural values, the development in the field of geothermal energy in Uniejów did not end only with heating the interior and domestic water.

It can be concluded that a small town with a population of 3,000 people has been developing since 2000 around their mineral resources in the form of geothermal waters. Since 2012, it has the status of a thermal spa (the first in Poland). The basis for granting the status of a health resort were the properties of local geothermal waters, containing e.g. sulfur, radon, fluorine, copper and iron chlorides, compounds of metasilicic acid and iodine, the content of which is the same as in the Baltic Sea.

The development in the field of balneology and recreation means that the city is visited by an increasing number of tourists. The hotel base and tourist attractions are developing intensively. This development was initiated by the construction of a geothermal swimming pool complex in Uniejów. The paper presents the current state and possibilities of further development of the city, taking into account the wealth in the form of geothermal waters.

## Research, innovation and development 1

## SDEWES2021.0017

# Heat and Mass Transfer Assessment for the Controlled Instantaneous Decompression Process Applied to Fruits and Vegetables: Modelling and Mathematical Validation

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## Abstract

The article focuses on rigorously describing and analyzing the dehydration process with regard to fruits and vegetables through the use of controlled instantaneous decompression (DIC) treatment. The mathematical modeling is obtained from the discretization of Fourier's and Fick's laws by the finite difference method. This is applied to the most common geometries in drying processes - the parallelepiped and the flat cylinder geometries.

The validity of the mathematical model is determined by the Pearson correlation coefficient, which provides the linear relationship between two quantitative random variables in the form of the data obtained experimentally in the laboratory of La Rochelle University (France), and the results obtained from the mathematical model presented in this article.

The aim of this article is to model and validate the heat and mass transfer processes that occur in the DIC process by a consideration of the laws that govern these mechanisms. The formulation of the mathematical model is carried out through the finite difference discretization method, which allows a consideration of the behavior of a number of dependent and independent variables such as the dehydration rate, drying kinetics, temperature and humidity behavior, and diffusivity effective mass.

## SDEWES2021.0038

# Sectoral and Geographical Diffusion Patterns of Technology for a Low-Carbon World Economy: an Input-Output Approach

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## Abstract

Diffusion of innovation and technology is a key element in the economic growth of countries. The innovative behaviour of each country determines its stage in each adopter category, and is essential in the development process, specially, in the reduction of the gap between developed and developing economies. Both innovation and its own diffusion depend on intersectoral relations of the economy. Different diffusion models have been developed to describe the innovation patterns between different adopter categories in the literature.

Technology innovation also plays a crucial role to achieve the climate goals agreed in different international commitments such as United Nations Framework Convention on Climate Change (UNFCC), and the Agenda 2030 of the United Nations. Innovation and environmental improvements have shown to be complementary, and international diffusion of technology performs an important role in the reduction of emissions worldwide. In this way, a faster diffusion of green technology is claimed in order to achieve environmental politic goals, and, in this way, address climate change.

Using series of input-output tables from 1970 to 2015, we explore diffusion patterns of innovation, technology and carbon intensity in key sectors for a group of advanced and developing countries (China, Germany, Spain, United States and United Kingdom). This paper makes use of a set of value chain indicators, such as the average propagation length, and upstream and downstream measures to analyse changes in their evolution and position throughout the period. The main aim is to explore the diffusion trajectories of innovation and technology, and to study the dynamic gap to achieve low carbon sustainable pathways. Our findings could contribute with a better the understanding of technology diffusion trajectories that allow countries reduce their emissions. The role of trade is also discussed in this context to reach emissions reductions established by international agreements.

## SDEWES2021.0164

# Biochar from Plant-Assisted Bioremediation: Potential Applications for Sorptive Removal of Phenolic Pollutants from Water

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## Abstract

A plant-assisted bioremediation strategy was applied in an area located in Southern Italy, close to the city of Taranto, historically contaminated by polychlorinated biphenyls (PCBs) and heavy metals. A specific poplar clone (Monviso) was selected for its ability to promote PCBs degradation. The harvested biomass was chipped and dried before being processed in a gasification plant to produce energy and biochar (BC), which could be used in agriculture as fertilizer or for environmental purposes as a decontaminating material for water and soil.The gasification has been conducted at a temperature of 850 degrees producing a BC suitable for decontaminating purposes.This work aimed to evaluate the capacity of the BC obtained by the gasification process to adsorb two well-known pollutants possessing endocrine disrupting (ED) properties, namely 4-tert-octylphenol (OP) and bisphenol A (BPA). Both molecules are widespread in water and terrestrial ecosystems as a consequence of increasing anthropic and agro-industrial activity, wastes disposal and the discharge of effluents from sewage sludge treatment plants. BC characterization indicated an organic carbon content of about 68%, a very alkaline pH and an electrical conductivity of about 5 dS/m. Using a batch equilibrium method, kinetics and adsorption isotherms were performed. Adsorption constants were calculated using the linear, Freundlich and Langmuir models. Kinetics data obtained evidenced a very rapid adsorption of both compounds, especially the more hydrophobic OP, onto BC with the attainment of a steady-state equilibrium in less than 1 h. Some differences among the compounds were found regarding the model and the extent of adsorption. Adsorption kinetic data were treated with the non-linear pseudo-first order and pseudo-second order equations in order to investigate the retention mechanisms. Results obtained showed that kinetic data followed preferentially the pseudo-second order model, thus indicating the occurrence of chemisorption between the compounds and BC. The remarkable sorption capacity of this material towards the two ED chemicals suggests its valuable exploitation for decontamination purposes, such as the treatment of wastewater before recycling into the soil and the retainment of pollutants in soil avoiding their entry into the food chain.

## SDEWES2021.0268

# Technological Learning in the End-of-Life Phase of Crystalline Silicon Solar Panels

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## Abstract

The approaching end-of life phase of the early installed solar panels has led to a variety of potential end-of-life strategies. Based on an extensive literature review, ten end-of-life scenarios with multiple potential learning effects were identified and their material flows were quantified using a combined material and substance flow analysis. Subsequently, material recovery rates from a mass, economic value and embodied energy perspective were calculated, taking into account the differences in secondary applications. The differences in mass-based recovery of the seven end-of-life scenarios which did not have landfill or municipal waste incineration as the main destination was found to be minimal, ranging between 71-75% for the best-case learning scenario. Using the economic value recovery rate and the embodied energy recovery rate, more profound differences were found. As the mass-based recovery rate might favor end-of-life scenarios that led to dissipation of valuable materials in non-functional secondary applications, additional targets are required.

## SDEWES2021.0452

# A Retrofitting Design of Automated Borehole Drilling System Using Legacy Draw-Works Mechanical Brake Hardware

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## Abstract

A notable portion of contemporary deep drilling rigs are still equipped with manually-operated lever-based draw-works (hoist) drum mechanical brake actuators, which are used for weight-on-bit (WoB) and rate-of-penetration (RoP) control. In order to meet increasingly stringent requirements on the WoB/RoP control performance, including completely automatic vertical drilling operation (auto-drilling), such mature drilling systems need to be retrofitted with a suitable brake actuator servo mechanism, along with appropriate WoB and RoP controls. To this end, this paper presents the development of a weight-on-bit and penetration rate control system based on electrical servomotor-based draw-works brake actuator. The control system has been arranged in the so-called cascade control system structure, with the superimposed (outermost) control loop based on the proportional-integral (PI) WoB controller, commanding the inner RoP PI controller, which in turn provides a position reference to the brake lever mechanism servo-actuator. The proposed WoB/RoP control system has been verified by simulations and experimentally on an actual oil-drilling rig equipped with electrical servodrive based-actuator of the winch drum mechanical brake.

## SDEWES2021.0475

# Valorisation of Technology Transfer Projects in Universidad De Buenos Aires

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## Abstract

Technology transfer plays a vital role in strengthening knowledge-based economies and hence in developing the local production effort of a country. The industry-academia partnership represents an indispensable factor in promoting global competitiveness. It has been observed that knowledge management and technology transfer are often unclear and complex concepts in developing countries due to certain organizational, technical and public policy barriers during the implementation stage of technology transfer. In line with this, knowledge generation in Argentina frequently experiences a lack of transfer instruments. In this context, the Argentine National Agency for the Promotion of Science and Technology (ANPCyT) decided to launch in 2013 a call for research proposals in order to provide financial support to those projects that had transfer potential in Argentina. Each convened research institution would be responsible for its internal funds management, and for the selection and counsel of the projects. Universidad de Buenos Aires (UBA) is one of the most important research institutions in the country. Given that there was no Technology Transfer Office in UBA at the moment, an ad-hoc interdisciplinary committee was created to manage the large number of projects presented. The aim of this study is to present this resulting initiative called Knowledge Valorisation Programme at UBA, and evaluate its impact. The Programme comprised four stages: evaluation of all submitted projects, identification of transferable projects, formulation of specific action plans, and implementation of the transferred technology itself. Within this Programme, 368 projects from all UBA Schools were reviewed, 149 of them (40,4%) were identified as transferable, 60 of them (16,3%) have already been implemented while the others are still in progress. Apart from these results, it is also important to highlight the participation of 2000 researchers (33% from university research' whole community) and therefore increasing their awareness and focus on technology transfer. Another positive outcome of this Knowledge Valorisation Programme was that it prompted the development of the Office of Linkage and Technology Transfer in 2014 as the main and first official promoter of policies and activities of linkage and transfer within the UBA. To conclude, it is of great importance that the policies and public institutions continue directing their efforts towards the technology transfer in Argentina, while also trying to properly understand the non-transferable nature of some developments due to lack of accurate guidance to researchers from the beginning of their investigation work.

## Research, innovation and development 2

## SDEWES2021.0094

# Experimental Investigation on Heat Exchanger Channel Preparation of Superalloy Inconel718 by Electrochemical etching

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## Abstract

In the field of nuclear energy, the temperature of a nuclear reactor can reach more than 1000 K. Converting nuclear energy into heat and then into electricity requires building heat exchangers that can withstand high enough temperatures. In order to produce heat exchange channel on Inconel718plate by etching technology, the NaCl - ethylene glycol solution, 35 ℃, 40 ℃ and 45 ℃, three kinds of working condition of temperature and 0.5 mol/L, 1 mol/L carries on the experiment in two kinds of concentration of electrolyte solution, and a 50 kHz ultrasonic wave was added for comparison. The experimental results show that the etching rate can be as high as 2.894 mm/h, and the inter-electrode current is as high as 908 mA. The roughness characterization of the etching channel $R_a$ and $R_q$ measured by the aspheric surface measuring instrument can be as low as 2.3482 μm and 2.9592 μm, respectively.

## SDEWES2021.0686

# Modeling a Novel Building-Integrated PVT-Air-Collector System Coupled to a Heat Pump Using Open Source Libraries

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## Abstract

A novel building-integrated photovoltaic and thermal collector (BIPVT), in form of a solar roof tile (SRT), is developed. To enable futher optimization, a quasi-steady model is presented, which is capable to simulate the electrical and thermal output. The open-source libraries pv-lib and TESPy are used and the model is calibrated with a CFD simulation of the SRT. A first exemplary thermal energy concept for a single family house is set up with the SRT preheating the air for a mono-energetic bivalent air-source heat pump for heating and domestic hot water. The simulation over one year with a simple rule-based forecasting algorithm shows an increase of the annual COP by about 2.3 %. A validation with measurements is planned. Other energy concepts, such as direct usage of the hot air for preheating a thermal storage or to regenerate borehole thermal storages in a district heating system will be subject to further research.

## SDEWES2021.0770

# Use of 3D Printing and Scanning in the Development of a Prototype Polymer Solar Collector

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## Abstract

In the process of development of a new solar collector the creation of a prototype is a key step in verification of the new design and a basis for further improvements to the design. Due to the novel geometry and materials used in the extrusion process for the prototype collector's parts and the inability to run the experimental extrusion in many iterations, the parts available for the prototype had significant deviations from the required tolerances and desired geometry. This presented a problem for the assembly of the prototype as the envisioned standardized fittings would not conform to the obtained geometry of the parts. It was therefore necessary to use 3D scanning to obtain the exact size and geometry of every single part with sufficient precision to enable 3D modelling of the necessary fittings required to assemble a prototype collector. Due to the application of this method, a prototype collector could be assembled using 3D printed fittings and tested. This paper provides an overview of the insights and practical considerations that were discovered in this process and suggests improvements in the process which could potentially save time and resources for future projects.

## SDEWES2021.0829

# Volumetric Optical Measurements of Solid Fuel Combustion in Oxy-Fuel Atmospheres

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## Abstract

Solid fuel combustion is a complex multi-phase phenomenon involving numerous Physico-chemical sub-processes. A better understanding of the individual sub-processes and their interactions often requires the simultaneous acquisition of essential quantities (i.e., scalars and vectors) in laboratory-scale experiments. This work reports a recent implementation of advanced laser diagnostics to facilitate multi-parameter and multi-dimensional measurements to study combustion fundamentals of solid fuel particles in oxy-fuel atmospheres. The ignition and volatile combustion are comprehensively investigated in a laminar flow reactor within a novel experimental configuration including two high-speed laser systems, two high-power pulsed LEDs, and eight high-speed cameras, as shown in Fig.1. Four non-intrusive optical diagnostic systems are deployed, i.e., the scanning-based 3D laser-induced fluorescence of the OH radicals (scanning OH-LIF), tomographic particle image velocimetry (TPIV), cross-view diffuse-backlight illumination (DBI), and luminescence imaging (LU), allowing for simultaneous measurements of relevant physical and chemical parameters. Their feasibility and capability are thoroughly characterized and properly demonstrated within this work.

The Darmstadt laminar flow reactor with well-characterized boundary conditions allows both $N_2$ and $CO_2$ atmospheres with diverse $O_2$ enrichment levels to assess oxy-fuel combustion. Different solid fuels, e.g., high-volatile bituminous coal and walnut shell particles, are considered with a broad parametric variation of the particle size and the number density. Based on that, the ignition delay time and volatile combustion duration are determined for single-particle combustion, and the combustion behavior is compared between different fuels. The 3D particle location and velocity are evaluated for various particle seeding densities, emphasizing particle-particle interactions' impact on the particle motion. Further analysis of the spatial and temporal flame topology in particle group combustion provides an insightful understanding of the particle-flame interaction and underlines the importance of gas-phase reactions for particle-fuelled flames' stabilization. Comprehensive data sets present a database for model validation and the development of more complex numerical simulation tools.

## SDEWES2021.0931

# Analysis of Exhaust Emissions from a Skidder Diesel Engine During Various Engine Loads

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## Abstract

The skidder is defined as a self-propelled, articulated forest vehicle for skidding trees or parts of trees. The skidding is the removal of entire trees or parts of the tree (trunk, wood assortment) from the felling and processing site to the roadside landing. In most countries of middle and south-eastern Europe the use of skidders are the most common way of timber extraction. In the forests of the hilly area and mountainous area of Croatia, skidders with a winch, weighing up to 10 tons are primarily used for timber extraction from regular felling of broadleaves and selective felling of coniferous species. About 55% of the total timber assortments are extracted by skidders with a winch.

During forest harvesting operations, exhaust emissions from forest vehicles are released to varying degrees depending on terrain conditions, wood species, management methods, operator performance, and type of the machines used in the process. With an expected increase in the level of timber harvesting, coupled with greater levels of mechanization, we can expect higher levels of total fuel as well as exhaust emissions used in future harvesting operations. Emissions of a specific forest vehicle engine mainly depend on engine speed. Various driving methods and use of implements with different work capacities can affect the engine load.

This study deals with the analysis of exhaust emissions from a skidder diesel engine during various engine loads. Measurements were done on the new type of skidder ECOTRAC 140 V with the new type of water cooling engine which meets the strict new European emission standards for engines used in non-road mobile machinery (NRMM). The composition and amount of exhaust gases (CO, $CO_2$, $O_2$, $NO_x$, PM, and K) at different loads of the diesel engine of the skidder were measured with a measuring device MAHA MET 6.3.

The results show changes in the amount of exhaust gases in relation to the engine speed and engine load. With the engine unloaded, the amount of $CO_2$ increases with increasing engine speed, while the amount of other exhaust gases decreases. During winch operation, there is an increase in the amount of $CO_2$ and $NO_x$ exhaust gases, which is in correlation with engine load. HC emissions do not show the same trend and do not depend on engine load but on engine temperature. The highest values of HC were at start-up, when the engine was not warmed up.

At the end, some important general recommendations and proposals are presented in order to enforce more environmentally-friendly harvesting practices that would reduce $CO_2$ emissions.

## SDEWES2021.0932

# Counteracting Against Range Anxiety: a Portfolio of Measures for Increased Driving Range of Electric Vehicles

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## Abstract

Efficient thermal management is an important aspect for market acceptance of electric vehicles by counteracting against range anxiety. Conditioning the passenger cabin at hot and cold ambient temperatures consumes a significant amount of energy, which must be provided by the traction battery. This, in turn, can reduce the maximum driving range of electric vehicles by more than 50 %. The European Horizon 2020 project QUIET targeted at increasing the driving range of electric vehicles in such conditions by 25 %.

This study presents a portfolio of measures for enhancing the driving range of electric vehicles at hot and cold ambient temperatures that has been elaborated in the QUIET project. The portfolio includes: 1) a novel Propane-based Heating, Ventilation and Air Conditioning (HVAC) system including optimized operating strategy for efficiently heating up and cooling down the cabin air; 2) infrared heating panels for locally and efficiently heating up the passengers, where required; 3) weight reduction of vehicle seats, closures and glazing for reducing the overall required propulsion energy of the vehicle; and 4) a thermal PCM storage for capturing and storing heat losses of the power electronics and the electric machine and supporting the HVAC system.

All the proposed measures have been implemented in a Honda Fit EV demonstrator vehicle and the range increase compared to a baseline vehicle has been quantified using measurements on a dynamometer in a climatic chamber. Applying the proposed portfolio of measures significantly increased the maximum driving range of the demonstrator vehicle at an ambient temperature of 40 °C by 2 % and at -10 °C by even 27 %.

## SDEWES2021.1045

# Research and Innovation Trends in Energy Technologies: the Role of Programme Managers at the European Innovation Council and the Challenges in Green Hydrogen Generation

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## Abstract

The figure of Programme Managers in the European Innovation Council has been recently introduced, in order to proactively manage portfolios of projects and catalyze innovation in the beneficiaries of both Pathfinder, Transition and Accelerator funding programmes within Horizon EU. Among the roles of Programme managers, there is the identification of strategic research and innovation trends where to allocate budget for challenge based calls. The Pathfinder challenge call of 2021 is focused on novel green hydrogen generation processes, with a specific focus on the use of non critical raw materials, system integration of H2 generation, and circularity in the whole supply chain. The key aims of this presentation are to describe the emerging research trends in the production of hydrogen from renewable energy and co-production of added value products, with specific links to ongoing projects funded by the EIC and by the Joint Undertaking of H2 and fuel cells. Also, the presentation aims to describe the process followed to define the specific challenges of the call, which takes into account both scientific and technological aspects, economic and societal implications, and the broader energy policy framework in support of hydrogen pathways.

## Smart energy systems 1

### SDEWES2021.0378

# Peer-to-Peer Energy Trading System Higashifuji Case – Electricity Trading Between Electric Vehicles, Households, and Office Through Blockchain Platform

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## Abstract

In recent years, the supply and demand of electricity has been undergoing a period of change, with a variety of needs arising for both consumers and suppliers, including increasing environmental needs and the rise of prosumers with the development of solar power. In order to meet various power needs, P2P power trading systems based on blockchain technology have been attracting attention. Among them, V2G, which uses electric vehicles (EVs) for power sharing, has been attracting attention, but few studies have actually conducted P2P power transactions between home users and EV users using blockchain technology, with algorithms tailored to the needs of individual users, rather than simulations. In this study, we conducted a demonstration experiment to examine whether the entire P2P electricity trading platform, including other users such as home users and office user, can optimize the adjustment of electricity supply and demand in a fully automated manner, up to the point of electricity fusion, while reflecting the usage trends of EV users and behaving in a way that is economically beneficial to each user. This verification experiment was conducted in the Higashi-Fuji area of Shizuoka Prefecture for approximately one year with one office user with solar power generation equipment, 20 household users including users who own storage batteries and users who own solar power generation equipment, and nine EV users owned by one of the home users. The amount of electricity traded, the amount of money traded, and the time of the transaction were recorded on the blockchain, and these were used to analyze the revenue of each user and the optimization of electricity supply and demand for the entire system. As a result of the demonstration experiment, all home users and EV users saw an improvement in their earnings, with home users seeing a 5.83% improvement in one month and EV users seeing a 25.4% improvement in their earnings compared to purchasing power from the grid. It was also confirmed that the power trading system as a whole functions as an ideal supply and demand adjustment, with power prices falling during times when excess solar power is generated, and each user purchasing that power. As a result, in the P2P power trading system including EV users, it was confirmed that the economic needs of individual users were satisfied and the supply and demand adjustment of the entire system was optimized.

## SDEWES2021.0556

# Advancing a Novel Customer-Centric Retail Energy Trading Framework: a Critical Assessment of Existing Modelling Techniques

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## Abstract

As society advances to a sustainable carbon neutral world by controlling excess anthropogenic greenhouse gas emissions, it is crucial that the advancement of the smart grid is accelerated. To support the modernisation of the energy system, this paper reviews existing modelling techniques and tools related to the retail energy market. Current modelling techniques applied in the research domain and industry are typically segregated. Existing modelling techniques tend to independently focus on specific topics such as smart meter data analytics, demand response programs and transactional technology to enable prosumer activity. A systematic literature review methodology is applied to ensure relevant resources are collated and a tube map is generated to visualise the progression of retail market research. A Pugh matrix was used to examine a range of proprietary tools for modelling effectiveness and ranked accordingly. The cross-linking of modelling techniques will help progress to an optimally functioning retail market, narrow the knowledge gap and address increasing customer engagement.

## SDEWES2021.0590

# Thermal-Hydraulic Evaluation of Different Configurations of Printed Circuit Heat Exchanger in S-CO2 Brayton Cycle

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## Abstract

Recuperator is one of the most important components in supercritical carbon dioxide (S-$CO_2$) Brayton cycle. However, the effect of thermal-hydraulic performance of recuperator on the cycle efficiency is seldom concerned. In present study, the printed circuit heat exchanger (PCHE) is selected as the recuperator in S-$CO_2$ Brayton cycle due to its high effectiveness and compactness. The effects of channel configurations (straight, zigzag, S-shaped and airfoil fin), effectiveness and inlet Reynolds number on the cycle efficiency are discussed. The results show that the heat transfer enhancement of the heat exchanger improves the cycle efficiency mainly by decreasing the volume of the heat exchanger and then reducing the pressure drop in the channel. Higher effectiveness may not benefit the cycle efficiency especially for channels with high inlet Reynolds numbers and friction factors due to the large pressure drop. Moreover, the cycle efficiency with different expressions of PEC factors (identical mass flow rate, identical pressure drop and identical pump power) is also discussed. Results show that the PEC factors fail to evaluate whether the channel configurations enhance the cycle efficiency. Instead, the PQ factor (i.e. the ratio of the heat transfer rate to pressure drop) is more suitable to evaluate the thermal-hydraulic performance of recuperators in S-$CO_2$ Brayton cycle.

SDEWES2021.0600

# Coupling H2 Fuel Cells and Heat Pumps for Tertiary-Sector Decarbonization from a Whole-System Perspective

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## Abstract

Fuel cells (FCs) represent a promising solution for combined electricity and heat generation with high electrical efficiency. The flexibility of low-temperature fuel cells (proton exchange membrane, or PEMFC) in terms of ramp rates and durability, makes them more suitable for intermittent use and load following applications in the tertiary sector. The potential of a micro-grid is here investigated considering integration of renewable energy sources, storage systems and energy converters, all feeding a typical tertiary sector end-user. PEMFCs are used by pure hydrogen, which is produced via electrolysis of renewable-based electricity to achieve an energy system fully decarbonized. An electric heat pump is coupled with the FCs to increase the operational flexibility of the system, providing enhanced load-following capabilities, and enabling the production of electricity, heating and cooling. The aim of this paper is to investigate the energetic and environmental potential, as well as the primary energy savings achieved by an integrated system (composed of a photovoltaic/wind turbine (PV/WT) power plant, an electrolyser, a $H_2$ storage, a PEMFC and a battery pack) feeding the total energy demand of some commercial buildings in the tourism area of Fayoum (Egypt). A simulation model has been successfully developed in TRNSYS to verify if the energy system would have met the buildings energy request. PV system, wind turbine, electrolyzer and fuel cell have modelled using existing types available in TRNSYS library, while the other components models were specifically developed. Results from simulations of two cases, a system based on photovoltaic and wind turbine and a simplified system which hinges only on the wind energy, demonstrated that the hybrid system is capable to feed the load throughout the whole year. An appropriate hydrogen production is crucial to match the load demand when the energy produced by renewable sources is inadequate.

## SDEWES2021.0680

# Imperialist Competitive Algorithm Applied to the Optimal Integration of Photovoltaic Distributed Generation Units into a Microgrid

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## Abstract

The demand for electrical energy in a country increases as it grows industrially, in terms of population and with the integration of electro-mobility. This means that, as demand grows, it will be necessary to transport more and more electricity.

In order to have the ideal capacity to respond to this growth in demand, on the first hand, some activities such as the installation of new electricity generating plants, hand in hand with adequate maintenance of the networks and the installation of new lines at different voltage levels (especially in the transmission stage), are of fundamental execution. Furthermore, the investments described above will make it possible to maintain an efficient supply and of good quality.

On the other hand, the implementation of Distributed Generation (DG) projects for electrical microgrids also contributes to having the ideal response capacity and the improvement of supply efficiency, but without the inconvenience of high investment amounts and long execution times what the first proposal implies. However, not doing a correct planning for the implementation of DGs for microgrids, instead of favoring, can harm the operation of the electrical systems. That is why it is important to design strategies that allow maximizing the integration of DG in microgrids through optimization tools.

The present article aims to demonstrate that with Imperialist Competitive Algorithm (ICA) the DGs of an electrical microgrid can be optimized through the connection or disconnection of small photovoltaic generations, having as its main objective to minimize electrical losses. Likewise, it aims to show that with the ICA better results are obtained than even with the most used metaheuristic algorithms such as PSO. For this, a microgrid based on the IEEE 37-bus feeder was modeled, where a photovoltaic generation unit was connected in 25 of its 37 nodes. The modeling of the microgrid was done in OpenDSS software, software that allows flow analysis, and was communicated with MATLAB where the ICA and PSO algorithms were developed.

Finally, the results show that with ICA is able to optimize the reduction of losses, and also its optimization exceeds that obtained by PSO because, although it is true that its reduction of electrical losses is only 0.01% better than PSO one, the processing time for the PSO took 23 hours; while for ICA, just 05 hours. The connected and disconnected condition of the DGs was optimized every 10 minutes between 08:00 and 18:00.

## SDEWES2021.0714

# Demand Side Management in Intra-Day Markets

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## Abstract

Demand Side Management (DSM) is a mechanism which aids in peak load management and thereby lead to sustainable consumption of energy. The DSM mechanism to change the demand pattern of an aggregated load consisting of multiple types of devices while conserving the total energy consumed w.r.t the forecasted demand curve is called Demand Shifting (DS). In this paper, we analyze the impact of DS on the demand pattern through an optimization algorithm. The DS is formulated as an optimization problem where the target demand curve is a flatter one, while the constraint is to keep the area under the original and augmented demand curve constant. The DS also abides by constraints that say that the devises cannot alter the connection timings more than a specified amount based on the convenience of the users. The problem is solved in two stages. In stage 1, an intraday market is dispatched few hours in advance based on the forecasted demand patterns. In stage 2, a DS target demand curve is created that is posed to lower the demand during high peak periods and an optimization problem is solved that can shift the responsive demands within time limits to bring the demand curve closer to the target demand curves. The ex-ante and ex-post prices are compared to analyses the effect of DS. The paper also mathematically proves in a simple setting that DS will always lead to cost savings. The problem is tested using DSM data coming from devices and the effect of DS is tested on a Modified Garver system for an intraday market. The economic benefits of DSM are analyzed.

## Smart energy systems 2

### SDEWES2021.0726

# A Study on Anomaly Detection of Energy-Related Data in Large-Scale Facilities

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## Abstract

In recent years, BEMS(Building Energy Management System ) have been installed in a variety of facilities, and energy-related data is being acquired and stored. However, at present, the use of BEMS data is limited to visualization, and further analysis must be done manually, which means that the data is not fully utilized and does not contribute to essential energy conservation. For example, in large facilities such as airports, energy managers monitor energy consumption data to discover inefficient energy use and control energy costs. In the current operation, thousands of graphs in the data visualization system are checked one by one by human eyes, which takes a huge amount of time and incurs high human costs. In addition, the time required for checking delays the detection of anomalies and increases energy costs. To solve this problem, the system automatically detects anomalies using a machine learning algorithm to quickly and effortlessly respond. Early detection of anomalies by machine learning algorithms reduces energy costs and automation reduces human costs. This research proposes an anomaly detection algorithm based on probability density estimation using neural networks. In addition, the effectiveness of the proposed algorithm was verified by applying multiple energy consumption data obtained from the BEMS of an actual airport.

## SDEWES2021.0747

# Microgrid Powered by Renewable Sources Improving Resilience in an Urban Settlement: a Case Study in Italy

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## Abstract

Nowadays, microgrid technology assumes a strong role not only in the research field but also in the commercial markets for its application into urban settlements. Regarding the application of microgrids, several advantages could be listed such as the use of clean energy resources (e.g. solar photovoltaic), the reduction of fossil fuel emissions, the improvement of the urban system resilience. Moreover, the supply of electric power in wide areas out of the National Grid is a reliable opportunity for the development of the energy transition plan promoted by the European Union. In this framework, the research aims to describe an electric microgrid powered by the photovoltaic system to supply energy for different users (two high schools, a green area and a market) located in a city in the Centre of Italy. In addition it is investigated the possibility to use the microgrid system together with an emergency generator during an hypothetical blackout of the electric national grid to ensure the resilience of the urban system. Matlab/Simulink is chosen to simulate the energy demand/loads and to calculate the performance of the proposed microgrid. Results show how the photovoltaic panel production could cover the entire consumption of the microgrid during favorable weather conditions with an overproduction of power in summer, allowing to supply more loads to be added to the system. As a consequence, only a limited amount of energy has to be requested from the national grid. In the event of a failure, a 250 kW methane emergency generator has been set up to guarantee the service and therefore its resilience. The results of this latest analysis highlight that the use of a microgrid system integrated with an emergency generator system allows to ensure a good energy resilience of the city, as well as economic savings for communities.

## SDEWES2021.0820

# Virtual Net-Billing with Proportional Fair Sharing: a Computationally Efficient Method for Real-Time Energy Sharing in Communities

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## Abstract

This paper proposes virtual net-billing (VNB) - a new energy sharing method that extends individual net-billing to a community level. VNB can be coupled with any benefit distribution concept, such the Shapley value (SV) and MinVar (MV). While both are used in this paper, the combination VNB-MV serves as a benchmark for fairness. To overcome the computation complexity of the VNB-SV and VNB MV, the proportional fair sharing (PFS) key is proposed. Unlike the former methods, VNB-PFS distributes the economic savings generated by VNB in real-time, thus significantly reducing computation complexity at only a slight compromise to the fairness of the payoff distribution. VNB-PFS is also compared to three pricing mechanisms from the literature related to community-based markets: bill sharing (BS), mid-market rate (MMR) and supply and demand ratio (SDR). The analysis is conducted on a population of 600 synthetically generated energy communities from a real-world dataset. The results show that, based on three metrics, VNB-PFS notably outperforms BS, MMR, SDR and VNB-SV in terms of fairness. In terms of computation time, VNB-PFS is only slightly slower than BS, MMR and SDR, but notably faster than VNB-SV and VNB-MV, making it a very useful energy sharing method for large communities.

## SDEWES2021.0982

# Application of Ann for Management of Energy Storage Systems with High Share of Renewable Energy Sources

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## Abstract

The aim of this paper is to preset the possibilities of using Artificial Neural Network (ANN) method for smart management of energy storages in a energy system with high share of renewable energy sources and integrated electricity, heat and transport. Electricity and heat are integrated through ground source heat pumps, and transport is integrated with battery electric vehicles (BEV's) in smart charging mode. The overall method consists from the two separate methods: (1) finding optimal energy flows for training and testing of the ANN in EnergyPLAN, where geothermal reservoir is optimized as the weekly or seasonal heat storage and BEV's smart charge provides the demand response and (2) training, validating and testing the ANN in TensorFlow module. Input variables are related to intermittent and stochastic, but predictable wind and solar insolation, heat and electricity demand, as well as demand for BEV's. Output variables are charge and discharge of both thermal and BEV storage. BEV storage is not constant over time, but depends on time of day. System also has a biomass cogeneration unit. Exchange of energy with the centralized system is only through the DSO and minimum exchange with the DSO is a goal function for all scenarios. Few configurations of ANN's have been tested, with different additional signals, number of layers, time series window size, activation function etc. Preliminary results show moderate-to-good success with few combinations of ANN features and R2 values of 0.8. Further investigation should lead to better performance in terms of testing and validation against the input data from EnergyPLAN.

## SDEWES2021.1065

# X-Flex Project for More Flexible Electricity Markets

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## Abstract

Flexibility markets help energy networks, which are becoming increasingly interconnected with other sectors such as e-mobility, to monitor energy flows and create market signals to motivate changes in energy supply and demand, integrating smart meters, smart appliances, renewable energy resources and energy efficient buildings and communities. The European Commission promotes flexibility markets as they can contribute and help the EU becoming a climate-neutral continent by 2050 and is a significant part of the new legislation.

Up to now, the projects and research activities in the area have been focused mainly on specific energy sources and actors, considering only a very limited and isolated part of the distribution network, leaving aside all the opportunities existing throughout the flexibility offered by the energy value chain. In this context, X-FLEX H2020 project (2019-2023) proposed a new concept that will integrate and create synergies among all energy flexibility sources and technologies, promoting cooperation of all the actors of the smart grid and energy market, in an efficient and cost-effective manner. Through this holistic approach, X-FLEX aims to create the optimal combination of decentralised flexibility assets located along the whole energy value chain and new market mechanisms, providing benefits to all the actors of the smart grid and energy market, offering an all-win scenario.

These solutions are being tested in real conditions in 4 pilot sites in Bulgaria, Slovenia and Greece, with different needs and socioeconomic and technological boundaries, involving multiple flexibility assets (batteries, power to heat/cold, vehicle to grid and other storage solutions) and all complementary actors of the energy network.

X-FLEX project proposes a set of efficient, cost-effective, integrated solutions, that will facilitate the optimum combination of decentralised flexibility assets, both on the generation (DER) side and on the demand side (V2G, power-to-heat/cold/gas, batteries, demand response), enabling all parties to offer their flexibility in the market creating benefits to all the actors. Thus, it develops 4 products: SERVIFLEX tool (Integrated flexibility management tool), closely linked to MARKETFLEX tool (Market platform and new market mechanisms), supported with necessary GRIDFLEX tool (Advanced tools for automatic control and observability), X-FLEX platform (Flexible and scalable integrated platform).

X-FLEX predicts to increase the RES production in the 3 pilot countries by 6,992 GWh over the next 5 years of the project. This increase in the RES production will entail a reduction of 5 MTn $CO_2$eq of $CO_2$ emissions in the pilot countries after the commercialization of the X-FLEX solutions. It is expected also that X-FLEX will enable the increase of 28% of energy renewable into the distribution grids of four project pilot sites by end of the project.

## SDEWES2021.1080

# Decarbonization and Employment in Europe

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## Abstract

What do we know about the consequences for employment of investing in renewable energy?

Abstract: When discussing a future decarbonized Europe, it is discussed in several studies how much employment an investment in such a future might lead to. Establishing this might be highly relevant, but it is treated as self-evident why so many try to estimate employment effect. In the paper some possible reasons are discussed. More importantly, we cannot estimate the employment effects with any degree of certainty. So, consumers, producers, and states must invest in renewable energy because it is the right thing to do and because it has been demonstrated that we can easily afford it.

Please note change of headline and abstract. It has also been shortened and should be longer than this. At this point of time I guess that it matters less with I have used a sufficient number of words as the abstract have been accepted. I am looking forward to presenting the paper in Dubrovnik.

## Smart energy systems 3

### SDEWES2021.0064

# Flexibility Options in 100% Renewable Energy World Regions

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## Abstract

Designing the energy systems for high variable renewable energy penetrations, one should look for the flexibility of an energy systems that may be provided from various sources at supply, demand or network level. The flexibility can be provided from different options including, but not limiting to: (1) electricity demand (household and industry), (2) thermal (power, CHP) plants, (3) power to heat (CHP, heat pump district/individual), (4) transport (V2G + smart charge, synthetic fuels), (5) interconnection and (6) storage (batteries, pumped hydro, rockbed, compressed air, hydrogen...). The flexibility might be provided according to different criteria: economics, technical complexity, utilization, acceptability, feasibility, material use. Further, different constraints regarding percentages, shares, emission reductions... might be set according to proclaimed sustainable energy policy in certain region. Therefore, we will simulate various flexibility options according to their availability and priority assumed by authors for each region of nine World regions (USMCA, Latin America, United Kingdom, China, Russia, South-East Asia and Oceania, Rest of the world,) using EnergyPLAN-Python permutation framework . This way number of synthetically generated temporary scenarios before finding optimal one and the execution time is increased in comparison to optimization approach.

## SDEWES2021.0108

# Current Progress on the Advanced Energy Planning on the Smart Islands

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## Abstract

Increased penetration of renewable energy sources in energy systems requires the development of new approaches in energy planning. The new approaches should account for the effects of smart energy systems. This paper presents four new advanced energy planning approaches with case studies conducted on the islands. The first approach presented a Smart Islands method that combines islands' needs and resources and creates possible energy planning on islands. The case study on Vis island showed that the island can operate in the island regime with a 5.4 MWh battery storage and 5.9 MW photovoltaic plant. The second approach proposed a demand response model and implemented it in the AC OPF model that represents electric distribution components, thus enables the financial and technical assessment of the proposed demand response. The case study in the Kvarner archipelago showed that the breakpoint incentive for stimulating the demand response provider amounted to 23% of the day-ahead electricity market price. The demand response did not cause any problems for the distribution grid as the voltage was always in the allowed limits (0.9 to 1.1 p.u.). The third approach soft-linked a Calliope energy planning framework with the power flow calculation using the Newton-Raphson algorithm. The model showed the importance of detailed spatio-temporal modelling in comparison to the existing models. The case study on the Krk island showed that the total costs were 27% higher for detailed spatial modelling and the total installed battery capacity was 3.3 times higher for the coarser scenario. Finally, the fourth model presented a risk assessment method for the energy planning scenarios on the islands. The model calculates the probability of the failure of the power system elements and the damage it causes. The results showed that a zero-import risk scenario for the island of Unije is achieved for a 0.5 MW photovoltaic plant and a 3.55 MWh battery storage capacity. The proposed approaches will be tested and demonstrated in the scope of the H2020 INSULAE project. It is planned to implement seven cases of application of innovative solutions on the Croatian, Denmark and Portuguese islands. The use cases include installation of battery storage systems, integration of water and energy systems, integration of energy electronics, the integration of energy and transport sector and the utilization of Internet of Things, blockchain and 5G technology.

## SDEWES2021.0500

# Digital Transformation and Efficiency Improvement of Gas Meter Readings on the Example of a Pilot Project

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## Abstract

This paper analyses a pilot project of installing modules for remote reading of natural gas consumption on existing membrane gas meters. Modules for remote reading were installed on around 4400 existing meters and their use, activation as well as the benefits that are achieved by using them are describe in detail. These modules use the increasingly popular Sigfox network, which has proven to be an excellent tool for data transmission with low energy consumption, which can greatly simplify the digitization of many energy sectors.

The installation of modules for remote reading on existing meters represent an improvement of classic membrane meters towards modern and increasingly sought-after smart meters. This kind of modules represent novelty solution which has proven to be cost and time effective because unlike some smart meter installation projects, this approach does not require significant financial costs or a long installation time.

## SDEWES2021.0889

# Smart Energy Denmark - Strategies for a Fully Decarbonized Society

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## Abstract

This paper presents the methodology and results of a strategy for achieving a fully decarbonized society. The methodology is applied to the case of the Danish Governments goal of a 70% decrease in CO2 emissions by 2030 and a fully decarbonized society in the years after. The principles and the methodology are relevant for most countries on a global level. The energy system analysis methodology includes hour by hour computer simulations leading to the design of flexible energy systems with the ability to balance all sectors of the complete energy system - also known as a smart energy system. Principles and guidelines are developed on how to design such a system as an integrated part of a global decarbonization taking into account issues such as international shipping and aviation, sustainable use of biomass and exchange of electricity and gas with neighboring countries. Moreover, the energy systems are coordinated with other sectors in order to achieve a fully decarbonized society

## SDEWES2021.0891

# Smart Energy Europe – Developing a Renewable Energy Scenario for a Decarbonized Europe

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## Abstract

The European Union have a clear target of decarbonizing the energy sector by the year 2050. This is necessary to mitigate climate change effects. Currently, a number of scenarios are models are developed to outline this transition, for instance the Commissions own "A Clean Planet for All" scenarios. However, the focus on the current modelling is very much towards either detailed scenario pathways that misses the need for hourly analyses, or scenarios that cannot capture the full potential for system integration, through a clear Smart Energy System, that utilizes not only the electricity grid, but also heating and gas grids to achieve cost efficient solutions for Europe. This paper presents a step wise approach to accomplish a renewable European energy system based on the concept of Smart Energy System. These steps include transforming the heating and cooling sector, as well as looking at both electrification of the transport sector and utilization of electrofuels in both transport, industry and power production. Combined, the utilization of multiple grids, cheaper storage options, and a more comprehensive sector integration allows for the Smart Energy Europe scenario to be a more feasible solution than the 1.5 TECH scenario proposed by the European Commission.

## SDEWES2021.1006

# Industry Electrification and Flexible Energy Demand in 100% Renewable Energy Scenarios

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## Abstract

Worldwide there is a shift towards renewable energy sources. Shifting energy demands from traditional fossil fuels to electricity in different energy sectors, such as the transport, heating and industry sectors, is seen as an important part of the transition towards increased use of variable renewables, such as wind power. However, because of their variable nature, basing an energy system solely on variable renewable energy sources requires other changes to the energy system. Due to this, future renewable energy systems with high shares of variable renewable energy production will need to also include technologies and measures to balance these production fluctuations. This could be in the form of electricity storage or energy demand adaptation, also known as demand-side management, or sector coupling solutions. Here industry electrification is especially interesting to investigate. Other studies indicate that a more flexible electricity demand enables a higher utilisation of the variable renewable sources and that the potential for a flexible electricity demand exists. However, the effects of this on 100% renewable energy systems are rarely investigated, and when the effects are investigated they are only investigated using one 100% renewable energy system scenario, often created by the same author, actor or organization, which evidently can result in a narrow view into the possibilities for future energy systems. This study quantifies the role of industry electrification in the context of different 100% renewable energy system scenarios created by different relevant actors, to identify how its role may differ based on the energy system scenario investigated. It is found that direct electrification of industrial process heat demands should be favoured over e.g. a fuel shift to hydrogen-based processes systems even when these provide more flexibility.

## Smart transport systems and policy

## SDEWES2021.0451

# Integration of Electrical Systems on a Hybrid Skidder Based on Parallelized Low-Cost Direct Current Power Converter Array

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## Abstract

Off-road vehicles are increasingly being equipped with hybrid electric powertrains in order to improve their fuel economy, and, consequently, to facilitate notable reductions in greenhouse gases emissions. The hybrid electric power-train apparently offers a favorable solution that can meet the above requirements for the propulsion of articulated forestry tractors, also known as skidders, due to the possibility of using a lower-power diesel engine, along with an additional battery storage system and driveline power source (i.e. electric motor). Due to the fact that hybrid electric vehicles utilize additional power from the high-voltage (typically 400V) battery energy storage system for vehicle propulsion, whereas many accessories (radio, lighting and similar) still operate at the low-voltage (24V) direct-current bus, two direct-current electrical systems are commonly present within such hybrid vehicles. Therefore, when the low-voltage bus requires addition power input (e.g. to recharge the low-voltage battery), the higher-voltage and higher capacity battery energy storage system can be used for that purpose by using direct-current to direct-current (DC/DC) power converters. In order to increase the power conversion efficiency and reliability, and also to avoid issues with overheating and reduce the maintenance requirements, a suitable parallel DC/DC converter array may be considered, along with an appropriate control strategy that minimizes the required number of active DC/DC power converters operating in parallel. Having this in mind, this paper investigates the effectiveness of one such parallelized low-cost DC/DC converter array within the electrical power distribution system of a hybrid skidder. The resulting direct-current bus voltage and current control systems have been verified by means of detailed computer simulations and experimentally on the hybrid propulsion system laboratory setup.

## SDEWES2021.0703

# The Economic Value of Hybrid Battery Swap/Storage Stations

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## Abstract

The majority of governments in developed and developing countries are set with ambitious solar Photovoltaic (PV) goals that may reach 2840GW, 13% of total power demand by 2030. However, considering the demand profile, the upsurge of PV to this scale may likely result in surplus electricity generation in the daytime. Additionally, newer business models of Battery Swapping Stations (BSS) present an appealing opportunity for accelerated Electric Vehicle (EV) adoption in the near future. The increased EV adoption is likely to surge the load on the grid. However, the inconsistent demand and supply from EV and PV will require a large-scale technical solution for the power grid. This paper presents the BSS model's economic feasibility, leading to a win-win situation for both utility and grid in the large scale EV and PV adoption. The charging infrastructure, including the BSS, enable the convenience of charging as the conventional cars. At a BSS, the drained batteries from vehicles are replaced with the charged one within minutes. In this scenario, BSS will always have a constant capacity for energy storage. In this paper, we evaluate the economic value of the scenario where the batteries in BSS are used as a countermeasure for PV's surplus electricity. The BSS model's economic value is compared with the scenario of domestic charging, including the costs of ownership and depletion costs. The calculations are extended for the feasibility of using depleted batteries in the energy storage system. The scenario comparison substantiates the economic feasibility at the current battery electricity costs.

## SDEWES2021.0781

# Life Cycle Assessment of Urban Public Transportation from Conventional to Electrical Buses: a Case of Study in Brazil

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## Abstract

The number of studies about Life Cycle Assessment (LCA) in urban public transportation focusing on global warming impact reduction is increasing in the last few years. A great quantity of researches suggest an insertion of green modals on local public transportation system could be a viable solution to reach sustainable development. However, the consequences of such insertion in developing countries is not clear yet. Based on this, the general purpose of this research is to evaluate the environmental impacts, present and future, of the public transport system of Porto Alegre, Brazil. Therefore, the relationship with three different scenarios aiming at renovation is analyzed, either through less impacting fuels or by the electrification of the fleet. To reach these goals, we followed the guidelines contained on BS EN 15643-1:2010, NBR ISO 14040/2009 and NBR ISO 14044/2009. Hence, we divided our method into four parts: (i) objective and scope; (ii) system and functional unit limits; (iii) life cycle inventory and (iv) life cycle impact assessment. The primary data was provided by the Public Transport and Circulation Company of Porto Alegre (EPTC) and background information was obtained from Ecoinvent version 3.6 and literature. Finally, SimaPro 9.1 software generated the environmental impact assessment. Results show, in agreement with previous studies, that the adoption of electric buses could be beneficial concerning the impacts studied compared to diesel and biodiesel powered vehicles. In all three analyzed scenarios, the production impacts of batteries and transportation represented small contributions to the CO2 emission results. The use phase was regarded as the most impactful and the change in power source the cause of the most significant reductions considering the GWP analysis in 2030. It is also worth notice, the scenarios proposed were based mainly on national fuel decrees, but the reach of the goals presented in them is dependent on the main municipal climate change plans and its willingness for change.

## SDEWES2021.0784

# Quantification of Savings for the European Transport Sector Through Energy Efficient Urban Planning

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## Abstract

The transport sector accounts for around 30 % of Europe's final energy consumption. In order to meet the ambitious decarbonization goals set forth by the European Commission by 2050, it is important to design future transport systems based on the energy efficiency first principle, which essentially means to prioritize energy efficiency both in terms of technology, as well as on the planning side. To achieve that, it is important to quantify these energy efficiency savings potential, which could serve as a possible benchmark to nudge future policy and planning initiatives in the right direction. Hence, this study aims to provide an analysis of the European transport sector in the context of traditional and energy-efficient urban development.

The energy-efficient urban development demonstrates a scenario where accessibility is provided through enhanced proximity to a destination rather than through increased mobility, and where transport and mobility are moved away from road transport and aviation towards rail and public transport. This development is ensured by, among other things, investing heavily in urban and inter-urban transport systems and abstaining from building new freeways and expanding airports. Namely, the following three areas are considered for quantification of these saving potentials in this study; urban spatial development, transport economic instruments such as parking fees, tolls, etc., and transport infrastructure.

The results are compared with a traditional development scenario in terms of final energy demand and annual transport systems costs. The results indicate that it is not only desirable but also economically beneficial to shift towards an energy-efficient transport system. The development of the European transport sector in the proposed trajectory of the energy-efficient development scheme significantly reduces annual final energy demand from the transport sector, and the investment made in new infrastructure for rail, bikes, and walkable urban areas are paid back by the reduced cost from road transport.

## SDEWES2021.0925

# Macro-Factors Driving Low Carbon Mobility Choices Across Europe

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## Abstract

Across the EU, spatial-structural aspects and the availability of transport options influence the mobility choices of European citizens. Spatial and structural factors are not adjustable in the short-run, or in some cases at all, but they likely impact individuals' decisions regarding mobility choices. Current research clearly points out that individuals' mobility choices are strongly determined by intentional, situational, and habitual factors, including personal norms, social norms, subjective and objective constraints (Klockner and Friedrichsmeier, 2011; Klockner and Blobaum, 2010), as well as individuals' socio-economic situations (Collins et al., 2019).

In our analysis, we aim at deriving the dynamics that drive the uptake of social innovation in mobility and provide insights into generalizable aspects of social innovation using bicycle mobility as an example. With the European Union becoming an ever more important driver of international and national climate and energy policy, understanding the common macro factors influencing the uptake of social innovations in mobility across Europe can support the development of more effective initiatives and legislation.

Our analysis is based on a data set collected in an online survey of European citizens during 2018 in 31 EU countries (EU-27, UK, CH, TR and NO). This survey, which included more than 18,000 Europeans, aimed, among other, at identifying the macro factors that drive Europeans mobility choices and affect the success of mobility goals in specific contexts. Data was collected about the respondents' socio-economic and socio-demographic characteristics, and travel behaviour. Furthermore, a set of psychological questions allows the derivation of respondents (social) norms and motivations. In addition to the individual-level survey data, we also collected location-specific variables, such as elevation, numbers of different public transportation stations (bus stations, bus stops, railway stops, railway stations and tram stops), urban land cover percentage, temperature, precipitation, and air pollutants.

The key ambition of our study is to disentangle the many influencing factors driving individuals' decision for or against biking. Some of these factors will provide low to no starting point for political interventions, such as the curvature of the landscape, while others may guide the way to promising avenues how policy can foster increased utilisation of bikes to cover citizens' mobility needs.

SDEWES2021.0936

# Energy Efficient Decarbonisation Strategy for the Danish Transport Sector by 2045

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## Abstract

The transport sector contributes to approximately one third of Danish greenhouse gas (GHG) emissions and almost half of emissions from the energy sector. A unified Danish parliament agreed to reduce total emissions with 70 pct. compared to 1990 levels by 2030. This paper estimates the potential for reducing the national transport sector GHG emissions in 2030 and proposes a pathway towards full decarbonisation in 2045 using a complex set of measures.

In this paper, a comprehensive transport-planning tool is used. The tool functions as a back-casting model, which allows for thorough exploration of individual measures as well as the interaction between different behaviour, infrastructure and vehicle changes towards decarbonisation. The model is built using detailed data about Danish travel patterns for both passenger and freight transport, divided into mode of transport and trip length. This dissolution allows for very specific implementation of alternative transport technologies and a possibility to suggest precise modal shifts based on trip lengths.

**Social acceptance/ Education in sustainable development**

## SDEWES2021.0522

# University Extension Projects to Train Engineering Students in Sustainability and Social Impact

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## Abstract

In order to achieve a complete engineering education, social aspects and their relationship with the environment must be taken into account during its course. Universidad de Buenos Aires (UBA) currently has an on-going program called Educational Social Practices, which represents a mandatory activity for all Schools in UBA. It is important that professional engineers get notice of the social impact and the sustainability quality of the projects they develop, therefore UBA annually opens the call for UBANEX (University Extension) projects seeking to support activities that tend to PSE strengthening. Framed in this premise, our team participated in consecutive UBANEX projects between 2018-2020 involving UBA Engineering School (FIUBA) as an educational and research entity. The project had its main activity in four locations within Buenos Aires: FIUBA, Kindergarten N° 922 of Rafael Calzada, Secondary School N° 65 of Claypole, and a cooperative that provides recyclable material collection service in Buenos Aires city centre. The objective of this work is to present the methodology and results of these projects as an educational tool example focused on strengthening the future engineers capabilities regarding sustainable and social impact matters. The first project proposal was to set up groups of Environmental Promoters (EPs) consisting of engineering students, to train them in source separation of waste, in the recycling chain, to link them with recycling entities, to tutor them as future trainers and then to attend each educational venue involved in order to transmit their knowledge and coach new EPs at each institutional level. Secondly, this project also proposed the design of a source-separating system for the different streams to be installed at FIUBA, and afterwards collected and recycled by the cooperative. Regarding results, a total of 10 initial EPs were trained, who then coached 25 other EPs in the different institutions, reaching also a total of 240 direct contacts between kindergarten and secondary school students whose families also participated in the program. Regarding waste separation in FIUBA, 7200 students, 1700 teachers, and 400 non-teaching staff were reached with the recycling system plan as separation stations were installed in the three FIUBA venues and 95 tons of separated, collected and recycled material were generated. To conclude, through these interdisciplinary projects, FIUBA is able to i) emphasize the importance for an engineer to have sustainability awareness and social impact understanding of their professional activities; ii) leverage in the PSE programs to enrich promptly and simply some fundamental aspects in engineers formation, iii) articulate the environmental education of engineers with the Sustainable Development Goals, promoting cooperativism among different social actors, learning opportunities in foreign environments, responsible and sustainable consumption, among others.

## SDEWES2021.0633

# Insights into the Integration of Environmental Sustainability in Slovenian Bachelor, Master, and Doctoral Programs

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## Abstract

The environmental and climate crisis is gaining priority among critical humans' concerns; therefore, environmental knowledge and sustainable solutions play a major role and gaining global popularity as an academic discipline. Additionally, United Nations-Sustainable Development Goal no. 4 acknowledges the role that education has in promoting sustainable development, sustainable lifestyles, human rights, social responsibility, circular economy, and greening of our economy and society. This paper, therefore, focuses on systematically analyzing data on 1052 bachelor, master, and doctoral programs in progress in Slovenia. The main aim is to reflect the conceptual basis of education related to environmental sustainability topics such as sustainable development, social responsibility, ecology, environmental protection, and circular economy. Defining the level of integration of sustainability in separate study fields as classified in CLASIUS-P as well as comparing bachelor, master, and doctoral programs is additional value-added on inter-and trans-disciplinary sustainability integration within specific course curricula. It was revealed that the highest share of study programs has an intermediate level of environmental sustainability with 2-3 courses (392 study programs) or a relatively high level with 4-5 classes (350 study programs), mostly represented by environmental protection, ecology and "greening" and less with circular economy and social responsibility. Significant differences among specific study programs as well as higher education institutions were identified; therefore, suggestions to smooth this challenge are suggested.

## SDEWES2021.0819

# Perception of Being a Low Carbon Nation Through Technology and Nature-Based Solutions

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## Abstract

Big Oil and many national oil and gas companies (NOC) are currently making genuine efforts to address global warming in terms of corporate and social responsibility by investing in renewables and utilities as well as in low carbon and decarbonisation technologies. In fact, society is coming together to tackle the challenges associated with climate change through international treaties such as the Paris Agreement and the UN Sustainable Development Goals. Big Oil and NOC have a key role in this transition, and it is important that we understand the perceptions of those working in the sector. Hence the aim of this research is to explore those perceptions. The method used was a modified Delphi study of employees in a NOC in Malaysia. The paper also briefly reviews Malaysia's low carbon policy plans, overviews its current $CO_2$ accounting balance, and identifies potential technology for decarbonisation to set the scene for the modified Delphi study. There are two key findings. Malaysia's NOC is the biggest player and has both the calibre and the financial resources to significantly contribute to convert Malaysia to carbon neutrality by researching and implementing technology-based solutions complementing nature-based solutions. The Delphi study survey of the employees clearly indicates the belief that a whole portfolio of solutions needs to be implemented in a coordinated effort to maximize the outcome and minimize the financial impact in term of economical sustainability.

## SDEWES2021.0867

# Unequal Regional Benefits and Vulnerabilities in Cost-Optimal and Near-Optimal Scenarios of the European Electricity Sector in 2035

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## Abstract

Ensuring equity is an emerging priority in current energy and climate strategies, such as the Biden administration's $2 trillion infrastructure plan for the United States or the European Green Deal. Yet, little is known to what extent current strategies encourage an equitable clean energy transition or rather produce new inequities and reinforce existing ones. Such inequities could become especially apparent in the European electricity sector, for which an ambitious transition from fossil fuels towards cleaner energy sources is expected until 2035. Especially, some regions would reap the benefits of the transition, such as new investments, reduced air pollution, and job gains. Other regions would become burdened by adverse impacts, such as increased electricity prices and job losses. Regions that are more sensitive and less able to adapt to adverse impacts would become especially vulnerable. Inequities in terms of regionally unequal benefits and vulnerabilities could jeopardize the credibility of energy and climate strategies such as the European Green Deal. Therefore, it is crucial to identify which regions are in the best position to reap the associated benefits and which ones would become vulnerable.

By means of electricity sector modeling, we investigate 150 cost-optimal and diverse near-optimal scenarios of the European electricity sector in 2035 at a high spatial resolution of 296 NUTS-2 regions, including electricity generation, storage, and transmission. We identify the European regions that are in the best position to benefit and those that would become vulnerable to possible adverse impacts of the electricity sector transition until 2035. For the assessment of benefits and vulnerabilities, we apply the methodologies of multi-criteria assessment and an extended vulnerability framework from climate change adaptation literature. We quantify and map out regional benefits and vulnerabilities to investment and divestment, job gains and losses, as well as impacts on electricity prices, land use, and greenhouse gas and particulate matter emissions. We show that even though benefits of the electricity sector transition outweigh adverse impacts on a continental level in 2035, such benefits occur in affluent Western European regions, while adverse impacts occur in more deprived and vulnerable regions, thus reinforcing existing inequities.

## SDEWES2021.0955

# A Comprehensive Study on the Aesthetics of Electricity Consumption Graphs on Appliance Level and Their Triggering Potential on Human Emotions

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## Abstract

Sustainable energy consumption behavior in households is a decisive factor in contributing to climate protection. To provide residents comprehensible insights into their household's energy consumption data, nonintrusive load monitoring on appliance level can assist. To give consumers a simple and comprehensible overview of their consumption data, which they also find aesthetically pleasing, in this work a two-stage experimental design is used to compare the perceived aesthetic appearance of different types of electricity consumption graphs on appliance level (aggregated or time-dependent) and their triggered emotion. First, a representative survey covers the general aesthetics assessment in a 2x3 mixed factorial design. Second, an in-depth eye-tracking and facial expression investigation is used to track and quantify emotions on different electricity consumption graphs on application level and their perceived advantages and disadvantages. The main results provide comprehensive insights into the aesthetics of electricity consumption visualizations to trigger positive emotions, in particular users' preferences for simple and conventional graphs like bar charts.

## SDEWES2021.0962

# An Experimental Investigation on the Comprehension of Electricity Consumption, Generation and Grid Supply Visualization

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## Abstract

Energy consumption at the household level has a significant environmental impact. However, it is often difficult for end users to understand this complex topic. Hence, end users need to sight and understand their own energy data by means of appropriate visualizations to achieve a sustainable change towards more efficient energy consumption behavior. By means of an experimental online survey, the comprehension of energy data visualizations with regard to the daily electricity consumption of a multi-person household was surveyed. A total of n = 538 respondents were asked about their comprehension at three levels of difficulty, considering the response duration. The results show that comprehension differs depending on the energy data visualization type and its information density. This work contributes to determine appropriate visualization types to unleash potential for more energy efficient end user behavior.

## SDEWES2021.1076

# Energy Sufficiency for Rural Communities: the Case of the Bolivian Lowlands

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## Abstract

Access to energy has proved to have strong links to other dimensions of socio-economic development. As a first step to ensure electricity coverage in developing countries' rural communities, a minimum energy access must be settled. To do this, the theoretical concept of energy sufficiency is expanded to fit in the rural energy access logic. Ideally, un-electrified communities must move from low energy consumption states to a position where they consume enough to have a continuous development without risking global environment goals. For that purpose, a bibliographic review is performed to define the components of an ideal rural community where people's basic needs for energy services are met equitably. Main findings show that besides the household component, public lighting, education, health, water and production services must be considered at the moment of estimated energy demands for rural electrification. To test the implication of this, a series of plausible village configurations of the Bolivian lowlands are proposed and simulated using a bottom-up stochastic model. Not considering community services and income generating activities, carries a 45 % underestimation on peak demand. In addition, improving people's living conditions has a considerable effect on the electricity demand of Bolivia's rural lowland communities.

## Storage 1

## SDEWES2021.0069

# Investigation of the Effect of Envelope on Building Thermal Storage Performance Under Mpc Control Strategy

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## Abstract

Dynamic pricing is designed for the load shaping to help match the amount of the energy demand to the energy supply capacity. Since the buildings' characteristics influence the performance of the energy shifting, renovation of the building towards higher energy flexibility is worth investigating. This study evaluated the effect of the envelope on building thermal storage performance. A model predictive control (MPC) was developed to achieve a multi-objective control (i.e., indoor thermal comfort and minimise the total energy cost) of a floor heating system. MPC automatically triggered the energy storage during the low price periods and use the stored energy during the high price periods. The results confirmed the ability of MPC on peak demand reduction. Besides, the results also demonstrated the ability of heavyweight thermal mass in terms of reducing energy consumption (used a 10 lower heating source than the lightweight thermal mass) and shifting a greater (6% of the total energy use) medium to high energy price to the low price times. Therefore, adding insulation layers into the lightweight thermal mass is highly recommended, especially for the places experiencing network congestion during daily peaks or the areas scheduling a large amount of intermittent renewable energy source in the energy production.

## SDEWES2021.0102

# Thermo-Economic Analysis of Changing the PCM Layer Thickness for CSP Plants' Combined Sensible-Latent Heat Storage Tank

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## Abstract

In this paper, the combined sensible-latent heat storage (CSLHS) device is suggested as a replacement for the existing two-tank storage systems, with a solid structure layer of low-cost material and different thickness of the phase change material (PCM) layer. On the basis of two-phase dispersion-concentric equations, a detailed transient numerical analysis is developed. Numerical investigations are used to compare the proposed storage system (CSLHS) to the sensible heat storage (SHS) system in the context of cost and efficiency. The impact of various performance evaluation indexes including axial temperature allocation, thermocline layer degradation, charging time, discharging time, and overall efficiency is investigated. Due to its optimized efficiency, reduced thermocline area, and comparatively low cost, the CSLHS (15% PCM-70% SHS-15% PCM) configuration demonstrates that it is a more viable choice among the considered cases.

## SDEWES2021.0244

# Optimization of Packed Bed Latent Heat Storages Filled with PCM-Capsules Based on Superellipsoids

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## Abstract

The optimization potential of capsules filled with a phase change material to be used in a packed bed latent heat storage system was investigated. Novel capsule geometries based on super-ellipsoids were introduced. Discrete element simulations validated by experiments with 4.8 % deviation were performed to create packed beds containing 116 differently shaped super-ellipsoid pellets of equal volume. For each geometry, the packing density was determined, and the highest packing density was 65.2 %. By performing a weighted value benefit analysis, the capsule geometries were evaluated with regard to their energy density and thermal performance. The three capsule designs, that received the highest ratings in the value benefit analysis, and a spherical design were used for a simulation study of the storage charging process. With a 40 % higher storage capacity and an approximately 60 % higher thermal power, the three optimized geometries clearly outperformed the spherical design.

## SDEWES2021.0448

# Integration of Thermochemical Energy Storage System Based on Ca(OH)2/CaO Reaction

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## Abstract

The development of new types of energy storage systems is crucial for the massive deployment of renewable energy on a large scale. This paper presents the analysis of a system for the storage of solar thermal energy in the form of thermochemical energy, on a large scale, based on the reversible reaction of calcium hydroxide formation. The $CaO/Ca(OH)_2$ system is based on the hydration/dehydration reactions of CaO, heating to decompose reactive calcium hydroxide into calcium oxide and steam and releasing heat through the reaction of steam with the calcium oxide, in the range of 410-550 ◦C. CaO-based material is one of the most promising storage media due to its abundant and cheap resources, the possibility to store at ambient temperature and pressure, its high energy density or its easy operation in industrial applications. The analysis shows that the technology can be the basis for competitive energy storage, achieving overall efficiency of 35% and LCOE values below 60 USD/MWhe in economic terms, addressing the problem of renewable storage without the limitations that other storage technologies incorporate.

## SDEWES2021.0648

# Electric Vehicles Batteries for Circular Economy: Second Life as Stationary Storage

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## Abstract

By 2030 the sales of electric vehicles (EVs), are set to increase six to thirty folds compared to the levels of 2019 (IEA, 2020) leading to an increased electricity demand and also growth in rejected EV batteries (BEV). This leads to a challenge of meeting the EV charging demand in a sustainable manner alongwith finding solutions for utilizing the second life of batteries for improved resource efficiency. In this paper we propose to analyze the utilization of BEV throughout its life cycle in the light of its contribution towards circular economy. The method is divided in two stages. Stage 1 is considering the optimal charging strategy for the EV while considering the techno economic constraints. After, the battery is utilized by the EV and degrades a certain level, it is rejected. In the second stage, we utilize the second life of batteries as a stationary energy for meeting the residential demand. Mixed integer linear problem (MILP) optimization is used for both the stages. For the stage 2 analysis, two scenarios are designed. Scenario 1 refers to optimal use of second life of battery for demand side management in a residential building. In scenario 2, second life of battery is used for maximizing self-consumption of PV for a residential building. The results from both the stages will be compared in terms of economic benefits and lifetime of batteries, while considering technical and economic constraints in the model. The results would aid in quantifying the benefits from full cycle utilization of EV batteries, thereby reducing stress on the resources and contribute towards circular economy goals of Europe.

## Storage 2

## SDEWES2021.0700

# Analysis of Wind to Hydrogen Production and Carbon Capture Utilisation and Storage Systems for Novel Production of Chemical Energy Carriers

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## Abstract

As the offshore energy landscape transitions to renewable energy useful decommissioned or abandoned oil and gas infrastructure can be repurposed in the context of the circular economy. Oil and gas platforms, for example, offer opportunity for hydrogen ($H_2$) production by desalination and electrolysis of sea water using offshore wind power. However, as $H_2$ storage and transport may prove challenging this study proposes to react this $H_2$ with the carbon dioxide ($CO_2$) stored in depleted reservoirs. Thus, producing a more transportable energy carriers like methane or methanol in the reservoir. This paper presents a novel thermodynamic analysis of the Goldeneye reservoir in the North Sea in Aspen Plus. For Goldeneye, which can store 30 Mt of $CO_2$ at full capacity, if connected to a 5 GW wind farm, it has the potential to produce 2.10 Mt of methane and abate 3.63 Mt of $CO_2$ from wind energy in the grid.

## SDEWES2021.0775

# Experimental Study on the Impact of Passive and Active Enhancement Techniques in the Storage and Use of Solar Thermal Energy

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## Abstract

Thermal energy storage (TES) is one of the most interesting technologies recently developed because they are capable of coupling solar energy production and consumption. On the field of energy storage, Phase Change Materials (PCM) are a possible solution using the latent heat of a PCM, used as a loading and unloading mechanism to absorb and release thermal energy.

However, PCM presents some drawbacks that must be addressed, such as low thermal conductivity that slows down the storage and release of energy. In order to enhance heat transfer mechanisms, several enhancement techniques can be applied to accelerate the melting and solidification processes.

In this work, the impact of passive and active enhancement techniques in thermal energy storage systems with PCM are studied. Moreover, results of melting and solidification processes from experimental facilities built at Polytechnic University of Cartagena are discussed.

SDEWES2021.0799

# A Performing System to Store Waste Heat: Composites of Mofs and Cacl2

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## Abstract

Solar energy is one of the most promising types of renewable energy thanks to its high availability and low cost.Energy storage systems have therefore been developed in order to reduce the discrepancy between demand and supply. In particular, thermochemical heat storage systems, using reversible sorption/desorption reactions, offer high energy storage density over variable amounts of time with minimal heat losses. Water sorption storage systems using hygroscopic salts, such as $CaCl_2$, inside a porous matrix are widely used.These composite materials allow the storage of energy (solar or from any other source) during dehydration (charge) and its release during hydration (discharge). Among porous materials, Metal-Organic-Frameworks (MOFs) have recently been of particular interest because of their high sorption capacity due to a very high surface area and tunable properties.

This work proposes a study of the heat storage/release and water sorption/desorption capacities of composites materials. Aluminium fumarate-based MOFs impregnated by different amounts of $CaCl_2$ (25, 37, 58 wt.%) were synthetized. Materials were subjected to analysis by TG-DSC coupled to humidity generator during successive hydration/dehydration cycles. DSC analysis showed that after impregnation, the heat storage/release capacity of MOFs gradually increases with the amount of salt until reaching 1840 kJ $kg^{-1}$ for composite MOF + 58 wt.% of $CaCl_2$. A concomitant increase in water sorption/desorption capacity, determined by thermogravimetric analysis is observed. Besides, storage properties of composite impregnated by the highest amount of salt decrease by only 6% after 3 dehydration/hydration cycles, and then remain stable thus showing high stability.

Furthermore, the storage properties of a new host material composed of an aluminium fumarate membrane on alumina support with both micropores/mesopores and a different morphology than aluminium fumarate have also been studied. The remarkable capacities of these new materials give them a significant place in the energy challenge.

## SDEWES2021.0928

# Application of Permanent Neodymium Magnets in Green Hydrogen Production

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## Abstract

An integral part of green hydrogen production is the use of renewable energy sources in water electrolysis. This paper deals with analyzing the impact of the magnetic field application on the energy efficiency of the alkaline electrolyzer. The research was done by the conduction of the experimental research. The overall experimental research consists of 12 individual experiments, which can be categorized into two groups. The first set of experiments is done without the application of the magnetic field and the second with the application of the magnetic field. The non-homogeneous magnetic field, created by two pairs of neodymium magnets, was applied to the electrolyzer. The magnetic flux density of the space between magnets is measured and presented in detail, ranging from 0,38 T in the centre of the field to 0,63 T at the surface of a magnet. The energy efficiency of the electrolyzer is calculated for a group of 6 experiments without the application of a magnetic field and 6 experiments with the application of a magnetic field. the average efficiencies for each set of experiments are calculated with the overall conclusion that the application of the magnetic field resulted in an increase in hydrogen production energy efficiency by 2,37%.

## SDEWES2021.1063

# Modelling and Performance Assessment of an Integrated Liquid Organic Hydrogen Carrier-Thermal Energy Storage (LOHC-Tes) Process for Hydrogen Heat Recovery

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## Abstract

Use of dibenzyltoluene for hydrogen storage in Liquid Organic Hydrogen Carriers (LOHCs) allows to alternate storage and release of hydrogen in one and the same catalytic reactor, with the same temperature range (290-310 °C) for hydrogenation and dehydrogenation. To improve hydrogen storage efficiency, this work explores for the first time the use of thermal energy storage (TES) to recover heat from exothermal hydrogenation and use it as the heat source driving the endothermal dehydrogenation, in a fully integrated LOHC-TES process. Research objectives involve: i) assessing the best technological options for TES integration with the LOHC process, ii) prediction of the achievable hydrogen storage efficiency and iii) evaluation of the energy savings compared to the case without hydrogenation heat recovery. A numerical tool for the integrated LOHC-TES process was developed, with detailed models of the catalytic reactor and the thermal storage individually validated against available literature and experimental results. The design of an integrated LOHC-TES storage system for the storage and release of 500 kW worth of $H_2$ and 10 h operation is presented, which achieves an overall system energy density of 176 Wh/l, including LOHC tanks, TES and reactor volume. About 1.5 MWh of thermal energy is saved per cycle, compared to the case with no TES, reaching 95% hydrogen storage efficiency. The study further highlights the need for accurate reaction modelling, including thermodynamic equilibrium, given the low temperature of dehydrogenation. Exploratory results in this direction provide a starting point for the accurate simulation of an integrated LOHC-TES process.

## Sustainability comparisons and measurements 1

## SDEWES2021.0076

# Review of Social Assessment Methodologies for the Case of Renewable Energy Technologies

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## Abstract

The decision-making on sustainable energy supply options is mostly focused on environmental and economic indicators while social impact receives comparable little attention. The energy transition brings a shift in material demand away from fossil fuels to (rare) minerals and metals for emerging energy technologies, such as wind and solar power, or storage technologies. The social implications of the changing material demand and the roll-out of renewable energy technologies need to be re-examined. Moreover, the locations of energy generation are shifting as well to a more decentralised system, which moves the technologies closer to the single communities that feel the individual impact on well-being strongly. There is a need for a comprehensive assessment of social implications of the transition to renewable energy systems both for the global and the local population.

This article puts the spotlight on the status of social assessment methodologies at different stage of the life cycle of renewable energy technologies. The objective is the quantification of social impacts that affect global and local target groups. This allows a comparison of the societal implication of different energy technology case studies such as wind, solar or biomass.

By means of these case studies for renewable energy technologies, the capabilities and limitations of existing assessment methodologies are illustrated. This includes the capability to quantify social impacts both on a global and local level as well as flag social hotspots. A major finding is that the assessment of different areas of concern such as social responsible supply chains, global health impacts or local population well-being are delimited areas of study. Additionally, effort is needed to find a common endpoint indicator which would allow an area-overlapping comparison of results and the balancing of impacts and benefits.

## SDEWES2021.0447

# Comparative Sustainability Assessment of Alternative Technologies and Fuels for Individual Motorized Mobility

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## Abstract

In order to achieve the goal of reducing greenhouse gas emissions in the transport sector in line with EU Directive 2018/2001 (RED II for short), further development and establishment of alternative drive train technologies (e.g. electric motor with fuel cell or only battery) and climate-neutral fuels (e.g. drop-in fuels) are required. Besides climate change, other environmental impacts, such as acidification and photochemical ozone formation, must be considered in the evaluation. For sustainability assessment, economic and social aspects must also be included. In this paper, the approach and results for the comparative sustainability assessment of three alternative drive train technologies and fuels for individual motorized mobility are presented and compared with the internal combustion engine powered by conventional gasoline: (1) internal combustion engine with synthetic biofuel, (2) electric motor with electric power, (3) electric motor and fuel cell with hydrogen. The life-cycle-based assessment covers the entire value chain, i.e. the production of the fuels, the production of the passenger cars (car body, powertrain, energy storage) and the use of the fuels in the passenger cars. For the sustainability assessment, the indicator set developed within the Helmholtz Initiative Energy System 2050 is used together with the multi-criteria assessment method TOPSIS. The set of indicators considered for MCDA comprises 13 ecological indicators according to ILCD (2011), the costs per unit of product as economic indicator, and the domestic value added per unit of product as social indicator. The years 2020 and 2050 are considered as reference years. Within the framework of sensitivity analyses, the influence of the weighting of indicators and sustainability dimensions as well as selected input variables on the result of the multi-criteria evaluation are being analyzed.

## SDEWES2021.0468

# A New Reliability-Centered Maintenance Programming for Sustainable Distribution Networks Based on New Indexed Components Ranking

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## Abstract

The appropriate strategy of maintenance based on reliability and accessibility of the distribution system's components and assets is the best way to reach these goals. This strategy is a kind of using reliability-centered maintenance (RCM). Due to the limited maintenance budget, performing maintenance activities for all components of the system is neither possible nor logical. So most of the resources should be allocated to the most critical and important components. This paper presents a new analytical method of prioritization of distribution systems' components by introducing a new Weighted Cumulative Reliability-based Diagnostic Importance Factor (WCRDIF). This new factor includes different reliability indexes in form of diagnostic factors and will show that the order of components obtained by this method is better than another method in saving the budget and providing reliability of the system. The process of decision-making for prioritization of distribution systems' components based on their criticality degree will both improve the reliability level of the total system and decrease the cost of load interruption and finally maintenance costs. The proposed model is implemented on a radial distribution network. Numerical results show the effectiveness of the proposed RCM model for micro-grids.

## SDEWES2021.0534

# Comparative Analysis of Energy Efficiency in Lithuanian Farms

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## Abstract

Efficient use of energy resources is the key element ensuring the development of agricultural sector in a sustainable way. Improved energy efficiency in agriculture reduces the environmental impact to climate mitigation, reduces the use of fossil fuels and increases energy independence from import energy. To reduce the fossil fuel intensity of agricultural production is one of the tasks of the Strategic Plan for the next long-term EU budget 2021–2027. National support is provided for Lithuanian farms in terms of reduced excise duty for diesel. This support comprises over 50% of total national support for agriculture from national funds. Therefore, the challenging task for agricultural sector may appear in achieving the increase of energy efficiency. The energy is an important costs element in all agricultural systems. The energy intensity and the share of energy costs in total farming overheads in Lithuanian farms is above the EU-28 level and that stresses the possibilities for more efficient use of energy. Therefore, the assessment of the energy efficiency across different agricultures systems is needed. The aim of this paper is to determine the use and excess of energy resources in Lithuanian family farms across the main agricultural systems. Lithuanian Farm Accountancy Data Network (FADN) data have been processed and energy efficiency was then explored through the nonparametric approach Data Envelopment Analysis (DEA). The research results identifies agricultural systems where the energy costs can be reduced and provides new an evidence-based insights for strategic choices which policy-makers should take into account when designing energy measures for agricultural sector.

## SDEWES2021.0635

# Development of a Tool to Estimate Carbon Emissions in Districts and Dwellings. Open Access Planner for Citizens and Policymakers

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## Abstract

Reducing the carbon emissions of buildings and whole districts is one of the main objectives of sustainable development. Both policymakers and end-users need reliable information to take actions that lead to positive outcomes. The framework of a tool has been developed to assess the effect that the sources of energy consumption have over the overall carbon emissions of districts, buildings, and house units. The tool intends to be an online planner service for the end-users of dwellings and policymakers. When it comes to the end-users, it would help them both to know the actual environmental impact of their home and to make environmentally and financially sound decisions before investing in new equipment. This study deals with the development of the $CO_2$ module calculator of the tool. The study first focuses on the obtention of open-source conversion factors for the different sources of energy and their equipment. Secondly, it presents two case studies to illustrate the use of the tool. The first case study goes through the way in which a civilian would be able to estimate the energy savings that would result from changing the energy sources. The second case study uses real data from a district in Valencia (Spain) to show how renewable sources would affect the carbon footprint of an apartment block. Both study cases show great GHG emissions savings by replacing the existing equipment with renewable ones such as heat pumps and photovoltaic panels. After the completion of the study, it can be concluded that providing smart tools could be pivotal to plan nearly Zero-Energy Districts (nZED).

## SDEWES2021.0636

# LCA Assessment of Zinc Recovery from Spent Pickling Acids

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## Abstract

Spent pickling acids (SPAs) constitute one of the main wastes generated in hot-dip galvanising (HDG). The conventional SPAs treatment consists of neutralisation-precipitation (N-P) and disposal in landfills of the metal oxides sludge. The main material resource used in HDG is high purity metal zinc, of which about 4% is lost in SPAs. The LIFE2ACID project is aimed at demonstrating the recovery of zinc from SPAs by membrane-based solvent extraction (MBSX) and electrowinning (EW) at pilot scale. In this way, SPA wastes can be transformed in raw materials according to the emerging concept of circular economy. Optimal technical results have been obtained, but the recovery of metallic zinc has not been analysed from an environmental sustainability perspective yet.

This work evaluates the environmental impacts and resource usage of zinc recovery by MBSX and EW from real SPAs following the life cycle assessment (LCA) methodology according to ISO 14040 and 14044. Besides, the MBSX-EW technology is compared with the conventional N-P and landfilling of SPAs. The study has a cradle to grave approach, considering the extraction of raw materials, waste and wastewater treatment, and transportation. The life cycle inventory was collected from the pilot plant results and mass balances, using Sphera professional database for secondary data. The system was modelled using the LCA GaBi software and CML 2001 as impact assessment method including some categories such as Abiotic Resources Depletion, Abiotic-Fossil Resources Depletion, and Global Warming Potential.

The results show that the environmental impacts of the conventional waste treatment are higher than those of the LIFE2ACID technology alternative, in which most impacts are assigned to the production of the neutralisation agent needed in N-P. In the case of MBSX/EW, the generation of electricity consumed in zinc EW is the main contributor in most of the impact categories. Material credits obtained from recovered zinc can play an important role in markets such as the substitution of primary zinc by secondary zinc, and/or zinc oxide production. Furthermore, iron chloride can be obtained after zinc extraction from SPAs at the MBSX, and its use in wastewater treatment plants will approach close the loop intended by circular economy.

## SDEWES2021.0690

# Domestic Value Added as an Indicator for Sustainability Assessment – a Case Study on Alternative Drivetrains in the Passenger Car Sector

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## Abstract

In order to broaden the economic pillar in sustainability assessment the indicator 'domestic value added' is introduced. 'Domestic value added' aims at comparing technologies with regards to their prospective influence on the added value of a country. This is done by classifying a technology's value added to the developed categories domestic, potential domestic and non-domestic. Within this paper methods for estimating this indicator are introduced. Two methods are proposed, presented and assessed especially considering their applicability in a sustainability assessment context. Both methods are tested on a case study comparing two alternative drivetrain technologies for the passenger car sector (battery and fuel cell electric vehicle) to the conventionally used internal combustion engine. The first method is based on a classic economic assessment whereas the second is based on Input Output analysis. The results show, that from a 'domestic value added' perspective the battery electric vehicle is more advantageous than the conventionally used internal combustion engine. Fuel cell electric vehicles have the potential to be favourable in the future. This paper gives practical information on how to prospectively assess 'domestic value added' due to substituting existing with less developed technologies or innovation.

## SDEWES2021.0704

# Traceability for Attaining Sustainability Towards Circularity of Electric Batteries

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## Abstract

With the increasing number of Electric Vehicles, the number of rejected batteries is going to increase in near future. It is projected that by 2025, the amount of second life of batteries will be 3.4 million (corresponding to 96GWh).With the increasing number of rejected batteries, alternative ways to utilize the second life of batteries for various applications ranging from demand side management, increasing self-consumption of PV generation to stationary storage for utilities are being explored. The reuse and recycling of the electric vehicle batteries contribute to circular economy. Traceability is one of the most critical element of recycling process that enables tracing back historical data related to product manufacturing, transport and usage. Hence, in this paper, information gathered from traceability indicators for electric vehicle batteries' supply chain will be studied in lieu of achieving sustainability in the electric vehicle batteries' sector. For this study, there pillars of sustainability which are ecological, societal and economic are explored, to assess the impact created through traceability on these pillars. The challenges and barriers associated with implementation of this system will be discussed.

## Sustainability comparisons and measurements 2

### SDEWES2021.0032

# Lessons Learned from Labyrinth Type of Air Preconditioning in Exergy-Aware Greenhouses

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## Abstract

An exergy-based performance model shows that a labyrinth system may not save energy unless the exergy of the electrical power demand due to the electrical fans and pumps involved in the system is less than the thermal power exergy gained. Based on this model, exemplary exergy and carbon-aware solar greenhouse concept was developed to decouple food products from fossil fuel use. Sample design calculations for such a solar greenhouse in a region located north of Zwolle in the Netherlands show that it may eliminate the use of fossil fuels, except grid connections. New terms define nearly-zero exergy greenhouse and nearly-zero carbon greenhouse. The paper further discusses that exergy-smart greenhouses with local farming close the decarbonization loop when coupled with the urban life in slow cities with low-temperature district energy systems.

## SDEWES2021.0044

# Deep Geothermal Energy Extraction: a Review on Environmental Hotspots with Focus on Geo-Technical Site Conditions

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## Abstract

Geothermal energy is a renewable energy source with abundant unexploited capacity. However, the scarce and scattered information about its environmental impacts is a major barrier to its further adoption. We review 28 studies performing environmental life cycle assessments (LCA) for geothermal energy plants. In contrast to existing LCA review papers, we focus on the environmental hotspots and the cause-effect relationships between the plants' geo-technical parameters and the environmental impacts.

For each study, we relate the reported environmental impacts to the plant's geo-technical characteristics and identify from the life cycle inventory (LCI) the factors that contribute the most to the reported impact categories and that form the basis for a hotspot analysis. This way, we achieve a triangular evaluation of the reported impacts (geo-technical parameters, LCI parameters, hotspot analysis results) to explain the variability in results for the studies under consideration.

For global warming potential (GWP) impact we show that for dry steam and flash plants operational direct emissions are the major contributor. In fact depending on $CO_2$ and $CH_4$ concentration in the geofluid, GWP can take very high values. For binary and Enhanced Geothermal Systems-binary plants, wells' development – and specifically steel and diesel consumption, raise the most GWP impact, although working fluid leakage can contribute significantly too. Depending on the plants' output, the reservoir's depth and the amount of steel and diesel used for the wells' drilling, the reported GWP impact varies widely. Conversely, for deep geothermal heating plants GWP impact mainly emerges during operation because of the pumping needs. However, depending on the coal-share of the electricity mix, the wells' depth and the distribution network's pipeline length the results can vary significantly. The same kind of analysis is performed for seven other commonly assessed impact indicators (AC, HTP, ADP, CED, FW-EC, EP and WC) for which however the information is much more scarce than GWP.

Based on these results, we present a research agenda in which we propose a more in-depth analysis of the environmental impacts especially for deep geothermal heat plants. Also, in contrast to other renewable energy sources, most of the impacts emerge during operation. Therefore, a dynamic LCA framework is considered to result into a more reliable environmental assessment of geothermal energy across its lifetime.

## SDEWES2021.0087

# Analyzing the Embeddedness of Climate Change in Sustainable Development Goals

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## Abstract

Climate change is an important apcet of sustainability, which is why the UN has set a separate sustainable development goal, SDG13, to tackle the problem. In order to achieve the mission set out in the Paris Climate Agreement, the 2030 Agenda alone is not enough, it only provides a framework for long-term strategic planning. The aim of this work is to identify potential external variables and interventions related to climate change, on the basis of which interactions with different sustainable development goals can be characterized.

The consolidation of measures to mitigate the effects of climate change into a structured system supports both the achievement of SDGs and the strategy planning of the Paris Climate Convention. Regression models are identified to describe the strength of the effects of the mitigation opportunities. The analysis shows what other sources of information can be used to address the general lack of data for SDG13 and what useful indicators can be developed for decision-makers on climate change.

## SDEWES2021.0157

# Sustainability Assessment of the Cantabrian Fishery: Combined Life Cycle Assessment and Data Envelopment Analysis (LCA+DEA) Approach Including Socio-Economic Indicators

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## Abstract

Sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs (UN, 1987). Three fundamental pillars are considered to achieve this goal: environmental protection, economic growth and social equality. In this context, methodological holistic approaches are required in order to identify and assess current problems and set policies and strategies that provide sustainable production and consumption patterns (Iribarren et al. 2016). Currently, there is not a stablished integrated methodology for the sustainability assessment, however, the use of life cycle-based tools is widely accepted to evaluate environmental, economic and social aspects, but in an isolated way. To handle this issue, the combination of life cycle assessment (LCA) and data envelopment analysis (DEA) has been proposed and applied to several case studies, including fishing sector (Laso et al. 2018). Nevertheless, previous studies about fisheries that combine LCA+DEA methodologies do not consider socio-economic indicators, but only environmental ones. To fill the gap, this study proposes the application of the LCA+DEA approach to the Cantabrian fishery sector considering socio-economic indicators, such as labor (in terms of working hours). A “five-step LCA+DEA method” is applied to determine the sustainable eco-efficiency of the Cantabrian fishery based on a sample of 133 vessels, which can be classified according to fishing gears and caught species.

The results obtained will allow to identify efficient vessels and to determine the potential reduction percentages for inefficient vessels. It will be expected that the obtained results are of interest for stakeholders and policy-makers aiding in the identification of social-economic and environmental flows that should be optimized. Moreover, this holistic approach offers a common understanding of complex problems to facilitate the decision-making process.

## SDEWES2021.0434

# Structural Changes in the EU Agricultural System: the Sustainability Prism and Energy-Induced Effects

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## Abstract

Over the recent decades, the EU agricultural system has evolved due to significant structural changes in member states. Knowledge about the nature and main patterns of structural change is critical to select a more sustainable development path for the EU agriculture. This paper contributes to the academic discourse on structural changes in agriculture demonstrating the nexus between socio-economic and environmental aspects of development. In this regard, results are important to understand the contribution of the EU agriculture to climate change, because study deals with energy use and greenhouse gas emissions. The research covers period from 2010 to 2018 and investigates the reallocation of fundamental structural change measures, namely gross value added, labour, and agriculture-related energy use and emissions, in EU member states. Structural changes are investigated applying a shift-share analysis that allows estimating a performance of individual member states, compared to the EU economy. The applied shift-share model investigates the situation of individual member states employing three components. $EU_{ij}$ benchmarks the development of the selected measures with the EU economy growth, $EA_{ij}$ shows the change due to effect of economic activities, and $MS_{ij}$ – competitiveness of agriculture in member states. The aforementioned components empower ranking member states in accordance with the decomposed structural change parameters. Findings suggest that EU economy faces the outflow of labour from agriculture and this trend is common for most countries. The changes of gross value added as well as agriculture-related emissions and energy use are county-specific. However, research results suggest that new member states often face more fundamental changes.

SDEWES2021.0862

# Environmental Life Cycle Assessment of Nano-Cellulose and Biogas Production from Elephant Manure

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## Abstract

Nano fibrillated cellulose (NFC) has been a popular topic of research in recent years, especially due to its wide range of potential applications and unique properties. The step from raw material (pulp is commonly used) to NFC requires a lot of energy. In this paper a new approach to first produce biogas from elephant manure and subsequently use the cellulose containing digestate for NFC production (manure scenario) is compared to the production from Kraft pulp from hardwood chips (wood chips scenario). To produce comparable outputs from both scenarios (NFC and biogas) a typical Austrian biogas plant with maize silage and pig slurry as input material is included in the wood chips scenario. A proxy approach is used to upscale the manure scenario from laboratory to an industrial scale (except for the pulp to NFC step) to ensure comparability of both scenarios. The impact categories global warming potential (GWP), fossil resource scarcity, freshwater eutrophication (FEP), human toxicity, terrestrial acidification (TAP) and terrestrial ecotoxicity potential (TEP) are analysed referring to the functional unit of 1 kg NFC. Results show that the manure scenario has lower impacts in all assessed categories. GWP is 4.41 kg $CO_2$ eq./kg NFC in the manure and, 9.74 kg $CO_2$ eq./kg NFC in the wood chips scenario. The pulp to NFC step is identified as environmental hotspot in both scenarios causing 35 % in TEP (manure scenario) and 22 % in TAP (wood chips scenario) and 81 % (manure scenario) and 93 % (wood chips scenario) in FEP, which is in line with other studies. Biogas production has the lowest impact in FEP of the manure and wood chips scenario (13 %; 5 %, respectively), and the highest impacts in TEP (26 %; manure scenario) and TAP (74 %, wood chips scenario). Pulp production has the highest impact in TEP of the manure and wood chips scenario (39 %; 19 %, respectively) and lowest impacts in FEP of the manure and wood chips scenario (5 %; 1 %, respectively). The LCA shows that NFC production from elephant manure is a sustainable alternative to the production from hardwood Kraft pulp.

## SDEWES2021.1070

# The Possibilities of Gpf Surface Modification in the Aspect of Micro-Contaminants Removal

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## Abstract

The European Union Fit For 55 program plans to cease the production and sales of the vehicles with the internal combustion engines in 2035, although fuel powered vehicles will remain on the road for many more years to come.

In addition to the limits of the exhaust components such as carbon oxides, nitrogen oxides and mass of the solid particles (PM) the European Emission Standard Euro 6b implemented in 2014 started limiting the number of the solid particles (PN) in gasoline vehicles with direct injection. However, this standard does not limit the micro-contaminants from the fuel and engine oil combustion that are harmful for health and the environment.

The micro-contaminants such as Polycyclic Aromatic Hydrocarbons (PAHs) and their nitric and oxygenated derivatives, ions, metals and metalloids are present in the exhaust in seemingly low concentration. Nonetheless compounds such as nitro-PAHs might be even ten times more carcinogenic than benzo[a]pyrene. Adding the fact that on the EU road there are over 330 million passenger and light duty cars traveling on average 12000 km/year the micro-contaminants become a serious concern.

The gasoline particulate filter (GPF) is the most commonly used solution for the solid particulate emission control. Its main task is to reduce the number of the particles in various physical mechanisms such as diffusion and interception. Nowadays to expand the GPF functionality beyond PN reduction the filters are close-coupled with the three way catalyst, externally heated or coated with the catalytic material. Increasing temperature improves regeneration, while adding e.g. KOH improves reduction of the micro-contaminants.

The other studies show, that use of the metals such as Cu, Co, Fe, Ni or Mn improves oxidation of PAHs and their derivatives. The possibility of the surface modification with catalytic materials should be further studied. Currently, most of the GPFs are made of cordierite, therefore research on alternate materials should also be carried. The aim of this study is to review to knowledge about the gasoline particulate filters, their mechanisms of pollutants removal and to highlight the probable insufficiency in avoiding of hazardous microcontaminants emission. The work is partially based on literature review and on own research of Authors.

## Sustainability comparisons and measurements 3

## SDEWES2021.0551

# Nutritional Footprint Comparative in Cantabria: Fisheries Production Vs Horeca and Household Consumption

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## Abstract

The economy and cultural heritage of Cantabria, a northern Spanish coastal region, has been traditionally based on the primary sector, highlighting fish and seafood products. Besides its economic and social importance, these products are greatly present on the stablished Atlantic diet of the area. Cantabria has a fleet of 133 fishing vessels, spread over seven ports and produced more than 70% of anchovy canning of the total Spanish amount in 2019 (ICANE, 2020). Its population consumed 23.13 kg per person and year, higher than the national average (MAPA, 2020).

This study addresses a comparative study between the nutrient content of the species captured by fishing fleets and the seafood products (fresh, cooked, etc.) that are consumed in both HORECA sector (restaurants, hotels, etc.) and houses. Thus, a nutritional footprint indicator will be applied in order to know the degree of correlation between the production and consumption of this kind of food.

Is the fishing sector efficient in relation with the kind of species captured? How the consumption step interferes in the use of food and the generation of waste? These and other questions were analysed.

## SDEWES2021.0552

# Enrivonmental Sustainability of Potato Chips Production Under a Life Cycle Perspective: the Case Study of a Cantabrian Industry

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## Abstract

Potato cultivation represents the third most important crop production worldwide, and a significant economic and agricultural activity in Spain. However, it is increasingly common for this food to be processed to obtain products of greater commercial value, with the environmental inconveniences that this entails. In this framework, the study aims to present and discuss the environmental impacts linked to the potato chips production in a Cantabrian (Spain) factory. For this purpose, the Carbon Footprint (CF) of the product is developed, considering a 'cradle-to-gate' approach and a FU of 50 g of potato chips (equivalent to a bag). The results of the study report a CF of 79.83 g $CO_2$ eq./FU, being the processing and cultivation stages those with the highest impact. Possible improvements of the system are focused on the application of organic fertilizers, the implementation of more efficient technologies, such as drip irrigation, and the replacement of diesel as fuel in the processing stage.

## SDEWES2021.0705

# Improving Measures of Local Sustainability Performance Enhancing Adaptive Capacity in Hungary

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## Abstract

The measurability and monitoring of sustainability are also linked to improving adaptation to the expected effects of climate change. Adaptive capacity to deal with climate risks is strictly related to sustainability transition on the local level. Enhancement of adaptive capacity implicates complementary requirements as the encouragement of sustainable development. Successful adaptation depends on actions taken at different spatial levels due to vulnerability that can occur at different scales. Improving local knowledge considering sustainability and adaptive capacity can play a significant role in the reduction of vulnerability.

Although Hungary has a national sustainability indicator system, that is revised every two years, containing a total of 103 indicators at the national level, which was developed by the Hungarian Statistical Office to present the status of the four national resources (human, environmental, social and economic), it can be characterized by a number of shortcomings that require further development.

There is insufficient knowledge considering sustainability transition on NUTS 3, moreover on LAU 1 and 2 levels in Hungary. The aim of this research is to provide indicators to promote sustainability on the local level. Furthermore, improve measures of local sustainability performance in such a way that they are also suitable for taking into account local spatial interdependencies. It can be also highlight the dynamics of adaptation and the role of non-climatic factors.

These indicators can be used as a monitoring tool and guidance to municipalities policy-making as well as development programs. Improving local measures in relation to sustainability performance can be pivotal in decision-making processes on the municipality level and is able to foster local solutions from a multidimensional perspective, effectively enhancing adaptive capacity.

## SDEWES2021.0809

# European Legislation and Thermochemical Recovery of Plastic Waste – Energy Recovery from the Sustainable Economy Development Point of View

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## Abstract

Only recently the EU started to address the problem of plastic waste more directly through its legislation, but also as a part of larger sustainability-oriented plans and legislation frameworks. In all of this, the focus was put on material recovery, and regarding energy recovery legislation is not elaborate enough because of which it classifies all thermochemical conversion technologies in the same category regardless of their final products. Therefore, this research analysed environmental, resource and energy intensity of energy recovery technologies for plastic waste to review the existing legislative technology classification for thermochemical waste recovery technologies. To give appropriate results, EU legislation on sustainable development was reviewed and legislatively most important impact categories were used, as well as those identified by previous research, as the most suitable for waste management and recovery system analysis. Results show that gasification with ethanol production and pyrolysis technologies for treatment of plastic waste show the best results compared to other analysed solutions by all analysed indicators, except for acidification where pyrolysis shows the worst results. Thus, it can be concluded that gasification and pyrolysis technologies can lead to better environmental impacts when compared with plastic waste incineration and help the EU to reach sustainable development goals. Thus, environmental impacts are largely dependent on the final products and sustainability of products it replaces on the market. Results of this analysis provide an overview of the environmental sustainability of the mixed plastic waste recovery, based on which current views on individual thermochemical recovery technologies may be re-examined.

## SDEWES2021.0814

# Demonstrating Environmental Benefits of Introducing Lupine as Alternate Crop in Autochthonous Winter Wheat – Oilseed Rape Rotation Systems

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## Abstract

Climate change (CC) is a significant threat to all aspects of food security, including food access, utilization, availability and price stability, reducing staple crops yields among other issues. In this regard, agriculture is certainly the sector most affected by CC. The relationship between CC and crops production depends to a large degree on when and which adaptation actions are taken. Understanding how alternative agricultural production systems drive environmental degradation is essential for reducing environmental consequences derived from agriculture.

Wheat and legumes are traditional crops in Mediterranean region. Among cereals, wheat is the most widely grown crop in the world. On the other hand, among the many important benefits that legumes deliver to society, their environmental benefits have been rarely addressed.

The main goal of this study is to demonstrate the environmental benefits associated to the introduction of lupine (Lupinus albus L.), a legume of the Fabaceae family, as alternate crop in a traditional cropping system based on autochthonous winter wheat (Triticum aestivum L.) and oilseed rape. Both plantations under study are in Galicia (NW Spain) and have been assessed for a 6-years rotation period. In the conventional system, wheat and oilseed rape are alternately cultivated. On the contrary, in the alternative one, lupine is firstly cultivated, followed by wheat and rapeseed. Increases in wheat yields of 10-15% have been identified when it is preceded by lupine.

The comprehensive analysis has been performed considering the Life Cycle Assessment methodology, a cradle-to-gate approach and the hectare as functional unit, allowing assessing different environmental impacts directly caused by the cropping systems. Inventory data are based on primary data directly taken from farmers by means of specific designed questionnaires. Only secondary data have been considered for background processes.

The ReCiPe 2016 hierarchist Midpoint method V1.03 World (2010) has been used for the selection of characterization factors required to estimate the environmental burdens considering five impact categories: global warming (GW), terrestrial acidification (TA), freshwater eutrophication (FE), marine eutrophication (ME) and fossil resource scarcity (FRS). The results suggest that introducing a legume as lupine in the cropping system contributes to considerably reduce the environmental burdens, with reduction ratios of near 40% in GW and ME, 12% in TA, 20% in FE and 15% in FRS. Arable operations contribute decisively to the environmental profile of the rotations in all the categories under analysis with an outstanding effect from fertilization in eutrophication related categories.

## SDEWES2021.0980

# Digital Solutions for the Sustainability Assessment of the Agri-Food Value Chain

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## Abstract

Combating climate change must be seen as a collective effort, so consumers need tools that guarantee them an informed choice about the sustainability of value chains and traceability of the products they buy.

BIOMA Mobilising Project was created by a consortium of several companies from the Agri-Food sector and several Innovation and Research entities from all over the country, representing all elements of the sector, from production to the valorisation of food and derivatives, with the purpose of developing a set of sustainability indicators that can be applied and verified along the chain and that can be translated into a classification that can be easily recognised and traced by the consumer. The objective is to elevate agri-food value chain to a more competitive and sustainable levels, promoting strategies and an ecosystem that encourages the adoption of integrated Bioeconomy solutions, supporting the National Strategy for Bioeconomy, and pursuing the United Nations (UN) sustainable development goals: 8 - Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all, and 12 - Ensure sustainable consumption and production patterns.

The work methodology was bases on a brainstorm of several specialists in governance, water, residues, agriculture, animal production and logistics and so on, in order to team up with companies of the complete value chain and define the indicators that should be addressed and the variables throught which they will be measured. These indicators will be compiled in a digital platform, but for the validation of the selected indicators a questionnaire form was used. The questionnaire was sent to companies and producers, from the outside of the project, in a bottom-up strategy, in order to understand if the questions were perceptible and if they had information about the different variables or if these were easy to measure.

The principal feedback from the enquiries were about the extension of the questionnaire and the time required to answer it. In larger companies or producers, the application of the questionnaire becomes easier, since in these organizations there are human resources responsible for corporate sustainability and there is already control regarding residues, energy and water consumptions, commodities and others. For the smaller companies/producers, where workers often accumulate several functions, the time required to collect the information and answer can be a real constraint. The project is in its first year and the indicators will be adapted in order to construct a valuable tool for the value chain and for the consumers.

## SDEWES2021.0985

# Strategies for Wine Environmental Impact Reduction Based in a Multiyear Analysis

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## Abstract

In recent years, it has become clearer that wine industries are facing the necessity to focus on a sustainable use of resources, reducing both the dependence on natural resources and production costs. A sustainable wine production can improve industries competitiveness through the energy and natural resources decrease, with economic and environmental gains. The use of environmental impact assessment tools can therefore help producers to find potential improvement strategies, since it will identify the most resource intensive processes. This type of tools allows the identification of hotspots and the evaluation of the environmental performance of alternative processes or procedures. With this objective a medium size winery was selected for monitoring, within a four year period, on Alentejo region – Portugal. This type of analysis, with several years of monitoring, may be more revealing of the true reality of wine production once it eliminates annual weather variability. The inventory data collected was used in a Life Cycle Assessment approach considering the impacts related to wine production from cradle to gate. With this in mind, it was considered the vine planting, vine management, vinification and bottling/packaging phases, and all the related inputs. The functional unit selected was the wine bottle of 0.75 L. The main sources of impacts were identified as well as the main strategies and alternatives that can be implemented to reduce those environmental impacts. The obtained data was analyzed with SimaPro software and the aid of Ecoinvent databases, and the results shows that the viticulture and the bottling/packaging phase are the main contributors for the overall environmental impact. In this last production phase, the weight of the glass bottle revealed to have great importance on the overall environmental impact.

## Sustainable resilience of systems

## SDEWES2021.0096

# Towards a More Sustainable Tourism Under a Life Cycle Thinking Approach: the Case Study of the Camino Lebaniego in Cantabria

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## Abstract

The tourism sector requires a standardized framework to define, evaluate and modify strategies, balancing environmental and socio-economic value. Results should provide tools that incorporate both consumers and public managers in the decision-making process. To achieve these results, it is necessary to include Life Cycle Assessment (LCA) methodologies such as the Carbon Footprint (CF) to promote the circular economy in the tourism sector, as well as scientific and methodological innovation and eco-labelling. In this scope and considering that the tourist attraction in the study is the pilgrimage (religious tourism), the main goal is developing a sustainable integrated model by assessing the impact of a hostel on the Camino Lebaniego in the region of Cantabria (Spain). The carbon footprint obtained in the study is 7.73 kg $CO_2$-eq/pilgrim overnight stay where the management of the municipal solid waste and the electricity consumption produce more than 78% of the total impact. These results lead to a high impact associated with municipal waste generation and excessive electricity use as well as a huge amount of greenhouse gases emissions which are avoided by means of the introduction of good practices and environmental commitments with the pilgrims themselves.

## SDEWES2021.0267

# Influence of Surrounding Buildings on Roof Mounted Renewable Energy Installations Using Fluid-Structure Interaction Modelling for Typhoon Resilience

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## Abstract

The Western Pacific region is frequented by strong typhoons for the past years. The Philippines a developing country in the same region with a population of 110 million has been hit hard the most with an average of 20 typhoons every year. In 2020, 4 typhoons have hit the country in a span of one month causing massive flooding and infrastructure damage due to high-speed winds. Blackouts or power outages are common in the aftermath of the typhoon as the electric posts and substations suffer significant damage because of strong winds. Installation of roof mounted renewable energy systems such as PV systems can alleviate the blackout problem by providing backup power in situations where the power grid fails. However, damage surveys show extensive roofing damage evident in most detached structures attributed to strong winds where majority of solar PV systems are mounted. Thus, there is a present need to evaluate the current configurations roof mounted PV systems and its structural integrity for it to properly respond to extreme environmental events in the future. Previous studies have demonstrated the use of Fluid structure interaction (FSI) and Computational fluid dynamics (CFD) on solar PV systems on an isolated low-rise building. Low- income communities are usually composed of unplanned cluster of buildings which has a significant effect on the wind-structure interaction on the houses. This study will investigate this effect on the structural integrity of the Solar PV using the validated FSI method in a rural environment typical in the Philippines. Results show that there is a shielding effect on the first cluster of buildings that can reduce the wind loads on buildings located at the back side of the community. Furthermore, the study showed the weaknesses in the current design considering the roof shape, pitch, structural support, building arrangements and materials. It also showed areas of failure in the panels with regards to different wind angle directions and installation locations. The methodology and its results can benefit the stakeholders (urban planners, Government, and the public) to aim for a better resistant infrastructure and more practical way of assessing building integrated renewables in a community.

## SDEWES2021.0480

# Exergy Based Optimisation of a Poultry Processing Wastewater Treatment Plant

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## Abstract

Poultry consumption is expected to grow by 13% in the period of 2018-2028 implying an increase in wastewater generation during the processing of the meat. Water is essential for the cleaning process areas as well as for certain operations such as scalding, chilling and carcass washing. As a result, significant amount of wastewater is produced. The nutrient ratios are not ideal for biological treatment therefore careful control of the process is required to satisfy the limit values. On the other hand, cost and resource optimisation is an important requirement regarding the long-term profitability of the facility. The poultry processing wastewater treatment plant that serves as a case-study consists of a physico-chemical pretreatment unit and three sequencing batch reactors (SBR) that are controlled by the signals of several sensors to achieve the required effluent quality even if the influent quality is fluctuating. The treated wastewater is planned to be discharged into a nearby river and the sludge is transported for further treatment to another site.

In this manuscript the exergy analysis of the above-mentioned plant is carried out to evaluate different development options from an exergy point of view. The baseline is when the solids from the pre-treatment and the excess sludge is not utilised and the SBRs are operated at a fix time schedule, regardless of the nutrient load. Then the exergy is calculated for different influent concentrations that result in changes of the aeration period and possibly in the increase of the total cycle time, depending on the sensor signals. Another scenario is when the chemical exergy of the sludge is utilised in an anaerobic digester. The last version the paper considers is when further treatment units are installed to make the effluent wastewater suitable for irrigation purposes. The different scenarios are evaluated and ranked based on their exergy efficiency to identify the sustainable options for further development of a poultry processing wastewater treatment plant.

## SDEWES2021.0515

# The Interaction of Environmental Systems and Human Development in a Time of Wild Cards. A Big-Data Enhanced Foresight Study

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## Abstract

Environmental systems and human development are closely connected and impact each other in many different ways. Economic geographers, anthropologists, environmental scientists, and human development specialists have varied opinions on the nature of their interlinks and mutual influence. The study is focused on the global trends and factors of integrated interaction between environmental systems and human development and face common challenges, including climate change, pollution, limited funds for capital investments in green technologies, and challenges for public education and healthcare. This foresight study encompasses a combination of quantitative (big data analysis) and qualitative (expert) methods. This approach allows for a systemic vision of changes and challenges, assessing their probability and impact. The outcomes of the study include the list of global environmental and human rights trends and factors classified by STEEPV categories, their effects that split into opportunities and threats, and an assessment of their mutual impact. Policy implications focus on possible areas of intervention for sustainable growth.

## SDEWES2021.0815

# The Potential of a Guiding Image for River Restoration Efforts: a Literature Review

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## Abstract

Some proposals for river restoration aim to recover the environmental quality by recognizing the perspective of ecologically and socially conscious practices for water management. They are generally based on four pillars: improvement of river ecosystems; improvement of water quality; reduction of hydraulic risk; and geomorphological recovery, all while encompassing socioeconomic objectives. Several projects associating the concept of an ecologically conscious and feasible design with urban resilience have been developed globally. To discuss and identify their successful development, we analyze the integration between the concepts of river restoration and guiding image as a methodological tool to set and communicate goals and contribute to the system's resilience. As a result, we focus on two issues: thematic trends of scientific research worldwide and engineering approaches over the past 20 years – since the publication of the European Water Framework Directive in 2020, which established the need to determine a reference for restoration. The research was conducted based on the mentioned conceptual integration and subsequent questions such as: What themes have been studied the most in recent years? What kind of approach is being applied and for what purpose? This is the first step of a wider study that aims to understand the importance of creating a guiding reference image for carrying out ecological restoration of degraded watercourses. A systematic review is used to identify, evaluate, and interpret all available relevant research. The review was carried out with the support of the open-source VOSviewer software. The results showed a lack of consensus regarding terms, but not between approaches; as well as discontinuity of the expression "guiding image" in the publications that followed its conception. The temporal analysis of the studies also showed the insertion of countries in the discussion and assisted the selection of three case studies for further analysis: two river corridors in South Tyrol, Italy; the Kissimmee River in Florida, United States; and the Hunter River in New South Wales, Australia.

SDEWES2021.0901

# Effects of Barriers Removal on River Ecological Status: the Tagus River Basin as a Case Study

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## Abstract

One of the main pressures suffered by rivers is the presence of barriers. Dams, weirs or ramps are among those structures, leading to environmental impacts such as fragmenting the river ecosystem and causing the disruption river continuity. They have a negative effect on hydromorphology, on physic-chemical water quality and on the diversity and abundance of biological communities.

To achieve EU Water Framework Directive requirements, removal of barriers can contribute to reaching a good ecological status in rivers, reverting their impacts on water quality. It may favour the restoration of the biological communities and the natural hydromorphological conditions due to the recovery of the river longitudinal continuity. River basin authorities across Europe consider barrier removal an imperative measure to address. Particularly, the Tagus River authority in Spain lists it as the second topic of importance for the implementation of the next revision of its plan.

The main objective of this work is analysing the impacts that river barriers removal has had in the ecological status of the rivers at the Spanish section of the Tagus River basin. A thorough data collection has been carried out in several public administrations websites and official reports, locating those barriers that have been removed. Then, streamflow and water quality data (biological, chemical, physic-chemical and hydromorphological) has been explored to select those barriers having data downstream and with availability before and after the barrier removal.

As a result, 24 barriers removed from 2005 were identified, but only in 10 of them – which can be grouped in five study cases – there are streamflow and water quality data to assess the impact of their removal. Results show that most of the river sections did not experience significant variations in quality indicators before and after barrier removal, consequently not showing a shift in their ecological status. In principle, this lack of change cannot be attributed to other anthropogenic factors or natural fluctuations either.

It can be concluded that, despite a significant impact of barriers removal in the rivers' ecological status has not been observed, it could contribute to the recovery of the ecosystem, improving river continuity and allowing fauna mobility. This work reveals the need of addressing exhaustive monitoring before and after barrier removal and focusing further efforts in those barriers that might cause larger impacts.

## Thermal power plants/District heating and/or cooling

## SDEWES2021.0341

# Assessing the Techno-Economic and Environmental Sustainability of Sludges Waste Management in the Italian Contest

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## Abstract

An innovative process layout for sludges waste management is analyzed in this work with the aim to promote the integration among chemical looping combustion, hydrogen production by renewable-energies-driven water electrolysis, and methanation. The core of the proposed layout is a multiple interconnected fluidized bed system equipped with a two-stage fuel reactor, fed with different sludges waste collected in Italy and using CuO supported on zirconia as oxygen carrier, coupled to a methanation unit entailing a series of adiabatic fixed bed reactor with inter-cooling, water condensation at the exit of each reactor, and product recycle. Performances of the system were evaluated by considering that flue gases coming from the fuel reactor, after purification and mixing with a pure hydrogen stream coming from an electrolysis cells array, reacts in the methanation unit over Ni supported on alumina catalyst. The environmental burdens of the proposed process were quantified using Life Cycle Assessment methodology. Furthermore, a hotspot analysis identified the most critical steps of the process. Finally, the environmental performances of the proposed system were evaluated by comparison with a reference system that includes the conventional waste management pathways and methane production.

## SDEWES2021.0546

# Analysis of Steam Turbine Operation in Cogeneration with Extremely Low Steam Flow

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## Abstract

Technological ecological environmental protection regulations are increasingly inclined to cleaner energy production, for which older thermal power systems are forced to adapt production to newer stricter regulations or otherwise to discontinue production. Adapting production to cleaner production is closely linked to high investment costs. In order to rationalize costs and to maintain the existing plant, we analysed the operation of the steam turbine in cogeneration with extremely low flow of input steam into the turbines. By replacing coal technology of steam production with gas technology, the production of steam that will power the existing steam turbine will be significantly reduced. The existing coal-fired boiler will replace the heat recovery steam generator, which will use the heat of the exhaust gases from the gas turbine, while the nominal amount of steam entering the turbines will be reduced from 50 kg/s to 15 kg/s. The steam turbine operating in cogeneration for the production of electricity and heat must also maintain the required quality of steam leaving the turbine at the turbine extractions. This steam is used for industrial needs and district heating of the city. The steam turbine operating in cogeneration is in fact a control element that, depending on the energy needs, optimally distributes the steam flows and thus also the energy flows through the turbine. The analysis shows that the operation of a steam turbine in cogeneration at extremely low flow is possible but the useful efficiency of the thermodynamic transformation of steam in the turbine deteriorates sharply. The poorer useful efficiency of thermodynamic transformation is reflected in the changed quality of the extraction steam. The quality of the extraction steam deteriorates to such an extent that it does not meet the required quality. When the turbine operates with an extremely low steam flow, the pressure is greatly reduced and the extraction steam temperatures are greatly increased. Adequate quality of the extraction steam from the turbine can be ensured by changing the regulation and the extraction point.

## SDEWES2021.0720

# Decarbonization Potential of Integrating Industrial Excess Heat in a District Heating Network: the Portuguese Case

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## Abstract

This paper assesses the decarbonisation potential of utilizing industrial excess heat to meet the baseload heating requirements of a district heating network (DHN) located in the Portuguese capital. It performs an economical comparison between two integration procedures: (i) extending the pipeline to the excess heat source; and (ii) using a continuous string of portable thermal storage modules.

In this scope, this work assesses the integration of the excess heat from a municipal waste-to-energy plant located 5km from a district heating and cooling network and the decarbonisation potential achieved by meeting the baseload heating requirements of the DHN. For the characterization of excess heat and economic analysis, the EMB3RS platform was used. The analysis showed that laying out a new pipe route was more economically feasible (with a levelized cost of heat of 17,25€/MWh), meeting the baseload consumption with a decarbonisation reduction potential of 30%. The higher levelized cost of heat (LCOH) of the portable thermal storage solution is mainly due to the high daily replacement cost for the thermal stores.

## SDEWES2021.0722

# CO2 Capture from Ambient Air and Methanation: a Modelling Study of the Integrated Process

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## Abstract

Negative-emission technologies, such as direct air capture (DAC), are largely investigated to better control atmospheric $CO_2$ concentration driving global warming. In this work, an integrated process using the concentrated $CO_2$ stream after DAC and a pure $H_2$ stream from $H_2O$ electrolysis to produce $CH_4$ has been proposed and numerically investigated. The system relies on packed bed reactors for both $CO_2$ capture and methanation. $CO_2$ capture was modelled by considering CaO as sorbent, whereas the methanation unit by considering adiabatic reactors with Ni-based catalyst. A comprehensive study on the overall system performance has been performed assuming a $CO_2$ capture target of $1\times10^3$ tons per year. Model computations suggest that roughly 212 in-parallel reactors (0.7 diameter each) are required for a continuos operation. The power demand of the different components ranges within 0.1–29 MW. The methanation process requires the use of at least three in-series reactors and, in phase with the calcination step, yields a gas stream with a flow rate of 500 kg $h^{-1}$ and a $CH_4$ molar fraction of nearly 91%.

## SDEWES2021.1067

# Optimal Investment Analysis for Heat Pumps and Nuclear Heat in Decarbonised Helsinki Metropolitan District Heating System

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## Abstract

Decarbonisation of district heating and cooling (DHC) system in Helsinki metropolitan area (including cities of Espoo and Vantaa) requires investments in new energy technologies and approaches to replace coal and natural gas fired district heating (DH) production capacity. In this study, investment paths involving (a) DH heat pumps (HP) from lower quality heat sources and (b) small modular nuclear reactors (SMR) are compared by utilising investment analysis based on optimisation model of metropolitan DHC system depicting the assumed 2030 situation in terms of policy and capacity development. Investment and scheduling model based on open source Backbone modelling framework is used in the analysis. Issues with SMR technology concern regulation and availability of novel technology, whereas good quality heat sources for heat pumps, e.g. excess heat from waste water treatment and data centres have already been utilised and the analysis focus on still available large heat sources from ground, water, air, and remote industrial sites. Several scenarios, with varying assumptions concerning existing DHC system, investment costs (CAPEX) and electricity prices, are analysed in terms of new capacity and total annualised costs. The scenario results indicate that the SMR based investment option is more cost-efficient than the HP option with the model assumptions. Evidently, biomass fired boiler investments, enabled in both options, are preferred to heat pump investments in most scenarios. The cost-efficiency of heat pump investments is strongly sensitive to investment cost, whereas SMR investments are relatively stable subject to CAPEX variations. Furthermore, varying electricity market prices affect especially cost-efficiency of large-scale heat pumps, and investments in SMR cogeneration units appear merely with high electricity prices.

## SDEWES2021.1071

# Systematic Mapping of Heat Sources in an Urban Area

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## Abstract

Increased use of heat pumps to utilize low-temperature excess heat sources and natural heat sources will undoubtedly be a part of future emission reduction measures in district heating systems and within the heating sector in general. Being able to identify these heat sources and to assess their heat potential is essential for utilization.

In this study different methods for estimating the heat potential of excess heat and natural heat sources found in the urban environment are presented. The presented methodology is based around publicly available or otherwise easily obtainable data to improve its replicability. The techno-economic feasibility of heat utilization is not considered, but the research aims at a method that could produce data accurate enough to support decision-making on a district heating company level, i.e. data that enables meaningful techno-economic feasibility assessments.

A wide range of potential heat sources in urban environments were identified and discussed in a literature review. Identified excess heat sources include industrial processes, buildings, refrigeration equipment and infrastructure, as well as sub-categories of these. Identified natural heat sources include solar radiation, water bodies, geothermal heat, and ambient air, as well as sub-categories of these. Methods for estimating the potential of the identified heat sources were developed based on findings of the literature review and the data expected to be available.

The developed estimation methods were applied in a case study where the potential of heat sources within the Turku area in southwest Finland was estimated. Heat sources available in the area were identified, and relevant data was obtained. The potential of each heat source identified in the area was estimated using the presented estimation methods and the obtained data.

The results of this study show the potential of the heat sources in the studied area. The difficulty of obtaining raw, high-quality data is also highlighted. This emphasises the need for advanced processing of available data and insight on the related sources, e.g. building management systems or industrial processes. The methods presented in this study give a good overview of the available heat potential and can be used as a base for further detailed techno-economic studies for utilizing the heat available in an area.

## Transport management

## SDEWES2021.0571

# Retrofitting Fuel Stations with Charging Infrastructure to Accelerate the Electrification of Transport

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## Abstract

With the increasing electric vehicle (EV) penetration, there arises an immediate need for charging infrastructure. In future, the electrification of transportation will reduce the requirement of existing fuel stations, thereby rendering them obsolete. In this paper, we propose a novel methodology to assess the techno-economic feasibility of retrofitting an existing fuel station with EV charging infrastructure. We design scenarios with various configurations of EV charging infrastructure (also known as Electric Vehicle Supply Equipment (EVSE)) and Battery Energy Storage System (BESS) and calculate the NPV and IRR for the designed configurations. The potential of integrating EVSE with BESS while retrofitting existing fuel station to reduce the grid connection costs, is studied. The proposed methodology is implemented for the UK as a case study. From the results, it is observed that the configuration with 4 EVSE, 1 BESS and 8 hours of operation is economically viable. The proposed methodology indicates that though the connection cost is the dominant factor affecting the feasibility, use of BESS can reduce the connection cost by almost 90% depending on the capacity of BESS. The methodology acts as a decision support tool to select a techno-economically feasible configuration of EVSE and BESS.

## SDEWES2021.0788

# Energy Economic and Environmental Challenges for Urban Mobility: the Case of Vienna

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## Abstract

Many cities have set goals for a low-carbon future, including Vienna, which aims to reduce its GHG emissions until 2050 by 80%. The problem is that mobility is still fossil fuels dependent and largely car-oriented with limited alternative solutions.

The major goal of this paper is to analyse historical development of the energy use in the transport sector in Vienna, as well as development of the resulting GHG emissions. It is of interest to analyse development of the modal split over time, as well as reediness to use public transport and alternative automotive powertrains such as different types of electric vehicles.

Different mobility indicators are evaluated. Moreover, policy framework implemented, as well as policy targets set for the future will be comprehensibly documented. Using “TransLoc” model different future scenarios are derived and evaluated.

## SDEWES2021.0825

# Electrification of Maritime Transport Through Integration of Battery-Powered Electric Ships and Renewable Energy Systems

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## Abstract

Batteries are progressively emerging in the maritime transport as a promising alternative to replace conventional power systems. Integration of battery-powered electric ships and the increasing penetration of renewable energy sources in the power sector are gradually striving to decarbonize maritime transport. Various studies have shown that maritime transport has a relatively high potential for $CO_2$ emissions reduction through utilization of battery-powered electric ships, due to shifting programmable consumption from fossil fuels to electricity. However, increased number of battery-powered electric ships could become a major energy load in isolated smart energy systems if the energy for battery recharging would come from mainly renewable energy sources. The objective of this research is to explore the opportunity batteries and their integration in ships offer in the framework of renewable-based isolated smart energy systems. A method for modelling supply of a particular battery-powered electric ferry is presented, whose batteries are recharged from excess energy produced by local renewable energy sources. In this study, the impact of electrification of a particular ferry line is assessed, considering the renewable-based isolated smart energy system, by using EnergyPLAN software. Case study results confirm that ship electrification can lead to significant reductions in operation costs and life-cycle emissions, especially with ferry lines with relatively lower installed capacity, overall distance and travel duration.

## SDEWES2021.0835

# Environmental Efficiency of High Capacity Transportation in Roundwood Trucking in Finland

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## Abstract

With “Roadmap for moving to a competitive low carbon economy in 2050” the European Union is seeking for cost-efficient solutions and methods to create the European economy less energy-consuming and more climate-friendly. Finland’s long-term energy and climate strategy lays out scenarios and impact assessments concerning the national carbon neutrality target set for 2035 and developments in greenhouse gas (GHG) emissions and removals by 2050. The Ministry of Transport and Communications in Finland has drawn up a proposal for an action plan for eliminating GHG emissions in domestic transport by 2045. Transport produces around one fifth of the total GHG emissions in Finland. One solution for carbon-free heavy-duty transport lies in renewable fuels as well as in high capacity transportation (HCT) (i.e. a maximum total mass of vehicle combination >76 t) vehicles in Finland.

In this study, the potential of the HCT timber truck to improve the environmental efficiency was investigated and compared to the normal timber truck combination of the maximum total mass of 76 t in Finland. The HCT timber truck studied was a maximum total mass of 92 t vehicle combination with the Sisu Polar Timber truck and Weckman trailer including a total of 12 axles. The study material consisted of a total of 1094 loads and further 62,912 tons of timber transported by the HCT 92 t truck and 6391 tons with the 76 t truck. The study data was collected by a long-term follow up study starting in May 2019 and ending in October 2020 in Eastern Finland. The average transportation distances with a loaded truck were 166 and 144 km with the 92 t and 76 t trucks, respectively.

The results indicated that the payloads (in tons of timber transported) of the HCT 92 t truck averaged 28.2% bigger than those of the 76 t truck. The fuel consumption was, on the average, 71.3 liters per 100 km with the loaded HCT truck being 12.6% higher than that of the loaded 76 t truck. Correspondingly, when detecting the fuel consumption with liters per tons of timber multiplied by transported kilometers (L / t×km), the fuel consumption was 13.4% lower with the HCT 92 t truck compared to the 76 t truck. On the basis of the study, we can recommend increasing the numbers of energy efficient HCT timber trucks in roundwood transport. Hence, the lower fuel consumption and further higher environmental efficiency in roundwood transport can be achieved in Finland and Europe.

## SDEWES2021.0942

# Energy Demand of Light Rail Transport Using Driving Cycle and Powertrain Analysis

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## Abstract

The traffic situation in Metro Manila has become more intolerable over the past years as the demand for travel has increased in proportion with its population density. According to Japan International Cooperation Agency (JICA), in 2012, the estimated economic loss is about P 2.4 billion daily. In 2017, the calculated figure rose to P 3.5 billion and is projected to rise to P 5.4 billion a day by 2035. There is thus a need for high capacity and more efficient public mass transport in Metro Manila which may be addressed by rail-based transit modes. However, the current condition and capacity of the Metro's Light Rail Transit Lines (LRT1 and LRT2), and Metro Rail Transit Line 3 (MRT) cannot keep up with the current demand. Aging trains coupled with poor preventive maintenance, and replacement parts that are not readily available are just some of the reasons for the deteriorating performance of Metro Manila's urban rail lines. A consequence of the deteriorating performance is increased energy consumption per passenger-kilometer. This research aims to improve the capacity and energy utilization of light rail transport operations in Metro Manila through a comprehensive analysis of train operating parameters and existing ridership data. The electric powertrain and auxiliary systems were also analyzed to develop an efficiency map. Combining these can provide information on how many trains must be operating at certain windows, how many passengers to let in, and the speed profiles that must be followed to achieve a balance between ridership, reliability, and energy and operating cost.

## Urbanism

## SDEWES2021.0088

# The Interconnectedness of City Sustainability and Climate Change Mitigation

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## Abstract

Comprehensive and objective assessment methods need to be developed to create inclusive, safe, resilient and sustainable cities. Monitoring the evolution of sustainability and well-being in the cities is an important task for researchers in implementing the 2030 Agenda. This research explores and analyzes the climate change hazards, adaptation- and mitigation actions and their implementation in cities located 84 different countries. The climate action co-benefits supporting the achievement of sustainable development goals, which is comprehensively integrated in the analysis.

The link between urban sustainability and climate change provides a complex picture of the current situation of cities and the identification of potential areas for development. The proposed methodology allows for comparisons of cities on an objective basis, thus providing an excellent benchmarking basis for decision-makers.

The analyzes are carried out based on the Carbon Disclosure Project (CDP) database, which was supplemented with urban population and Köppen-Geiger climate class data, thus making the 2020 data for 776 cities more interpretable in the developed new context, contributing to further develop the climate resilient planning of world cities.

Based on the analyzes, it can be seen that the occurrence of climate hazards is related to the Köppen-Geiger climate classes and the role of settlement size can also be justified. Cities around the world focus primarily on flood defenses and heat waves, while mitigation sees the potential in energy efficiency and retrofit measures. Cities' actions support the achievement of Sustainable Development Goals, primarily through enhanced resilience and enhanced climate change adaptation.

## SDEWES2021.0089

# The Future Health-Related Challenges in Urban Environments Caused by Climate Change

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## Abstract

Climate change can cause multiply potential health issues in urban areas, which is the most susceptible environment in terms of the effects of the presently increasing climate volatility.

Since the majority of global human populations live in urban areas, the health risks should be revealed and adequate adaptation strategies have to be developed. In this study, the projected July near-ground ozone concentration changes, the alterations of heat-related total mortality risks, the future increase of the relative campylobacter and salmonellosis incidences and the potential generation numbers of an invasive mosquito and a malaria parasite species were modelled in a medium-sized Hungarian city. As realistic adaptation strategies, the different level of the greening of the city were concerned with the combined impacts of climate change and the urban heat island effect. The model results show that individual health indicators respond to temperature changes with increasing values, but not to the same extent. It was found that although the impact of the establishment of pocket parks lags behind the impact of large parks, the establishment of a large number of small green areas can still contribute notably to reducing the impacts. Another important finding of the study is that it is not the type of health factor but its climate sensitivity that determines the extent to which it responds to temperature rises and how effective greening strategies are in addressing the expected problem posed by the factor.

## SDEWES2021.0634

# Mapping Heatwave Vulnerability - Case of Budapest, Hungary

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## Abstract

Budapest, the capital of Hungary, will face significantly changing weather patterns in the near future, which poses its almost 2 million inhabitants to a more vulnerable condition regarding heatwave-related issues. The average amount of per capita green area is cca. 5 $m^2$; therefore, the rising temperature can be defined as one of the most significant climate-related risks in the city. The well-documented urban heat island effect occurring nowadays in Budapest is projected to increase due to the change climate conditions; consequently, a heatwave-related vulnerability assessment is unquestionably needed to define the best adaptation options. After revising the existing literature, it became apparent that qualitative analysis of different urban climate adaptation issues is one of the most actively studied areas in the international literature in the last decade. However, these analyses are often lacking from the Hungarian case studies and publications, except for some studies focusing on the urban heat island phenomenon without paying parallel attention to socio-economic perspective and changing land-use patterns. As the analyzes cover only a narrow topic area, they are particularly selective for the indicators used; nevertheless, the present research aims to synchronize widely available statistical data and related land use values to develop a unified evaluation methodology. The primary analysis aim of this research is to assess the heatwave-related vulnerability on a district-scale by using socio-economic indicators, remote sensing values, and land use characteristics from 2006, 2012, and 2018, respectively. Expected results may contribute to revealing spatial and temporal dynamics of heatwave vulnerability in the districts of Budapest; thus, relevant planning-related outputs can be defined. Since the Hungarian context is rarely studied, this research aims to fill the existing scientific gap and widening the existing literature by analyzing one of the largest cities from the Central and Eastern European region.

## SDEWES2021.0653

# Heating and Cooling Demand Assessment with European Legislation, Degree Days Approach and Gis-Based Tools. Climate Change Impact on Demand and Retrofitting Benefits in Mediterranean Case Study

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## Abstract

Energy planning plays a key role in the development of sustainable and resilient cities. One of the main parts of this analysis is the assessment of the building energy demand, especially the heating and cooling necessities.

The objective of this work is to analyse the heating and cooling demand of a Mediterranean district (València, Spain) and to study its response to global warming. In order to carry out the study, the procedure for calculating the energy needs of heating and cooling found on the European standards has been used, in combination with the degree days method. Geometric information has been collected from cadastral and satellite data obtained with GIS-based technologies. The diagnosis of the current state of the district energy demand is presented, as well as the improvement potential of retrofitting by type of building, zones and age of the construction. The impact of global warming on these parameters is also evaluated.

## SDEWES2021.0881

# Role of People-Participation in Sustainable Development at Local-Level in Indian Context

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## Abstract

Sustainability (ability to sustain) is an important parameter in planning and it can be considered in a much more specific manner at the local-level as these are building blocks of the cities. One of the key parameter to achieve sustainability is the local level participation. People Participation is considered as important component for Sustainable Development. Current literature suggests that lack of people-participation is one of the key reasons for non-implementation of Sustainable Development Goals (17-SDG's, 2015). Goal-11 is directly linked with my research topic whose aim is- To study the avenues of People-Participation in Sustainable development at local-level in Indian context.

This Research paper included the study of Sustainable Development at various levels but focused on local-level and role of human behavior and comfort into sustainability at local-level with respect to different criterias for sustainable measurement tools at same level.

Sustainable development is a challenging social process. The different objectives of society - social, economic and environmental - need to be integrated where possible, and traded-off where they are incompatible. Institutional and individual roles and responsibilities have to change, so that new patterns of behaviour will foster sustainable development. These challenges demand new approaches to decision-making and action.

Individuals efforts can greatly contribute towards advancing the sustainable development goals. We are often faced with the doubt of how we can positively influence our sustainable development behavior, it is necessary to understand that the problems that affect sustainability are not restricted to large companies, in one way or another we all contribute to our grain of sand.

The solutions to the problems that affect sustainable development should not be limited solely to the policies, strategies and standards designed and established in companies.

Although they seem insignificant, our individual actions can contribute significantly and positively to sustainability, our commitment and awareness is needed to achieve truly sustainable development.

At Developing Our World, we present a set of measures that we must contemplate to contribute to this very important cause.

**Reduce (not waste resources)**

- Reuse everything you can
- Recycle
- Use technologies that respect the environment and people
- Contribute to education and citizen action

- Participate in socio-political actions for sustainability
- Evaluate and Compensate

"Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCED 1987, p8)

There is a need for better links between theory and practice.

## Waste and wastewater treatment and reuse 1

### SDEWES2021.0160

# Water Reuse and Water Utilities: an Economic Framework

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## Abstract

Concerns for water scarcity are pushing academics, operators and regulators to consider alternative solutions such as water reuse. Both non-potable (i.e. irrigation, industrial, urban services) and potable applications are feasible, although the latter are more controversial due to health and social acceptance concerns.

Water reuse diffusion may yield environmental and economic advantages. Yet, it is hampered by inadequate standards harmonization and policy support.

Water utilities - urban water operators - are key stakeholders in water reuse projects. Their wastewater treatment plants are a major supply source for reuse and their profits and strategies are deeply affected by the diffusion of reuse.

We contribute to research by filling two research gaps:

- RQ1. What is the role of water reuse schemes in the urban water system?

- RQ2. Which conditions make reuse schemes economically sustainable for the utility?

To address the first question, a framework modelling the water reuse system was developed along three dimensions:

i. Reuse loop topology (reuse water source and destination)

ii. Effluent quality (basic reclamation or potabilization)

iii. Reuse technology owner (investor)

To address the second question, after a review of policies adopted in Europe to incentivize utilities, an analytical model of the utility's operating profit variation caused by major reuse patterns was built. The model builds on data from a water utility in South Italy, an area subject to frequent water shortages.

Results show that water reuse technologies may be per se economically unsustainable. Despite cost savings in urban water operations, adoption is made unprofitable by the cannibalization of urban water revenues and costs of installing and operating such technologies. However, two contextual conditions enhance the economics of reuse adoption for water utilities: i) very disperse users, which raise urban water operating costs; ii) regulatory measures – stricter quality targets on wastewater releases and allowance of reclamation costs into urban water tariffs, acknowledgment of reuse costs as ERC, earning sharing clauses on reuse profits.

In conclusion, utilities, as central actors of the system, may slow down water reuse technologies diffusion due to economic concerns. Nonetheless targeted policy measures and appropriate context characteristics could re-establish the utilities' incentives to invest in reuse technologies.

## SDEWES2021.0214

# Experimental Investigation on Thermal Decomposition of Waste Materials Under Different Conditions for Oxy-Waste Incineration Technology Development

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## Abstract

The oxy-waste incineration is one of the carbon capture technology that consists of waste combustion in oxygen and recycled flue gas atmosphere. As a result, the partial pressure of $CO_2$ in generated gas is high, and thereby the flue gas is quasi ready for sequestration. Moreover, taking into account that about 50 percent of the carbon contained in waste has a biological origin, the total $CO_2$ emission will be negative. Thus, application of this technology in the industrial sector will cause the reduction of $CO_2$ in the atmosphere and mitigation of climate change. This study presents the results of an experimental investigation on thermal decomposition of different types of municipal solid waste under various conditions using the vertical tube furnace equipped with a gas analyser based on chromatography. The obtained experimental data can be used for further development of oxy-MSW combustion.

The oxy-waste incineration is one of the carbon capture technology that consists of waste combustion in oxygen and recycled flue gas atmosphere. As a result, the partial pressure of $CO_2$ in generated gas is high, and thereby the flue gas is quasi ready for sequestration. Moreover, taking into account that about 50 percent of the carbon contained in waste has a biological origin, the total $CO_2$ emission will be negative. Thus, application of this technology in the industrial sector will cause the reduction of $CO_2$ in the atmosphere and mitigation of climate change. This study presents the results of an experimental investigation on thermal decomposition of different types of municipal solid waste under various conditions using the vertical tube furnace equipped with a gas analyser based on chromatography. The obtained experimental data can be used for further development of oxy-MSW combustion.

## SDEWES2021.0387

# Data-Driven Modelling Based on Artificial Neural Networks for Predicting Energy and Effluent Quality Indices of the Wastewater Treatment Plant

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## Abstract

Real time optimization, control and decision making based on first principle models meet difficulties caused by the high computational load and incomplete knowledge of parameters. Data-driven modelling is able to cope with such limitations, while successfully reducing model dimensionality, capturing nonlinearity and simplifying deployment.

The present work aims for energy reduction and effluent quality improvement of wastewater treatment plant (WWTP) operation. This is accomplished by accurate and fast data-driven dynamic models based on artificial neural networks (ANNs).

Time-delay artificial neural network (TDANN), recurrent neural network (RNN), radial basis function neural network (RBFNN) and general regression neural network (GRNN) were employed for the model development. The inputs and targets used for training the ANNs relied on data obtained from a first principle calibrated model, based on municipal WWTP measurements. The set of inputs comprised WWTP influent and control system variables. The outputs of the models were the WWTP effluent variables, such as Chemical Oxygen Demand, nitrate & nitrite nitrogen, total nitrogen, free & saline ammonia and organic nitrogen, to which Aeration Energy (AE), Pumping Energy (PE) and Effluent Quality Index (EQI) inferential variables were added.

The ANNs training results were assessed by the mean absolute percentage error (MAPE) between ANNs predicted and targets of the testing data generated by random variation of the inputs. Compared to the other ANNs, the RBFNNs and GRNNs necessitated about two orders of magnitude less time for model development, making them appropriate for adaptive on-line training. In terms of prediction accuracy, the best ANNs were the GRNNs. They showed MAPE less than 2%, for single output models and less than 10%, for models with several outputs.

The GRNN model was further used to optimize the WWTP operation by finding the optimal setpoint values of the Dissolved Oxygen and nitrites concentration control loops, for minimizing the objective function consisting of the weighted sum of AE, PE and EQI terms. The optimal setpoints were validated by simulation and showed improved energy and effluent quality results.

## SDEWES2021.0393

# Experimental Study of the Ultrasonic Effectiveness Combined with Other Advanced Oxidation Processes in Water and Wastewater Treatment

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## Abstract

Recently, due to some limitations of the conventional treatment processes such as filtration and sedimentation, innovative and novel techniques need to be developed to prevent the discharge of many undesirable, anthropogenic substances into the water environment. Acoustic cavitation which is one of these methods, has emerged as a promising technology in water and wastewater treatment, particularly when the process is combined with other advanced oxidation processes. Furthermore, sonication technology reduces the amount of chemicals that get into the aquatic environment, and thus the risk of secondary water contamination is also reduced. Despite the significant progress in understanding the ultrasonic treatment process, there are still some misunderstandings and gaps related to the mechanisms of pollutants removal and impact of the operational parameters on the process efficiency. Due to that fact, the experiment was performed under various conditions to evaluate the influence of the operational conditions of the process on Bisphenol A (BPA) removal effectiveness. It was observed that parameters such as time of the process, initial concentration of the BPA, pH value, and dosage of the $H_2O_2$ and $O_3$ had a great impact on the treatment efficiency. The experimental results showed that this technique can improve the water quality with high efficiency of BPA removal. After 45 min. of sonication it was 79%. Moreover, the experiment has shown that using ultrasonication combined with $H_2O_2$ or $O_3$ addition can be more efficient compare with using it separately. Therefore, it can be a promising technology in the future in large-scale applications, however, further theoretical and experimental researches are necessary.

## SDEWES2021.0572

# Applications of Waste Materials in the Production of Concrete: a Review

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## Abstract

The aim of this literature review is to identify suitable waste materials that can be used as a partial aggregate or cement replacement in concrete. This is important as the sustainable use of resources is crucial to maintaining and sustaining the environment. Extensive research was conducted in this area using online databases that provided the most up to date information. The research was compiled into this report to create a concise overview of the application of waste materials in concrete. It was found that recycled concrete, plastic, glass and oil palm shell can be successfully implemented in the production of concrete. In some cases, these materials provide beneficial effects improving upon the properties of ordinary concrete. For example, a lightweight concrete can be manufactured using oil palm shells that is critical in the construction of lightweight structures.

## SDEWES2021.0595

# Medium-Chain Fatty Acids Production from Organic Municipal Solid Waste in the Pilot-Scale Reactor: Effect of Leachate Recirculation and Dilution

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## Abstract

The organic fraction of municipal solid (OFMSW) is a promising potential feedstock for producing medium-chain fatty acids (MCFA) and methane in an acidogenic digestion process, due to its easily biodegradable nature, rich nutrient, availability, and high moisture content. However, the production of MCFAs in presence of some inhibitors is known to be limited in the process. Nonetheless, leachate recirculation and dilution have been proven to increase methane production, but up to now their effect on MCFA production has not been studied yet. Therefore, the purpose of this study is to investigate the effects on MCFA production and hydrolysis during acidogenic digestion of OFMSW by modifying two parameters: 1) leachate recirculation, and 2) dilution. Batch experiments were conducted to investigate the influence of leachate dilution and recirculation in anaerobic reactors. The experiments were carried out in pilot reactors for one year under mesophilic temperature and uncontrolled pH. The experiment results show an improvement in the hydrolysis and degradation efficiency of OFMSW. Furthermore, the results show a high MCFA production rate by using leachate recirculation. Meanwhile, systems with water addition or leachate dilution show apparition of fatty acids with longer carboxylic chains. Concluding, those results clearly demonstrate the significance of the control parameters, particularly leachate dilution and recirculation in enhancing MCFA production.

## SDEWES2021.0844

# An Examination of Covid-19 Impacts on the Australian Construction and Demolition Waste Management and Resource Recovery Industry

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## Abstract

**The COVID-19 crisis has brought unprecedented challenges to many sectors, including housing, building and infrastructure. The Construction and Demolition (C&D) waste management and recovery industry have been affected by this pandemic through a change in waste amount, composition, timing/frequency, distribution and risk, which affects the handling and treatment practices. However, there are limited precedents to assist C&D waste management practitioners to address these pandemic-related challenges. Therefore, this study explores COVID-19 impacts on the Australian C&D waste recycling and construction industry and the practical responses to overcome pandemic-induced challenges. Through a literature review and a series of semi-structured interviews with 27 industry stakeholders, this study established that there is a critical need for leveraging digital technologies, developing business contingency plans, creating coalitions between government and industry, and diversifying supply chains to reduce supply chain risks. This study also uncovered a range of targeted responses and recommendations to deal with pandemic-induced disruptions. Our findings can immediately assist industrial practitioners and government decision-makers in managing the impacts of COVID-19 on the C&D waste management and resource recovery activities.**

## Waste and wastewater treatment and reuse 2

## SDEWES2021.0603

# Thermodynamic Analysis of the Process of Decomposition of Hazardous Waste in Thermal Plasma with the Use of Different Working Media

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## Abstract

Persistent Organic Pollutants (POPs) are long-lasting organic pollutants dangerous to the environment and human health. The most hazardous are polychlorinated biphenyls - PCBs (two phenyl rings and at least one chlorine atom that has replaced hydrogen). A widely known example of environmentally dangerous substances that are resistant to chemical and microbiological degradation in natural conditions are transformers oils. By introducing such hazardous waste in conventional incinerators (with temperatures up to 1200 °C), a significant percentage of PCBs will remain undecomposed. Even if PCBs were decomposed into lower-order compounds, in the process of the flue gas cooling, they could form even more dangerous compounds than the starting hazardous waste itself - dioxins and furans. The paper considers treating this specific type of hazardous waste in low-temperature DC electric arc thermal plasma. For this purpose, a complex mathematical model was developed to define the thermodynamic equilibrium of chemical systems, which primarily relies on the principles of mass action and the minimum of the Gibbs free energy. The analysis included more than a hundred elements and compounds that can occur in the considered temperature range of 1000-6000 K. In addition to the equilibrium chemical composition, the enthalpy of the obtained system in the entire temperature range is determined to consider the possibility of using produced synthetic gas for energy purposes. The conducted analysis shows that from the ecological point of view, the most favorable temperature range of plasma decomposition is between 3500-4000 K, while taking into account the required energy for the process evaluation, the optimal temperature range is restricted by the plasma torch power for the degradation process and it is 2500-3000 K. Developed mathematical model can be used for the improvement of the technological procedure of thermal plasma treatment of PCBs, but also of other types of liquid and solid waste and their mixtures.

## SDEWES2021.0738

# Feasibility Study of an Anaerobic Digestion Plant in a Small Island

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## Abstract

The geographical discontinuity in small islands causes a strong dependence on maritime transport for energy import and waste export. In addition, the European Union and Italy, through various initiatives, have expressed their interest in encouraging and supporting the energy transition in small islands. Therefore, it is important to efficiently exploit local renewable resources, especially biomass, to reduce dependence on fossil fuel imports and waste transport, enhancing a waste product for a circular economy.

This paper investigates the economic, energy and environmental benefits given by the installation of an anaerobic digester in reducing costs, greenhouse emissions and primary energy imports in small islands. Current anaerobic digestion technologies to produce biogas from the organic fraction of municipal solid wastes were analysed to identify the most appropriate in the small islands' context. The island of Procida was chosen as a case study. The annual quantity of waste was given in the national waste cadastre and its seasonal variation was deducted considering the population variation.

Three scenarios were hypothesized for the use of biogas produced:

- upgrading of biogas and injection into the gas grid for the residential sector;
- upgrading and use in the transport sector;
- use of biogas in a Combined Heat and Power (CHP) plant using the thermal power to heat the inlet biomass and for the fast thermal digestate drying.

Although biogas covers just a small part of consumption, it is very versatile and can give its contribution to the diversification and the increasing of renewable energy sources penetration. All the analysed scenarios were compared through multicriteria analysis, considering the primary energy and emission savings and the main economic parameters. The results show good payback times for all of them; this is mainly due to the incentives and also to the significant savings in the maritime transport and disposal of waste on the mainland, deducted from the national waste cadastre. Therefore, through anaerobic digestion on small islands, emissions and annual costs for transport and disposal of waste are reduced and clean energy is produced by exploiting a local waste product.

SDEWES2021.0807

# Perspective on the Use of Tire Waste in Multilayered Acoustic Boards for Civil Engineering Applications

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## Abstract

Increasing amount of waste tires is currently becoming one of the global environmental issues. Increasing demand from the automotive industry for tire production, the lack of appropriate technological development for their disposal, and the fact that such waste cannot be easily decomposed due to the complexity of the involved components, such as natural or synthetic rubber, carbon black, steel and other additives are the main arguments for the need of finding reasonable ways of tire waste re-utilization. In 2017, the worldwide tire demand reached 2.9 billion tons and approximately 1 billion tires were disposed. In 2017 in the Czech Republic, about 71 % of waste tires corresponding to 36 thousand tons were mainly stored, incinerated in cement plants, alternatively used within the production of asphalt or used as a filler for cement-based composites. Taking into consideration the good weather resistance of rubber-based materials, other meaningful applications can be sought, such as the utilization of tire waste in construction elements used for acoustic protection of residential areas against intensive car or train transport. The paper focuses on the acoustic characterization of multilayered tire waste boards based on a crushed rubber granule outer shell and the core consisting of other minor tire waste components, such as tire fluff, rubber mulch or micronized rubber powder. Acoustic properties of the 14 designed boards (2 reference boards without the core) represented by the frequency-dependent sound pressure level decrease were determined in the frequency range 50 Hz – 5 kHz and 1/3 octave resolution using small-sized acoustic chambers. It was observed a significant improvement of the acoustic insulation ability of multilayered boards, especially in comparison with the reference board based on rubber granules 1-3 mm (D $SPL_{avg}$ = 8.9 dB). The rate of improvement was strongly influenced by the core composition. The best acoustic performance of low-density boards ($r_v$ < 650 kg/m$^3$) was observed for the board with rubber mulch core (D $SPL_{avg}$ = 18.1 dB). In the case of high-density boards, the best performance was observed for those with hot-pressed fluff core (D $SPL_{avg}$ = 22.2 and 23.6 dB).

## SDEWES2021.0827

# Catalytic Pyrolysis Process for the Valorisation of Municipal Plastic Wastes

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## Abstract

Plastics are synthetic organic polymer materials that, in the end-of-life, have a very negative impact in the ecosystems if they are not recovered and valorised. Approximately 70% of European plastic waste is not being recycled due to technical or economic reasons and are thus sent to landfill (27%) or incinerated (42%). Pyrolysis of plastic waste may have an important role in dealing with the enormous amounts of plastic waste produced all over the world, by decreasing their negative impact on the environment. This waste may be converted into economically valuable hydrocarbons, which can be used both as fuels and as feedstock in the industry. Pyrolysis is a thermochemical process that can be performed in the presence or absence of a catalyst. The use of catalysts can help to improve the homogeneity of the obtained product mixtures and allows softening the reaction conditions and adjusting the product distribution. The work performed was focused on the pyrolysis processes in order to convert plastic mixtures derived from MSW into highly valuable liquids, as well as profitable gases and solid. Two different pyrolysis concepts (thermal or catalytic) were evaluated in order to develop a process in which plastics mix are treated to attain valuable products with the proper characteristics to be used in the alkylation step. Tests were performed in a batch reactor using a mixture containing 30%PE, 60%PP and 10%PS. The choice of this mixture was directed towards the maximization of olefins and aromatic contents in the liquid product. These compounds are fundamental for the success of the alkylation step, and the ratio of olefins/aromatic should be approximately 1. As in thermal pyrolysis, these values were difficult to obtain, several catalysts were tested (Zeolites, FCC, Co-Mo) to access their influence on product yields and especially on liquid composition. After each experimental test, all gaseous hydrocarbons were collected for direct analysis by GC and the light liquids were analysed by GC-MS and by GC-FID to quantify their main compounds. Solid products were also anaysed. It was observed that the use of catalysts increased the aromatic compounds. Also, a more favorable liquid composition was observed at lower temperatures and reaction times.

Acknowledgments

This work was carried out within the scope of the project i-CAREPLAST. This project has received European Union's Horizon 2020 research and innovation funding under grant agreement Nº 820770.

## SDEWES2021.0910

# Quantifying the Nitrogen and Phosphorus Fertilizer Value of Latrine Dehydration and Pasteurization (Ladepa) Machine Processed Sludge

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## Abstract

Decentralised wastewater treatment systems are considered as an alternative to centralized wastewater treatment methods for sustainable wastewater management in smaller communities. Municipal wastewater sludge from decentralized wastewater treatment plants and pit latrines are expected to be further processed to eradicate pathogens and stabilise the sludge employing certain techniques, such as latrine dehydration and pasteurisation machine (LaDePa). LaDePa is a decentralized approach where a LaDePa machine is used to process emptied domestic sludge into dried and pasteurised pellets, which can be used as a soil fertiliser. This study aimed to determine the nitrogen and phosphorus fertilizing value of LaDePa processed sludge. To achieve the stated aim, nitrogen mineralization and phosphorus release studies were conducted under controlled laboratory conditions (employing both leaching and non-leaching methods) and on the field. The laboratory study was conducted at a constant temperature room set to 26±1 °C. The field study was conducted both under rainfed and irrigated fields at a long-term field trial, employing ceramic tubes and fibre bags. Soil and sludge samples were analyzed for total N, inorganic N, total P, and plant available P using Carlo Erba, steam distillation, and Bray-1P, respectively. The total N (2.64%) and P (4.52%) content of LaDePa sludge were within the ranges reported for sludges of various origins reported around the world. The organic fraction of the N from LaDePa sludge accounted for 95% of the total N, where 11-25% was mineralized during field and laboratory incubation periods of 93 and 120 days, respectively. The nitrogen fertilizer value of LaDePa processed sludge, as defined by mineralization studies, is lower than sludges and biosolids of various origins as reported in the literature. This is mainly attributable to a combination of the lower nitrogen content and relatively lower mineralization rate. Plant availability of P from LaDePa sludge (100-200 mg $kg^{-1}$) was within the ranges reported for biosolids. This is attributed to the relatively lower nitrogen content of LaDePa processed sludge and its slightly lower mineralization rate. Further study is recommended employing fresh LaDePa sludge of various origins to quantify the corresponding N and P fertilizer values.

## SDEWES2021.0948

# Degradation and Mineralization of Ibuprofen by UV/persulfate Oxidation Process in Batch and Continuous Plug Flow Reactors

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## Abstract

The occurrences of human pharmaceutical drugs are widely observed in various waterbodies and cause high considerations of public as emerging pollutants in our environment. Ibuprofen is one of the above mentioned drugs widely detected in various waterbodies. In this study, UV/persulfate advanced oxidation process is performed in both batch reactor and continuous plug flow reactor setups to degrade and mineralize synthesized Ibuprofen wastewater. The experimental setups are equipped with 14W and 30W intensity low pressure UV lamps and various numbers of 0.5 cm annular gap cylindrical stainless steel reactor with 30 and 60 cm in lengths. The operating parameters such as reaction time, persulfate dosage, initial pH, coexist of scavengers are investigated to evaluate their effects on Ibuprofen degradation. The results demonstrate that the UV/persulfate process is a powerful technology for treating Ibuprofen wastewater and is also capable to mineralize total organic carbons (TOC) under suitable conditions. The UV irradiation alone can photo-degrade Ibuprofen up to 41% with various residence time. The degradation behavior of Ibuprofen presents pseudo first order kinetics. The higher the persulfate dosage is applied, the higher the Ibuprofen removal efficiencies can be obtained up to 0.776 mM. The degradation efficiencies for various persulfate dosages from 0.0485 to 0.776 mM are in the range of 51.2 to 100.0% at initial Ibuprofen concentration of 10mg $l^{-1}$.with 3.0 min of residence time in continuous plug flow reactor. For short residence time as 1.5 min, the mineralization efficiency is only 4.0-18.8% based on Total Organic Carbons measurement. The initial solution pH shows affective on Ibuprofen degradation, the best pH value of acidic pH 3 presents the fastest reaction and best TOC removal as well. The Ibuprofen degradation kinetic curves obtained from batch reactor tests can be used to verify the degradation efficiencies of Ibuprofen for continuous plug flow reactor at various residence times in good accuracy. This study demonstrates the feasibility of scale-up the UV/persulfate photo-reactor for treatment of Ibuprofen wastewater.

## SDEWES2021.0963

# Simulation of Technical and Economic Performance for Waste Processing Technologies for MSW in Region of Slovenia and Croatia

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## Abstract

Waste and waste handling are one of the major environmental and energy problems in the 21st century, which is why waste management is of the utmost importance for the most efficient use and the most efficient recovery of energy. Simulation of technical and economic performance for waste processing technologies is a basic requirement for planning a meaningful and effective waste management process in the mechanical biological treatment (MBT) facilities. In the present article, the mixed household waste in Slovenia was analysed by innovative approach. Only a small amount of mixed household waste can be disposed of in landfill and only small amount of the recyclables remains in the mixed household waste stream after sorting at source is achieved. The main residue of mixed household waste is to be converted to alternative fuel in MBT plant. With the use of waste processing technologies, the derivation of the alternative fuels in different varieties is achieved. The shares of alternative fuels of different qualities, derived from the mixed household waste, according to the requirements of the end users were calculated. The quality of alternative fuel is conditioned by the waste-to-energy technology. For that purpose, the waste-to-energy technologies were analysed to determine the input requirements of waste-to-energy technologies to reach the quality of the alternative fuel derived from mixed household waste. For reaching the requirements, different waste processing technologies were presented and valorised according to production costs of MBT technologies. The analysis varied according to origin of the household waste (urban or rural environment). Overall, our analysis and simulation results show that the innovative approach is more effective to understanding the waste management process purpose and environmental strategies of waste-to-energy plants.

## Waste and wastewater treatment and reuse 3

## SDEWES2021.0066

# Simulation of Municipal Solid Waste Incineration in an Industrial Grate Boiler Coupled with an In-House Bed Model and Analysis for the Feedstock Flexibility

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## Abstract

With the rapid development of urbanization, municipal solid waste (MSW) is increasing dramatically. The proper way to dispose the MSW is essential for the environment and society. Among the waste disposal technologies, MSW incineration stands out due to the efficient reduction of solid waste volume and energy recovery. As one of the major MSW incineration technologies, grate-firing technology has been widely applied in industrial boilers, in particular for the lower heating value feedstock. Since it is difficult and costly to investigate the MSW incineration process inside the boiler experimentally, simulation of MSW incineration is particularly crucial to guide and optimize the boiler operation. In order to achieve an in-depth understanding of the MSW incineration and optimize it, we simulate the MSW incineration in an industrial grate-fired boiler coupled with an in-house bed model in this paper. The bed model, which describes the solid wastes conversion processes (i.e., moisture evaporation, pyrolysis, gaseous combustion, char oxidation) on the grate, was programmed by MATLAB. The calculation results from the bed model offer the inlet boundary conditions of the freeboard simulation. The simulation of the fluid flow and secondary combustion in the freeboard was performed via the commercial computational fluid dynamics (CFD) software Ansys Fluent. The freeboard simulation and the bed model were coupled with each other, by the incident radiation heat flux on the fuel bed and the combustibles leaving the fuel bed into the freeboard. The simulation results agreed well with the boiler operation data. After validation, a simulation-based parametric study has been done to investigate the impact of changes in the feedstock, especially in its heating value, addressing the transformation of the MSW feedstock due to the new garbage classification rules implementation in China. The distribution of the primary air and secondary air has been optimized accordingly, as well as the feeding rate of the MSW. Useful guidelines for the boiler operation were derived, tailored to different MSW feedstocks.

## SDEWES2021.0163

# Recovery of Salts from Synthetic Erythritol Culture Broth via Electrodialysis

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## Abstract

Erythritol is an extracellular metabolite produced by osmotolerant microorganisms in submerged cultures. Different carbon sources, salts, and other compounds as peptone and tween 80 are used in culture media. An increase in osmotic stress by the addition of salts is used to stimulate the production of erythritol.

Electrodialysis (ED) is a membrane-based technology suitable for the removal and potential recovery of ionizable molecules. ED uses the electrical potential applied across the ED membrane stack for the separation of ions through cation- and anion-selective membranes.

This work aimed to assess the application of ED for the removal of salts from a synthetic erythritol culture broth and to monitor the behavior of the products during the treatment. The efficiency of removing ions in the diluted fraction, the concentration factor of ions in the concentrated fraction, and the overall losses of products and by-products during the treatment were calculated.

The assessment was developed in three stages, considering an increase in the complexity of the fed solution according to the nature of the compounds. Stage 1 considered only the ionizable compounds in culture broth (macronutrients, micronutrients, and trace elements). Stage 2 considered the compounds used in stage 1, plus erythritol, glycerol, and glucose. Stage 3 considered the compounds used in stage 2, plus tween 80 and peptone, to simulate the spent culture broth.

The experiments were developed in an electrodialysis unit (PCCell GmbH, Germany). The current applied during the process was selected based on the limiting current density (LCD) determined using the Cowan and Brown method. HPLC was used to determine the concentration of erythritol, glycerol, and glucose. The concentration of ions ($Na^+$, $NH4^+$, $K^+$, $Mg^{2+}$, $Cl^-$, $SO4^{2-}$, $PO4^{3-}$) was determined by ion chromatography (IC).

This study assessed the use of electrodialysis (ED) to purify synthetic culture and the recovery of salts, for minimizing the generation of waste by representing an efficient alternative to remove ions, ensuring their recovery process contributing to reaching cleaner standards in erythritol production. ED removed between 91.7- 99.0 % of ions from the synthetic culture broth, with 49-54 % current efficiency. Besides, further recovery of ions into the concentrated fraction was accomplished. The anions and cations were recovered in a second fraction reaching concentration factors between 1.5 to 2.5 times while observing a low level of erythritol losses (< 2 %), with an energy consumption of 4.10 kWh/$m^3$.

In conclusion, ED is a suitable alternative for erythritol culture broth desalination and recovery of nutrients, reducing waste generation, and contributing to reaching cleaner production standards.

## SDEWES2021.0265

# Thermoeconomic Analysis of a Municipal Solid Waste to Energy Plant: Case of Fier (Albania)

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## Abstract

Municipal solid waste nowadays is becoming a global challenge. The increasing amount of waste generation requires a new approach to tackle this problem. Albania, a Mediterranean country is facing this issue equally. Although, in recent years a considerable progress has been achieved, still the country is lagging behind the European standards. In general, the overall progress is slow and the requirements set by the policy and legal framework are not yet met. However, in recent years in Albania there are some developments related to the waste treatment issue. Thus, the government chose the public-private partnership model to operate in the field of waste treatment. Currently a waste firing plant is in operation in Elbasan, central Albania and another is under construction placed in Fier some 130 km from the capital Tirana. This article sheds light to waste to energy practice for the municipality of Fier under the Albanian conditions. The parametric design of the plant and determination of thermodynamic properties are proposed in this study. A thermal analysis of the plant is carried out with the aim to determine the main parameters of the cycle. Additionally it takes into analysis the economic cost and benefits of the incineration plant.

## SDEWES2021.0987

# Valorization of Horticultural Waste and by-Products Through Composting Processes

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## Abstract

The Mobilizing Project BIOMA includes 24 Portuguese entities from the scientific system and agribusiness companies (fruit and vegetables, wine, olive oil), promoting synergies for the development of a sustainable value chain.

The processing of these products generates a significant amount of waste, which in some way, can be valorized as high-quality compost for agricultural use.

In the framework of the BIOvalue task- Solutions for valorization of agri-food waste and by-products – a pilot-scale composting processe was conducted using fruit and vegetables waste provided by the promoter company, CAMPOTEC. The objective of the study was to evaluate the effect of C/N ratio on the quality of the produced compost. Four assays were carried out, in triplicate, with different C/N ratios treatments: C/N=25; C/N=30; C/N=40 and C/N=50. The turning operation mixed the composting materials and enhanced passive aeration. During the mesophilic and thermophilic phases, key parameters were monitored, namely temperature and humidity (monitored by probes), organic matter, total nitrogen and density. After maturation, humic and fluvic acids will be analyzed in order to ensure the compost quality. The survival and growth of Escherichia coli, Salmonella spp. will be also carried out. At the end of this process, it is intended to obtain a series of composts with an indication of their chemical composition and useful life, phytotoxic or allelopathic potential and functional capacity to be used as biostimulants or soil correctives.

With this project we intend to evidence the role of composting in closing the nutrient cycle between industry-agriculture, in the context of the circular economy.

## SDEWES2021.1009

# Sustainable Materials for Resource Recovery from Wastewater in Agricultural Systems

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## Abstract

Nutrients (nitrogen and phosphorous) required for food production are finite resources which need to be protected for securing the future food supply systems. Food demands are on the constant rise worldwide indicating the need for nutrient sources. Agricultural and municipal wastewater effluents contain valuable nutrients which can be recovered and recycled for agricultural application to close the gap between the urban food consumers and rural agricultural producers. Microbial electrochemical systems allow for recovery of nutrients from wastewater sources with concurrent electricity production. There is a strong potential for these systems; however, the electrode and membrane separator components of the process are still expensive. Use of external catalysts and expensive process components is unsustainable. Moreover, for safe recovery and recycle of nutrients, natural and sustainable materials should be developed. This paper presents a detailed evaluation of novel and sustainable materials for the construction of microbial electrochemical systems. Terracotta (an earthly material) and agricultural waste derived biochar materials were used to construct a microbial electrochemical system to enable nutrient capture and electricity generation from the organic substrates present in agricultural wastewaters. Municipal and agricultural (dairy production) wastewaters were evaluated for the potential resource recovery in the novel, sustainable microbial electrochemical systems. The results from this study confirm the beneficial use of sustainable materials for resource recovery applications in agricultural systems.

## SDEWES2021.1010

# Evaluation of Nutrient Recovery Potential of Biochar, Bentonite and Terracotta Materials and Their Performance in Microbial Electrochemical Systems

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## Abstract

Wastewaters originating from agricultural, domestic and industrial processing systems contain large quantities of nutrients (nitrogen and phosphorous) required for food production in agricultural systems. Acknowledging the fact that these nutrient sources are finite, it is essential to develop methods and techniques that allow for successful and sustainable recovery and reuse of these valuable elements. Many biological, chemical, and physical processes are available to accomplish this objective, however, most of them are energy- and cost-intensive and are unsustainable or environmentally unfriendly. There is a pressing need to efficiently recover and recycle these essential nutrients to the source applications such as agricultural fields to ensure circular economy and sustainable development. In this research, we identify sustainable and natural materials such as bentonite soil, biochar and terracotta for the recovery of nutrients from wastewater sources. To understand the potential for these materials in agricultural settings and to identify opportunities for enhancing their adsorptive capacities, we have conducted a series of experimental studies using these materials. Four different types of kinetic models (pseudo 1$^{st}$ order kinetics, pseudo 2$^{nd}$ order kinetics, Elovich model, Intraparticle diffusion model, and liquid-film diffusion model) were evaluated for the determination of rate constants and adsorption capacities. Further, these results were compared with microbiologically assisted nutrient adsorption by these materials in microbial electrochemical system set up. This presentation will discuss the detailed analysis and evaluation and present the potential and application feasibility of these materials in successful applications of agricultural systems to enable sustainable nutrient recovery and circular economy.

## SDEWES2021.1012

# Activated Carbons from Lignocellulosic Agroforestry Wastes for the Biosorption of Hazardous Pollutants from Waste-Waters

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## Abstract

The processing and disposal of different chemicals that are used in many industrial processes, such as dyes, drugs or heavy metals, is becoming a big concern as the legislations get stricter about the potential toxicity of these compound in soil and water environments. Adsorption has been proved to be a successful technique in the treatment of wastewaters as it offers high effectiveness for the removal of toxic compounds even at low concentrations. Chars prepared form different sources (wood, coir, lignite, coal or different types of lignocellulosic biomass) are typically used as adsorbents in these applications. Thus, as a precursor for the production of these chars, the use of lignocellulosic agroforestry waste materials, which are generated in huge quantities in the processing of wood and crops for the food or pulp and paper industries, is an interesting option, available, renewable, local and inexpensive. In this work, different lignocellulosic residues, such as walnut and hazelnut shells or cork wastes have been submitted to a thermochemical process, in particular pyrolysis at 10k/min, 900 ºC, 1 hour, 40mL/min $N_2$, in order to obtain bio-chars, which were subsequently submitted to chemical activation with KOH (1:1, 2 hours, 900 ºC, 20K/min, 20mL/min $N_2$). The biosorption capacity of the obtained ABC was measured by UV absorbance of the methylene blue concentration of a water stream. The obtained results showed that the adsorption efficiencies were deeply dependent on the lignocellulosic precursor physical and chemical properties but also on the thermochemical and activation processes, which were defined to obtain the better results. High effectiveness and complete removal of the measured compound even at low concentrations indicated the good properties of the ABCs for the mentioned purpose. Finally, studies of the separation and recovery of the methylene blue were performed as well in order to be able to close the cycle and design a recyclable process capable of recycling the used adsorbents and recover the dye for further uses.

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## SDEWES2021.0295

# Thermal Degradation and Kinetic Analysis of Multi-Layered Plastics

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## Abstract

Multi-layered plastics are a great challenge for the waste recycling industry. The majority of multi-layered plastics consist of two or more types of polymers, making it difficult to recycle mechanically, which leads to landfill or incineration plant. As a way of thermochemical recycling, pyrolysis is a promising cleaner technology that could use multi-layered waste plastics potential and convert it into valuable products like fuels and chemicals. To better understand the pyrolysis process of multi-layered plastics, thermogravimetric analysis was carried out to determine their thermochemical behaviour and kinetic parameters. Thermogravimetric measurements were conducted in a nitrogen atmosphere at heating rates of 5, 10, 15 and 20 °C/min in the temperature range 40–600 °C. Kinetic analysis was done using the isoconversional model-free Friedman method in combination with an advanced statistical approach. Thermogravimetric analysis revealed how decomposition occurs in the range 350–510 °C and the weight loss >90% indicating high volatile matter content, hence potential for pyrolytic oil production. The results of the kinetic analysis showed how pyrolysis of multi-layered plastics is a complex process consisting of three decomposition stages. The activation energy values determined by Friedman were rising with the degree of conversion from 127 kJ/mol at 0.01 to 219 kJ/mol at 0.95.

## SDEWES2021.0372

# Application of Opoka-Rock in Effective Nitrogen and Phosphorus Management According to Circular Economy

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## Abstract

European Green Deal (EGD) and the Circular Economy Action Plan (CEAP) promote recycling of materials in line with circular economy principles and enhance the value of material flows. Recently, new technologies have been introduced to produce value-added products from agricultural residues and food processing side streams. However integrated approach is necessary for organic waste utilization as environmentally safe product according the bio-economy rules. Recovery material should not pose a risk of surface/groundwater contaminantions.

The so-called opoka-rock is characterized as a transitional rock between carbonate (app. 71%) and those of a silica character (app. 26%). Recently more research is focusing on the new use of opoka-rock: as an additional integrent for organic fertilizer, sorbent for removal from wastewater different contaminations, such phosphorous, iron, or manganese ions.

This study identifies research gaps on how circular bioeconomy can be achieved through application of opoka-rock for improvement of sustainable nitrogen and phosphorous management of poultry manure as safe fertilizer according to EGD and CEAP. Initially, it was found that opoka-rock was able to effective absorb the N and P ions from water solution and then gradual release to environment. Thermal treatment (900 $^{o}$C) increased rapidly sorption capacity of opoka-rock to 100% in the case of phosphorous.

Moreover, the ratio of opoka-rock to poultry manure was optimized to determine of nitrogen and phosphorus release into the solution. The product was characterized by good fertilizing properties - the batch tests confirmed gradually release of N and P to solution with the maximum concentration obtained after 32 hrs equal almost 95% of initial value in mixtures in the case of phosphorous and almost 40%in the case of nitrogen.

Such approach gives opportunity use opoka-rock for improvement of poultry manure as mineral-organic fertilizers in the context of CE. This also allow to control for ions N, P release and maintain suitable pH value of soil environment.

## SDEWES2021.0426

# Valorization of the Depleted Fermentation Substrate of Ganoderma Lucidum Production: Study Case to Treat Wastewater from Coffee Processing in Colombia

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## Abstract

Agro-industrial processes generate a high amount of wastes that can be reused in the productive chain as raw materials. One of the main wastes generated during the production of fruiting bodies of medicinal mushrooms such as Ganoderma lucidum is the Depleted Fermentation Substrate (DFS). This is a porous lignocellulosic material with high biological activity of the fungus and high potential to be in biotechnological processes. Colombia is one of the most important coffee producers worldwide. During conventional coffee processing, about 40 L of highly contaminating wastewater are generated to obtain 1 kg of dry parchment coffee. Several technologies for wastewater treatment have been suggested. However, disadvantages such as high operational costs and large treatment areas make impossible their application in Colombian fields. This work evaluated the degradation capacity of pollutants present in wastewater from coffee processing using the DFS of G. lucidum in bioremediation processes. Three main variables were evaluated: the inoculum of G. lucidum compared to the respective DFS, agitation, and time. Response variables were total organic carbon, reducing sugars, pH, laccase activity and color. The obtained data was evaluated performing a three-way ANOVA. The obtained results corroborate the potential of the DFS for the treatment (29% reduction of reducing sugars, 400% increase of enzyme activity, and pH increase from 3.5 to 5.0) of the wastewater and show the limitations of the study (color removal and pH-organic load reduction tradeoff from the agitation). Research following from this work should focus in longer treatment times to evaluate organic load removal and a more detailed characterization of the system to calculate kinetic models to be used for the design of a bioreactor using the depleted substrate.

## SDEWES2021.0471

# Water Reuse in a Poultry Processing Wastewater Treatment Plant

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## Abstract

The European Union issued a new regulation that sets the minimum requirements of water reuse for agricultural irrigation, and is will be applied from 26th June 2023. The regulation is expected to increase water reuse in the EU but it is less likely to be so without investment in the wastewater treatment plants. Most of them do not have rigorous disinfection or polishing steps installed thus they are unlikely to meet the water quality classes (E.coli <100 number/100 ml) that do not pose serious restrictions on the application of the reclaimed water.

In the wake of circular economy water reclamation should also be considered, especially in water intensive industries such as poultry processing. Its wastewater is nitrogen-rich, and the nutrient ratios are far from ideal for biological treatment. Nonetheless, in case of agricultural irrigation the nitrogen and phosphorous content could be even beneficial for the crops and the amount of fertiliser could be reduced, saving money for the farmers.

In this paper the biokinetic model of a soon to be finished poultry processing wastewater treatment plant is prepared. It comprises of a physico-chemical pretreatment unit and three sequencing batch reactors (SBR). Influent and effluent parameters are taken from the measurements of a laboratory-scale version of the system supported by the information provided by a pilot scale unit using the pre-treated wastewater of an operational poultry processing plant. During the 77-day operation of the laboratory scale system 98.18% chemical oxygen demand, 99.62% $NH_4^+$-N and 91.64% orthophosphate removal efficiencies were achieved from the pre-treated wastewater stream without using external carbon source. The model will be used to assess different operating conditions and the corresponding control settings involving the signals of pH, dissolved oxygen, ammonium and nitrate sensors to meet the limit values for discharge in surface water. Furthermore, additional polishing technologies will be tested in the model to achieve sufficient quality for irrigation and possible reuse options within the processing areas.

## SDEWES2021.0496

# Stability Improvement of Laccase for Micropollutant Removal of Pharmaceutical Origins from Municipal Wastewater

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## Abstract

The expression micropollutant refers to persistent and hazardous materials that are in low concentration (ng/l – μg/l), including substances such as pharmaceuticals, personal care products and industrial chemicals. Pharmaceutical compounds – discharged with treated municipal wastewater – have recently become a matter of increasing concern due to their tendency of bioaccumulation and detrimental effects on the environment. Micropollutants can be detected owing to the development of analytical chemistry but an efficient and economical treatment solution is yet to be installed. Nanofiltration and reverse osmosis could remove these compounds but to the detriment of the water's chemical composition. Physico-chemical and biocatalytic methods are both researched to overcome the issue of discharging organic micropollutants to the environment.

Numerous oxidoreductase enzymes have been shown to be successful biocatalysts of these compounds, with fungal laccase being an example. Large scale application of free enzyme is currently not feasible for the removal of micropollutants that are present in wastewater, partly due to the enzyme losing its stability under a relatively short period. It is therefore desirable to design processes that can increase stability and allow enzyme retention and reuse. Enzyme immobilisation may be very useful in this regard.

In this paper a combination of β-cyclodextrin and glutaraldehyde was chosen to immobilise the laccase under various conditions (varying pH and concentration of the substances) with the aim to improve the stability of the enzyme. A response parameter in the experiments was the laccase activity, which was measured by the conversion 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) substrate. Diclofenac served as a model compound to test the efficiency of the resulting immobilised enzyme.

The efficiency of β-cyclodextrin immobilisation was demonstrated by the fact that although the initial activity of the enzyme decreased slightly after the entrapment, it retained its activity for the longest time, as the rate of decrease in activity in the samples was the smallest over time.

## SDEWES2021.0502

# Analysis of the Zinc Adsorption Properties and Toxicity of Solid Non-Conventional (Biomass) Adsorbents

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## Abstract

Ashes from solar pyrolysis of selected biomass, i.e. waste straw and dried sewage sludge, were assessed as unconventional adsorbents. Comparatively, biomass samples before thermal treatment were also evaluated. The adsorption materials used were characterized on the basis of the determined BET surface area and porosity, as well as the degree of zinc adsorption from aqueous solutions, and SEM pictures which were taken for the ashes. The toxicity of the post-process solutions was also tested using the Microtox® enzyme assay. It was determined that the degree of zinc adsorption depended on the type of biomass from which the ashes were derived. A higher degree of zinc adsorption was noted for ash from dried sewage sludge than from waste straw. It was related to the determined values of the BET surface and porosity of the tested adsorptive materials. However, very good zinc removal effects were obtained with the dried sludge prior to thermal treatment. Toxicity tests showed that the dried sludge before and after thermal treatment caused low toxicity of the post-process solutions, and the waste straw samples in both cases were non-toxic. Acknowledgments

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## SDEWES2021.0637

# Municipal Solid Wastes in Covid-19 Situation – Management and Environmental Studies

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## Abstract

The current COVID-19 pandemic situation and associated restrictions increase the amount of generated wastes. It results from necessity of personal protective equipment application. Thus, the utilization of masks and gloves is a hot topic and requires immediate investigation. The main aims of this work are management and environmental studies of municipal solid wastes (MSW) which are particularly generated during Covid-19 pandemic time. The effective waste management in relation to circular economy was presented. For experimental and calculation studies, sample of refuse derived fuel (RDF) with a high content of plastics. The pyrolysis was selected as a best thermal utilization process for this kind of wastes. The proximate and ultimate analyses were done for RDF and products. Pyrolysis was carried out using a pilot scale reactor with a continuous flow of 250 kg/h at 900°C. Additionally, thermogravimetric analysis (STA) was applied to pyrolysis investigation and showed that the main decomposition of RDF took place in the temperature range of 250-500°C. The pyrolysis gas had contained the combustible compounds like CO (29.7%), $H_2$ (12.4%), $CH_4$ (17.8%) and $C_2H_4$ (13.8%) giving its high calorific value– 29 MJ/m$^3$. Experimental results were implemented for numerical calculations. Chemkin-Pro software was applied to predict the chemical composition of pyrolysis gas.

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### SDEWES2021.0601

# Composition Analysis, Characterization and Physico-Chemical Properties of Separately Collected Packaging Waste Residual Waste Streams

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## Abstract

World plastic materials production has increased 240 times in the last 70 years and now consists of hundreds of different polymers but only a few of them are used in everyday products and account for the production of the majority of all polymers. The biggest share of polymers use is in packaging production (around 40%) followed by construction (20%), while other significant consumption of polymers can be found in electronic, electrical, automotive, sports, household leisure and agriculture industry. The life cycle of material is determined by its use, where some products lifespan is measured in decades while others reach the end of the life in less than a year. Some of the most problematic plastic products and co-products are packaging waste which is discarded soon after product sale, thus they reach waste streams very quickly. These wastes are mainly used for material recovery while residual waste can be used in energy recovery technologies. Because of this, it is important to know the characteristics of waste streams that consist of such wastes. This research analyses composition and morphological characteristics of separately collected packaging waste stream, but puts emphasis on residual waste fraction after each sequential separation. Residual fraction of packaging waste stream, which is not used for material recovery, is sampled during the municipal waste separation and recovery chain, thus, the efficiency of primary and secondary waste separation, as well as of tertiary, i.e. during refuse-derived fuel production, are tracked. Material characterisation and composition analysis results show that primary waste separation results in material with only 7% of contaminants and manual secondary waste separation efficiency ranges between 45 and 55%, while physico-chemical comparison results show very high level of separation quality of tertiary separation in RDF production step, thus produced RDF properties can be approximated through the use of input residual waste composition and technological characteristics of RDF production facility. Results show that both analysed MRF facilities produce residual waste fraction suitable for production of RDF usable in wide range energy recovery and fuel production technologies. Results of this analysis can be used by decision makers for planning the both environmentally and economically sustainable system for recovery of residual waste fractions from packaging waste management systems.

## SDEWES2021.0602

# Plastic Waste Pyrolysis Plants Overview and Economic Viability Assessment of Implementation on a Small Scale

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## Abstract

From 1869 when the first synthetic polymer started substituting natural materials, the use of polymer materials in industrial production has started increasing exponentially during the decades. This has led to increasing the quantity of polymers materials which, after reaching the end of the lifespan of corresponding products, become part of municipal waste streams, but also materials which are being discarded much sooner, during production, as scrap, rejects and byproducts. The overall composition of discarded waste is different and its suitability for recovery of these two types of waste polymer streams, as well as economic sustainability, need to be analyzed separately. In this research techno-economic analysis of the pyrolytic conversion of industry generated residual plastic waste fraction is conducted. To do that, a review of techno-economic parameters of exiting plants for plastic waste pyrolysis, by technology supplier, is done. The collected data were used to derive the dependence of economic quantities, technological parameters and production on the size and type of plant, as well as the composition of the input raw material. Results show that the economic viability of such recovery is greatly influenced by types of polymer materials that are treated, price of alternative treatment/disposal of residual plastic waste and size/capacity of the analysed plant. Pyrolytic conversion of industrial plastic waste cannot be economically viable, without a gate fee, while treating waste from only one industrial plastic waste recovery facility with the production of 10000 tonnes per day of residual waste. If only polyethylene and polypropylene are used as a feedstock, due to the economy of size, the needed gate fee is over 80 €/t, but that means that only 28% of industrial waste is recovered. If also PET is used as a feedstock, 51% of residual waste van be recovered, and the needed gate fee is decreased under 40 €/t. Conducted sensitivity analysis shows that the greatest influence on the economic viability of such plants has the economy of scale and that it is the most suitable for treating municipal plastic waste.

## SDEWES2021.0628

# Challenges on Trace Metal Recovery from Saltwork Bitterns: Equilibrium, Kinetic and Morphological Properties for Sorbents Selection

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## Abstract

Securing sustainable access to raw materials, including metals, industrial minerals and particularly Critical Raw Materials (CRM), is of high importance for the EU economy [1]. Between the different options to achieve this objective, recovery of metals and minerals from sea resources (e.g. seawater brines, seawater reverse osmosis brines) represents a potential option. In particular, brines generated in solar saltworks after NaCl(s) crystallization are a suitable candidate. These brines, typically discharged to the sea, contain valuable elements such as Mg, B and other trace elements included in the CRM list. Between them, it should mention those belonging to the alkaline/alkaline-earth metal (e.g. Li, Rb, Cs, Sr) and transition/post-transition metals (e.g. Co, Ga, Ge) groups.

Different theoretical studies have estimated the potential economic benefits that could be obtained by extracting minerals, which depend mainly on the concentration of these elements in the brines and their corresponding market price [2]. In this respect, apart from major components at $kg/m^3$ levels as Na, Ca, Mg, K and Br, only elements at $g/m^3$ level as Li, Sr and B are potentially attractive for extraction. For these trace elements, suitable extraction methods can be found that are more economically viable than in-land mining. Review of state of the art indicates that sorption processes are probably the most suitable technology to extract metals at the $g/m^3$ (e.g. Li, Sr and B), whereas technical and economic barriers arise for those in the $mg/m^3$ range (e.g. Co, Ge, Ga, Rb and Cs).

The objective of this study is to critically review the selection of potential sorbents that provides both the technical feasibility and cost-effectiveness of highly efficient and effective recovery processes. The main extraction mechanisms for increasing the selectivity and separation factors will be discussed. Innovative sorbents based on chelating functional groups, bifunctional groups as well as groups based on molecular recognition principles as calixarenes or crown-ethers using both organic and inorganic base structures will be presented. Additionally to equilibrium and selectivity factors, the kinetic performance of sorbents and the influence of their physical properties as form (e.g. granular, fibrous and powder) and porosity (macro, meso and micro) and their chemical stability along regeneration cycles will be presented.

## SDEWES2021.0779

# Thermal Upgrading of Hydrochars from Anaerobic Digestion of Municipal Solid Waste Organic Fraction

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## Abstract

Thermal processing of waste materials is an effective way for waste minimization and as well as the production of new valuable products. Such technologies subscribe into circular economy concept, one of the main pillars of the European Green Deal which is EU plan to make the European economy more sustainable. One of the challenges is a proper upgrading and management of process by-products.

In this study thermal upgrading of hydrochars and biochars by steam gasification was analysed. The hydrochars were obtained from hydrothermal carbonisation (HTC) of digestate from anaerobic digestion of wet fraction of municipal solid waste. HTC was performed under following operating conditions: temperature of 200 and 230 °C and residence time of 60 and 120 min. Main aim of the chars upgrading by steam gasification was to develop active surface area and produce activated carbon from waste materials. The main problem associated with such a product is its high contamination with heavy and alkali metals. However, contaminated activated carbon might be used with success in adsorption chillers in working pair with methanol. The gasification process was performed at 800 °C and residence time was 10 min under nitrogen with steam atmosphere. The experimental results showed that, the quality of activated carbon, developed surface area and pore size distribution depend upon process parameters and feedstock properties like carbon and ash content in the raw material. Together with solid products, also liquid and gas products were collected. During gasification process of chars a small amount of liquid products was produced and condensed on colder parts of the reactor. Unlike raw materials: biomass and waste, the vapours did not condense in cooled scrubbers. The analysis of the main gaseous products from gasification process showed that syngas is composed mainly of $H_2$, $CH_4$, $CO_2$, $O_2$, CO, and some trace amounts of $C_2H_6$, $C_2H_4$, $C_2H_2$were also detected.

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## SDEWES2021.0811

# The Impact of Environmental Attitudes and Group-Level Selection on Individual Recycling Behaviour in a Public Good Framework

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## Abstract

As recycling helps to limit the use of primary resources, it becomes a core element of sustainability policy. However, recycling needs large technological investment in regional circular flow systems and bears large commercial risk if potential users do not show a large participation. Economic theory suggests that behavioural barriers to contribute to recycling activities can be explained by its public good structure and free-riding: individual contributions to recycling systems face private costs (e.g. due to inconvenience as compared to cost-free waste disposal) and non-exclusive public benefits enjoyed by all members of society (e.g. due to saving scarce resources and resulting price effects). In reality, the institutional structure of recycling systems also faces elements that are more exclusive. Private households may have access to municipal recycling yards, which offer their services and benefits exclusively to citizens of the municipality.

In the interdisciplinary project presented in this paper, we use economic experiments to investigate how variations of supply-side elements affect recycling behaviour of users. Our experiments show that low and inefficient contributions to recycling systems in a public good framework can be increased significantly by adding a club good option where only members can contribute and benefit. This increase in cooperation depends on the composition of clubs and takes place only in those clubs, where members with higher environmental attitudes are gathered. Such kind of altruistic and environmentally friendly behaviour might be explained by the idea that members of clubs feel able to protect against free-riding of non-contributing individuals. In addition, to separate clubs with respect to environmental attitudes of their members, we also introduce randomly assembled clubs, which are independent of environmental settings of their members. We allow these clubs to face an implicit competition by introducing group-level selection. We expect that competition between groups of individuals contributing to a group-specific public good also can force altruism and increase cooperation and efficiency. In different treatments of a controlled laboratory experiment, the impact of environmental attitudes and group-level selection on recycling behaviour is compared. The experiment will be conducted with 150 subjects in April 2021. Its experimental design and the hypotheses are drawn from a game-theoretic model.

Notice:

The research presented here represents a follow-up to the pilot experiment that we presented at the Dubrovnik conference 2019 and subsequently published in 'Clean Technologies and Environmental Policy'. It was already scheduled for the SDEWES conference 2020 in Cologne, but had to be cancelled because data collection could not be performed as planned due to the pandemic. We are now able to conduct the experiment online.

## SDEWES2021.0850

# Determination of Heavy Metal Concentration in the Aced Rouiba Tannery Effluents in Algeria and Theoretical Study of Chromium Reduction by Complexation with Dithiocarbamate

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## Abstract

The transformation of animal skins into leather in a tannery consists of many stages, each with its own input requirements (water, chemicals) and discharge characteristics (quantity of water, pollutants). In this work, we have assessed the impact on water resources of industrial wastes from the Rouiba tannery located in the capital city of Algiers. The pre-tanning operations are the most polluting with COD levels that can reach 30,000 mg/L. Analysis of the wastewater

in the collection basin, where all the factory's effluents are moving, shows a significant pollution load that varies with time. COD produces between 600 and2500 mg/L and suspended solids between 600 and 7000 mg/L, respectively. These waters are also loaded with chromium with levels between 50 and 300 mg/L. Our purpose is to identify the concentrations of heavy metals (especially chromium) in the tannery effluents, as well as the application of molecular modeling at the level of Density Functional Theory (DFT) using the Gaussian program on the chromium complexes with dithiocarbamate ligands, in order to define their characteristics and their reactivity.

## SDEWES2021.0947

# Evaluation of Up-Concentration Potential for Direct Membrane Filtration of Municipal Wastewater

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## Abstract

Organic matter in municipal wastewater should be regarded as a resource for energy production in the future. Direct application of anaerobic digestion to municipal wastewater is easy if the concentration of organic matter is increased. Different treatment processes are being studied to up-concentrate the municipal wastewater, such as high-rate activated sludge system for carbon recovery [1], chemical enhanced primary treatment (CEPT) [2], dynamic membrane [3], direct membrane filtration (DMF) [4-6]. The DMF is an advantageous process thanks to extreme compactness, small footprint, and reduced energy consumption [7]. In this study, sequential DMF for up-concentration of primary treated municipal wastewater using dead-end filtration cell was performed. Raw wastewater was collected from the effluent of the pre-settling tank in Kayseri municipal wastewater treatment plant (WWTP), which is applied to conventional activated sludge processes.

Cellulose acetate-based microfiltration membrane filters were used with 0.45 µm pore size and 14.6 $cm^2$ filtration area. The experiments were conducted using Sterlitech HP4750 dead-end stirred cell (Sterlitech, USA). The stirred cell was equipped with a magnetic stirrer, rotating at 300 rpm to minimize concentration polarization. The data of permeate weight as a function of time was collected by a data logger attached to the digital balance. Filtration experiments were conducted at 0.5 bar. In the first filtration experiment, 300 mL of wastewater sample was used and filtered until 80% recovery was reached. 30 mL of the remaining 60 mL concentrate was removed, and the second filtration experiment was started by adding 270 mL of the pre-settling effluent sample to the remaining 30 mL concentrate. These steps were repeated in steps 3, 4 and 5. Permeate and concentrate samples were characterized after each filtration.

In sequential DMF experiments, the duration of the experiment was prolonged at each filtration step by using the recovery rate of 80%. This recover rate was reached in 6 hours in the first filtration experiment, in 7 hours in the second filtration experiment, and over 7 hours in the third, fourth and last filtration experiments. While the COD concentration of the feed wastewater was 322 mg/L, it was concentrated up to 4 times to 1268 mg/L after sequential filtration experiments. Assuming around 25% of the COD removed in the primary settling tank, the organic matter recovery potential can be computed as 75% with the suggested process. DMF is a promising technology for concentrating organic matter from municipal wastewater and promotes the recovery of organic matter content as energy by subsequent anaerobic treatment processes.

## Water desalination

### SDEWES2021.0271

# Energy Analysis of a Seawater Desalination Plant Using Energy from Waste

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## Abstract

Municipal Solid Waste represents a valuable source of energy due to their significant calorific value which varies between 6-12 MJ/kg. In Albania, in recent years a number of waste-to-energy projects have been promoted thus reducing waste volume in Albanian municipalities and generating electricity. Although the cost of such projects results very high for Albanian economy the initiatives were not stopped. On the other hand the country's position in the Mediterranean is seen as very favourable for the development of tourism, since it results as a significant driving force in the local economy. The possibility combining waste use and desalination remains the aim of this article. Desalination requires energy which could be supplied by use of waste as an energy source. Investigation of the possibilities with respect to energy analysis of the plant will be discussed in this paper. This study proposes the use of Reverse Osmosis (RO) and Multi-Effect Distillation (MED) desalination technology. Reverse Osmosis method is largely used for drinking water production and water treatment in the Albanian industry sector. Configuration of each desalination plant diagram and evaluation of energy requirements are subject of this paper. The system can provide a useful step to assess the development of waste-to-water plant in the future in Albania.

## SDEWES2021.0655

# Direct Contact Membrane Desalination Similarity Analysis

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## Abstract

The performance of direct contact membrane distillation is affected by several parameters, such as the feed and permeate flow rate, the temperature of feed and permeate sides, the module dimensions, the membrane properties, and other operating and design parameters. A considerable effort has been placed in analyzing these parameters effect separately by a range of experiments using lab modules to optimize the system performance towards maximum permeate flux rate. However, it does not indicate the same results when it comes to being applied on the prototype scale. In this study, the Buckingham Pi theorem was applied to gather these parameters into dimensionless similarity groups that can be used in scale-up studies. The frame work of this study established a dimensionless group that describes the direct contact membrane distillation permeate flux performance in different scales as a function of homogeneous dimensionless operation parameters that has not been published elsewhere. The fluid properties that affect the performance were collected with the operating parameters to build these dimensionless groups. Literature's experimental data for different membrane distillation scales were used to examine the developed dimensionless groups' relevance. Also, these data were used to establish a relationship between dimensionless groups that cover a great range of parametric studies. A computational model supported with experimental validation is used to test the developed dimensionless groups' trend and sensitivity to parameters variation. The preliminary results showed a significant interaction between membrane properties, flow channel dimensions, and flow regime. The created dimensionless parameters were able to predict the membrane distillation prototype's performance using laboratory module results experimentally and computationally.

## SDEWES2021.1028

# Investigating a Few-Layered Graphene Based Adsorbents for Hybrid Adsorption Cooling and Water Desalination

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## Abstract

The increasing water scarcity has resulted in over 2 billion people not having access to fresh water supplies over the globe. To alleviate the fresh water scarcity, the focus has been on brackish and sea water desalination. However, most of the societies facing water scarcity also face high temperatures and require sustainable cooling, not only for comfort but for protecting process and food preservation. Conventional cooling systems are energy-intensive and utilise refrigerants of long lasting environmental impacts, such as hydro-chlorofluorocarbon (HCFC) and Chlorofluorocarbon (CFC). However, the increasing energy consumption for cooling systems also cause major environmental problems related to energy production such as air, water and thermal pollutions. Therefore, adsorption cooling emerged as a less polluting alternative technology for cooling cum desalination in urban and rural areas. Nevertheless, low heat and mass transfer in current adsorption reactor designs lead to low energy conversion efficiency, hence poor clean water and cooling production. The adsorbent material is very influential on the overall performance of adsorption systems. Recently few-layered Graphene derivatives showed unique thermal and adsorption characteristics. This study investigates Graphene Oxide (GO) of 1-3 layers experimentally and numerically through 3D computational fluid dynamics simulation (CFD) modelling. The adsorption and thermal characteristics of Graphene Oxide were benchmarked against conventionally used Silica gel (SG). The results showed that GO enhanced the thermal diffusivity by 22%, the adsorption performance by 62 % and overall performance by 37%.

## SDEWES2021.1039

# 3D Multi-Phase Lattice Boltzmann Simulations in Hydrophobic Membranes for Membrane Distillation

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## Abstract

Membrane distillation (MD) is a thermally driven separation process operated below the boiling point. Evaporation and a hydrophobic membrane are used to separate potable water from sea or brackish water. Compared to other desalination technologies, MD has the advantage of small investment, low operating costs and can be driven by non-concentrated solar energy or waste heat at low temperature. Since the performance of MD modules is still comparably low, the current research aims to optimize the membrane and module structure to increase the energy efficiency. A common membrane material in MD is Polytetrafluoroethylene (PTFE) with a pore diameter of about 200 nm. Based on existing 3D membrane geometries (up to 0.5 billion voxels with 39 nm resolution) obtained from ptychographic X-ray computed tomography the D3Q27 Lattice Boltzman (LB) method was used to investigate the interaction of the liquid and gaseous phase with the porous membrane material. In particular, the Shan and Chen multi-phase model is used to simulate multi-phase flow at pore level to gain a better understanding of the underlying mechanisms and to increase the efficiency of the MD module. The code is accelerated by using a hybrid CUDA-MPI programming layout which can be executed on several GPUs in parallel.

## SDEWES2021.1041

# Experimental Characterization of the Temperature Gradient Inside a Membrane Distillation Module

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## Abstract

In a context of growing demand for freshwater, in parallel with its amplified scarcity due to climate change, aggravated by an increasing use of carbon energies, a method for freshwater recycling and production powered by low-grade heat seems promising. Air-gap Membrane Distillation (AGMD) is a thermally driven process based on evaporation, induced by a temperature gradient across a hydrophobic membrane. The air-gap improves the energy efficiency of the process by limiting the heat losses, while hindering the mass transfer at the same time. Hence, a balance between heat losses and mass outflow has to be found. An optical test bench and a prototypical AGMD module are specifically designed and set-up to characterize the temperature gradient inside the AGMD module in order to analyze thermal boundary layers and optimize evaporation flux. This paper describes the selected optical method and material, the tailor-designed module, and provides a theoretical framework for results analysis.

## Water-energy nexus

## SDEWES2021.0176

# Evaluation of Water and Energy Systems by Novel Operational Coefficients Considering the NEXUS Between Exergy and Water

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## Abstract

Sustainable development was established in a consolidated multi-aspect framework in which the interconnections among various sectors needed to be concurrently considered to attain the ultimate goal. Hence, the nexus between clean affordable water and energies gained a special attention in the sustainable engineering field. Water-energy nexus was successfully addressed in strategic management, development plans, systems optimization, sustainable design, and monitoring of the pertinent technologies in favor of reducing hazards and costs as well as increasing efficiency in the recent three decades. In spite of many successful applications, the water-energy nexus concept suffered from intrinsic restrictions of neglecting the Second law of thermodynamics. These shortcomings can be obviated taking the available energy (exergy) into account in the systems analytics. In this study, water-exergy nexus concept is elucidated, new conceptual definitions are presented, and the available engineering technologies are evaluated quantitively by means of novel coefficients and variables. The scientific concept is divided into four departments including water for exergy, water for water, exergy for water, and exergy for exergy. Various wastewater treatment and power plants are compared by means of new evaluation criteria at the operational stage. The results address the sustainable systems and processes considering the operational water losses and exergy destruction during energy conversion and water treatment. These results were compared with similar water-energy nexus-assisted coefficients to highlight the significance of energy quality (in addition to its quantity) in evaluating sustainable engineering systems. The new interdisciplinary field of water-exergy nexus can be further developed considering the whole life cycle of the systems, and various scenarios at the upstream and downstream stages of the supply chain to adapt climate change effects by sustainable water and energy production.

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## SDEWES2021.0179

# Demonstration of Renewable Energy Sources and Demand Side Management Implementation on the Future Smart Island

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## Abstract

Water Utilities face numerous challenges in their field of work. Problems of infrastructure aging and high replacement costs lead to a lack of finance for operation and maintenance. Energy is required in all stages of water production and distribution, from pumping and treatment to transportation. Hence, the energy costs are of great concern for the water utility companies. In the last decade, there has been an increase in research on demand-side management, which was followed by the development of numerous educational programs to encourage producers and users to conserve water reserves and to efficiently use available water. Usage of information and communications technologies, and internet of things technologies will also play an important role in future water systems, and it will allow for easier implementation of efficiency measures. Therefore, the overall objective for the water utilities is to be able to holistically manage their operation flexibly and be focused on decreasing the water losses, save energy and water, and at the same time promote social and environmental sustainability, while having a high quality of service. This paper studies the implementation of renewable energy sources on an island basis. A model linking water and energy system was developed for the Unije island case study using Python and GUROBI. Two scenarios were studied differing in hourly electricity price curves used for the nexus analysis. Scenario 1 uses a common two-tariff electricity price curve, while Scenario 2 employs a future dynamic electricity price curve that follows the hourly demand curve. Results are showing that optimal battery storage for a two-tariff electricity cost curve is equal to 6.87 kW/61.84 kWh. The optimal value for battery storage in Scenario 2 is 18.46 kW/83.10 kWh. Moreover, for both scenarios, the total system cost was lower than the reference scenario where only the grid electricity was used.

## SDEWES2021.0424

# Field Studies for Strategic Planning of Sewage Treatment in a Highly Urbanized City – Inclusion of Biosolids Control in Water-Energy Nexus

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## Abstract

The modern wastewater treatment strategy has broadened its targets from water quality control to energy saving and carbon recovery. Enhanced primary treatment, anaerobic ammonium oxidation, ultra-fine bubble diffusers, and membrane bioreactor are fundamental advances towards water sustainability. However, direct integration of those techniques together into full-scale practices may result in unexpected operational issues. The shifted oxygen consumption pathways owing to the adjustments of biosolid control strategies may lead to the competition of oxygen uptake between ammonia oxidation and endogenous carbon consumptions. The accumulation of non-settable bacteria due to upgraded solid/liquid separation on water-air interface may affect the gas transfer efficiency. This study demonstrated the importance of the process control parameters affecting the Water-Biosolid-Energy Nexus. Numerical simulations were established upon field experiment results to clarify the impacts of operation conditions to dynamic oxygen transfer efficiencies and the fates of oxygen in biosolids. The established model contributed to a comprehensive aeration strategy to avoid the sudden drops of alpha-factor (α) while including the fouling profile with gas flow adjustments along the aeration tanks. Wastewater characteristics, salinity, and coalescence of bubbles were taken into the calculation of additional energy consumption at different diffuser ages. With the adjustments of aeration strategies, a detrimental trend of simulated α of 5-12% within year-long operation was evaluated. The diffuser cleaning period can thus be extended by 8-10% to create an annual reduction of aeration energy cost at US$20,000-$23,000 in a wastewater treatment plant serving 96,000 citizens.

## SDEWES2021.0567

# Linear Modelling of Water Potential and Supply for Decentralized Energy-Water-Food Systems - Case Study St. Rupert Mayer, Zimbabwe

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## Abstract

Limited water accessibility threatens the economic and social development of communities, especially in remote populations with agriculture as the main income source, and where the production depends on the rainfall pattern. This tendency is prone to worse due to climate change, threatening the food security.

Water infrastructure as pumps and tanks would improve the local water availability, but most rural communities cannot afford the investment and maintenance costs. An approach to prompt development is implementing decentralized Energy-Water-Food (EWF) systems, which create synergies and improve the profitability of the system. The proposed system integrates renewable energies for water supply. The model urbs optimizes EWF systems to generate the highest revenues, regarding the local conditions and sustainability limits.

However, in remote communities, water is often the limiting resource. Therefore, this work creates a method to calculate the local water potential, considering environmental limitations and maximizing the long-term benefits of the EWF System. This work establishes the interrelation of hydrogeological parameters with the other system components – energy and food production – in the urbs model. Further on, a sensitivity analysis evaluates the impact of specific input parameters.

The proposed method was applied to the rural community of St. Rupert Mayer in Zimbabwe, in the frame of the potential analysis to establish a decentralized Energy-Water-Food system.

SDEWES2021.0754

# Competing Water Uses Between Agriculture and Energy: Quantifying the Future Impacts of Climate Change for the Portuguese Power Sector

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## Abstract

Long-term climate trends point to an increase of water use for irrigation due to accelerated evaporation, competing with other water uses, as for hydropower, which in turn will be affected by the reduction of runoff due to lower precipitation. Climate change (CC) may also affect the variability and availability of other renewable resources and trigger changes in the electricity demand patterns, enhancing or mitigating overall power system vulnerability.

This paper analyses to which extent the competition for water resources between agriculture and hydropower may affect the future Portuguese renewable-based power sector, also considering CC impacts on wind, solar PV and electricity demand. Portugal is a relevant case study as hydropower has a significant weight on national power generation and three main watersheds are shared with Spain. Both countries are known as climate hotspots.

Our methodology is supported by: (i) estimation of irrigation water demand in the larger Portuguese and Spanish watersheds, by 2050, considering the global data set on potential irrigation water withdrawals simulated under the ISIMIP Project, for RCP8.5; (ii) assessment of the reduction hydropower capacity factors, considering current surface water for irrigation in the transboundary Douro and Tejo watersheds, and historic runoff data for average and dry years (iii) using the eTIMES-PT technology optimisation model for the Portuguese power system to assess the interplay between different renewable power technologies. The climate projections (RCP8.5) from 11 climate models from EURO-CORDEX were translated into the effects on electricity demand and capacity factors of hydropower, solar PV and wind, which were later used as eTIMES inputs.

Results show that, by 2050 and under RCP8.5, Portuguese irrigation water demand is projected to increase between 3.5%-9.7% (relative to the reference period 1985-2005), with Spain increasing up to 29.5%-26.7%. This will lead to a reduction of the annual average hydropower capacity factor between 9-10%. Comparing with historical average hydrological years, CC can lead to a reduction of hydropower production between -9% to -30%, which may be aggravated to -21% to -39%, with water competition. This reduction is compensated with a rise of Offshore Wind, less affected by CC. This analysis concluded that for a Mediterranean country, like Portugal, the competition for water, can reduce the already vulnerable hydropower production.

## SDEWES2021.0816

# Updated Perspective on Using Batteries for Mitigating Hydropeaking

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## Abstract

In this study, we explore the option of using batteries for mitigating hydropeaking by means of reviewing case studies and of optimization-based modelling. Hydropeaking is an operational scheme in which hydropower plants alternate between high and low flows during on-peak and off-peak hours. This operation can severely harm the downstream ecosystem.

The present study is divided into two parts. The first part reviews existing hydropower installations that are coupled with battery systems. Here, we focus on the multiple services batteries can provide, along with updated cost projections, installation sizes, and trends. We conclude that batteries coupled with hydropower plants are being deployed at growing rates, especially in relicensing to provide greater operating flexibility.

In the second part, we use an optimisation tool to study under which future scenarios batteries can cost-effectively be coupled with hydropower plants. We conclude that batteries emerge as cost-attractive option to provide ecosystem services as soon as 2025, especially when used in combination with other services. From a battery perspective, providing ecosystem services is novel and not yet fully mapped by stakeholders.

## SDEWES2021.0896

# Swat Model Optimisation Incorporating Geological Catchment Heterogeneity Through Calibration Strategies: the Henares River Basin (Spain)

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## Abstract

The main objective of this work was to compare four calibration schemes applied in a geologically heterogenous catchment to determine which one achieves best performance and most realistic simulations. SWAT was the model used, semi-automatic calibration was performed, following by split-sample validation. One weakness of SWAT is its simplicity modelling groundwater, which could be determinant on relevant water balance components such as groundwater contribution to streamflow. Therefore, realistic groundwater modelling would increase SWAT simulations credibility.

All the schemes showed satisfactory performances, obtaining the most complex scheme the better metrics for validation. This scheme also allowed to simulate in a more realistic way the Henares River basin, according to its geology. The schemes showed differences in the water balance and streamflow components. To the best of our knowledge, our work addresses for the first time this issue, providing new insights about how to simulate catchments including aquifuge substrates.

## SDEWES2021.0897

# Hydrological Impacts of Climate Change in a Groundwater-Dependent Mediterranean Basin: the Salado River Basin (Spain)

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## Abstract

Water management under a climate change context is challenging. Latest IPCC reports predict that global warming will be particularly intense in southern Europe during summer, and the decrease of water resources will be one of the most concerning effects. This circumstance has to be taken into account in the revision of the European river basin management plans.

In many rural areas in Spain, water supply relies entirely on groundwater. These areas are already experiencing the climate change struggle: springs yield less and less water during summer, when the population increases. In order aid relevant authorities on this situation, a SWAT (Soil and Water Assessment Tool) model has been set up in the Salado River catchment, a medium-sized catchment located in central Spain. A semi-automatic calibration was carried out, resulting satisfactory.

Once the model was set-up and calibrated, climate change scenarios were simulated to assess water availability and water balance impacts in the mid (2046-2065) and long (2081-2100) term. Two emission scenarios were considered, RCP 4.5 and RCP 8.5 (low and high emissions, respectively), using the latest projections from the Spanish Meteorological Agency. Combining both temporal horizons and emission scenarios, four climate change scenarios were simulated.

Results obtained suggest that a decrease in precipitation varying from 7.5% to 18.6% could cause a reduction in streamflow between 28.1% and 56.5%, respectively, with small differences between the mid-term and the long-term scenario under a low emissions future, but foreseeing a much more severe decrease under a high emissions future. Also, the model predicts a reduction in aquifer recharge between 31% and 55% by the end of the century for the RCP 4.5 and the RCP 8.5, respectively. This implies that groundwater contribution will be the most affected streamflow component, decreasing up to a 73.8% in the most pessimistic scenario. This is particularly relevant, considering that groundwater is the only resource for water supply in the area and furthermore that rural areas population - and thus water needs - increases in summer, when rivers are solely feed by groundwater contribution.

Results prognosticate a challenging future water management situation in this catchment, which could be extrapolated to any other groundwater-supplied catchment in southern Europe. This work can help water administrations in anticipating decision-making to overcome this foreseeably adversity.

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