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Article

Energy Transformation in Municipal Areas—Key Datasets and Their Influence on Process Evaluation

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Abstract: The energy transformation that began in 2022 led to a breakthrough in green energy. It has opened opportunities to develop regional areas, as they have the land needed to build wind and solar power plants, as well as biomass waste power plants. Energy transformation enables regions to solve long-standing social problems determined by the inconvenient geographical location and the growth of agglomerations. However, in order to assess the potential of the regions, it is necessary to use different data groups, covering economic, social, environmental, and governance aspects. This article aims to create conditions for gathering quantitative and qualitative data that would allow us to assess the extent of energy transformation in regional areas. The article presents the case of Lithuania. Since the beginning of the energy crisis, there has been a breakthrough in the fields of wind and solar energy in the regions of Lithuania. This article is relevant because it aims to solve the problem of insufficient use of renewable energy resources in the regions. This article will present the regions' potential to contribute to the energy transformation. The "research by design" formula was used for the research, which was chosen as the basis for further research. Based on this method, quality information was collected from interested parties—energetically innovative Lithuanian municipalities.

Keywords: energy transformation; municipality; ESG; synergies effects; renewable energy

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1. Introduction

Global economic, energy, and political changes encourage us to search in new directions for sustainable and safe energy supply. Decentralized solutions are being developed to ensure a secure energy supply, local energy production is being expanded, and the amount of imported fossil fuels is being reduced. The ongoing process is still difficult to define—there is a lack of data that would allow us to evaluate action alternatives and optimal transformation solutions. Currently, energy transformation research is fragmented, covering narrow aspects. Changes in energy are based on the macroeconomic dimension, without considering the potential of regions to initiate changes. This article outlines the main aspects of energy transformation:

- Energy efficiency refers to the ratio of useful energy output to the total energy input. The goal of energy transformation is to maximize energy efficiency by minimizing energy losses during the transformation process. This can be achieved by using energy-efficient technologies and practices, such as insulation, energy-efficient appliances, and renewable energy sources.
- Renewable energy sources, such as solar, wind, hydro, and geothermal power, offer the potential for clean, sustainable energy generation. These sources of energy can be harnessed through various technologies, such as solar panels, wind turbines, and

hydroelectric generators. The usage of renewable energy sources could reduce our reliance on fossil fuels and decrease greenhouse gas emissions.

- Energy storage is a critical component of energy transformation, as it enables us to store energy when it is abundant and release it when it is needed [1–3]. Energy can be stored in various forms, such as batteries, pumped hydro storage, and compressed air energy storage. Development of better energy storage technologies could improve the efficiency and reliability of renewable energy sources and reduce our reliance on fossil fuels.
- Energy policy plays a crucial role in shaping the transformation of energy system [4,5]. Governments can incentivize the adoption of renewable energy sources and energy-efficient technologies through policies such as tax credits, subsidies, and energy efficiency standards. Implementation of effective energy policies could accelerate the transition to a clean, sustainable energy system.

Until now, the energy transformation process has been static, centralized, and based on the goodwill of countries and industrialists. The developed global instruments did not encourage small or medium energy users to achieve maximum operational efficiency. The reverse process took place—developing countries, in order to solve economic problems, increased environmental pollution and worsened the social situation. This was served by international agreements that taxed environmental pollution but did not eliminate it. The decarbonization of the energy sector has been the subject of research for several years, gaining increased attention recently. It is commonly acknowledged that the most obvious way to achieve decarbonization is the use of renewable energy. However, the decarbonization of the energy sector entails several challenges and the interdependencies between the secondary energy carriers and end-use energy sectors should not be underestimated. The United Nations defined mechanisms that support the countries with commitments under the Kyoto Protocol in reaching their emission reduction targets cost effectively [6]:

1. Emission trading (ET). The parties have emission limitations, which are expressed as emissions allowances.
2. Joint implementation (JI). This mechanism allows a party to earn emission reduction units (ERUs) from an emission reduction or removal project with another party.
3. Clean development mechanisms (CDM). Parties can implement emission reduction projects in developing countries and earn saleable certified emission reduction credits (CER).

However, in order to achieve real environmental protection goals, complex, decentralized solutions are necessary, ensuring the largest possible number of contributors to the changes. This turns to the regional dimension, where different energy systems can exist. Regions' efforts to make energy systems more efficient by choosing renewable, local energy resources can create an effect of scale, while simultaneously solving sensitive social and economic problems. This study aims to find ways to assess the possibilities of energy transformation in regional areas. In the past, there have been studies that show efforts to carry out energy transformation, but they are fragmented and inconsistent. This is related to the lack of infrastructure and coordination and the selection of strategies. In one case, the transformation is initiated in cities. The lack of implementation of green procurement in the metropolitan areas can therefore be attributed to the lack of adequate policy frameworks. In spite of this, the study found out that all the metropolitan areas are undertaking mitigation projects to reduce greenhouse gas emissions. Projects in the transport sector such as bus rapid transport, in the waste sector such as recycling and methane capture from landfills, and in the energy sector such as installation of solar energy were identified. All the identified projects are, however, fragmented. These projects were found to be in different departments with limited coordination between departments and at times within the same department. This sometimes led to duplication, and in such instances, resources are wasted [7]. This study focuses on regional areas, as they can provide themselves with fuel, waste, and human resources, thus ensuring the involvement of interested groups.

Energy transformation is an important part of the circular economy, ensuring the progress of other areas as well. Energy production is related to the utilization of biological waste, at the same time utilizing previously unused resources. Sustainable supply chains enable the release of fewer pollutants into the atmosphere. The process of energy transformation includes complex factors that must be considered naturally and consistently. The application of circular economy principles ensures the smooth progress of transformation and the pursuit of goals. A study conducted by [8] showed that the impact of the circular economy on sustainable development is an essential condition for the economic competitiveness of countries:

- All CE indicators considered in this study are found to positively affect economic growth;
- If the CE indicators are associated with the sustainable economic development triangle adopted for the circular economy (environmental–social–economic), the findings show that they have a positive effect on economic growth as well;
- Theoretically and empirically based, the study underpins the necessity of innovation in the core of CE;
- This study emphasizes and strongly supports the stipulation of the collaboration among academia, government, business, and civil society.

The purpose of the paper is to indicate the main directions of the energy transformation, while presenting groups of data that would allow the analysis of the positive impact of the transformation in terms of sustainable development. The transformation effect is analyzed on a regional basis, forming the main idea of the article—the decentralized renewal of the energy system would allow us to accelerate the development of renewable resources and the solution of social problems.

The research will be conducted for two years. This article outlines the initial research phase, which involves tasks related to problem identification and transformation directions. Figure 1 presents the overall structure of the entire study. The final goal of the research is the creation of a model of energy transformation at the municipal level. This article provides a walkthrough for the first objective. Next to the analysis of technical aspects, special attention is given to the analysis of governance, since it is this aspect that will significantly depend on the success of the transformation. In this case, innovative municipalities were selected for research, whose experience will be partially applied to achieve progress in other municipalities.

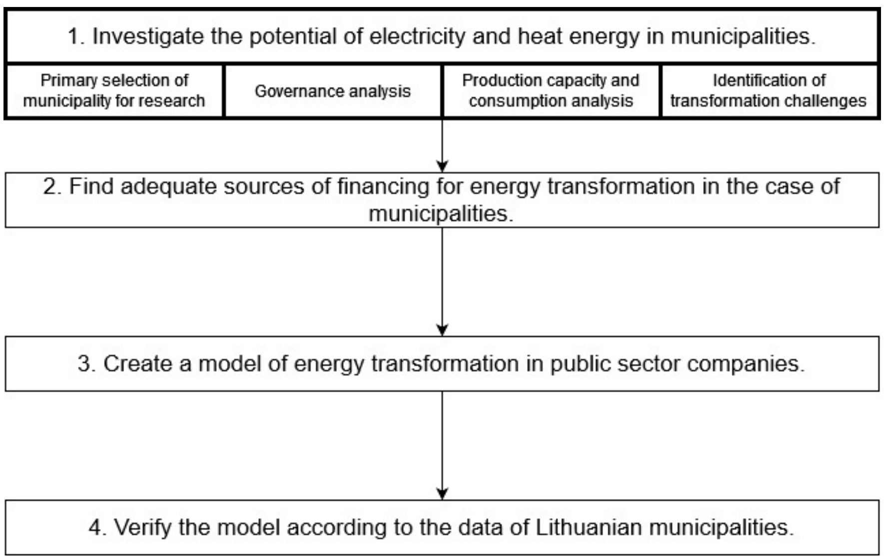

Figure 1. Structure of the entire study. This article analyzes the first objective.

2. Literature Review

2.1. New Horizons in Energy Strategy

The military conflict in Ukraine in 2022 encouraged developed countries to accelerate the transformation of the energy system. Rising energy prices have made wind and solar more competitive. In addition, investments in green hydrogen production, as well as power-to-X solutions, have increased. These processes fundamentally change the economy of the country and regions—new jobs are created, available biological resources are better used, and electricity storage solutions are developed. Hydrogen production technologies allow the use of cheaply produced energy at a time when its demand is reduced. Later, hydrogen can be used to produce either electricity or as fuel for other equipment with hydrogen engines. The new energy concepts are fundamentally different from the energy canons established in the last century. The traditional model of an energy system, based on fossil fuels, was built on the following principles:

- Centralized production of electricity and heat and transport management;
- Limited central planning and energy policy;
- Restrictions in the supply of fuels;
- Limitations on the number of energy producers and passive consumers;
- Growing demand for energy and targeted production [9].

The transformation of renewable energy in the regions fundamentally changes their economic situation. Next to production development, the service sector is expanding, the quality of life is improving, and parallel businesses serving energy facilities are emerging. The main developer of renewable energy in the world is currently the European Union. It produces the greenest energy in terms of consumption. The development of renewable energy promotes the emergence of new businesses and economic development. The EU assists member states to develop these businesses by providing subsidies and grants. The approved European Green Deal is aimed at energy transformation based on renewable energy. The following directions of support and promotion are provided:

- Clean energy and energy efficiency technologies;
- Regeneration, decontamination, renaturalization, and land redevelopment;
- Strengthening the circular economy;
- Diversification and creation of new enterprises, including start-ups;
- Support for employees;
- Digitization and digital communications;
- Research, innovation, and technology transfer [10].

When studying the directions of renewable energy development, there is a need to gather different data groups. In the initial stages of research, clustered groups of data are selected, according to which more detailed data is later unified. The links between renewable energy and social integration encourage the study of broader datasets. This is because it aims to demonstrate to prospective investors not only the economic returns but also the wider factors that could encourage investment in green energy production. By associating the cluster themes derived from both social innovation–energy transition and social innovation–circularity cluster themes, it could propose five key elements that need to receive attention and be put forward as future agenda directions: policy for climate change, circular justice, energy business models, transition innovation, and sustainability [11]. Energy transformation can be considered an integral part of the circular bioeconomy. It is a rapidly growing field that has been gaining traction in recent years. It is an interdisciplinary field that combines biology, economics, and technology to create sustainable solutions to produce food, energy, and materials [12].

A wide spectrum of synergistic effects exists in the field of renewable energy. Synergies arising from the combination of different energy types help to increase competitiveness in the context of fossil fuels. Harmonizing different energy technologies can ensure sustainable energy production without harming the environment. At the same time, competitive energy prices and uninterrupted energy supply are ensured. In order to produce large amounts of energy, different types of production are combined, various wastes are used, or several production processes are developed at the same time. Key synergies in renewable energy:

- Wastewater management (mixing sewage sludge with grass, leaves, and food waste, extracting biogas);
- Animal waste, oil in the extraction of biogas;
- Biomass waste in cities and regions used to produce heat and electricity;
- Secondary processing of used oil into biofuel 2.0;
- Utilization of municipal waste;
- Power-to-X production from wind and solar energy.

When going deeper toward the directions of synergy and into the data required for more detailed research, it is necessary to single out those types of energy that will have the greatest potential for municipal energy transformation. Rising concerns about global warming are driving investment in green energy solutions. Depending on the climatic conditions and the abundance of available natural resources, the countries of the world choose different methods of green energy production. As for traditional sources of energy production, biomass energy occupies the main part of investments [13]. The structure of the biomass energy sector is determined by the specifics of the origin and development of biomass. Economic output is related to the natural processes that produce biomass resources. Certain natural processes form different types of biomasses that can be used for heat, electricity, or biogas production. A business structure is formed according to the type of biomass and the type of its occurrence, the purpose of which is to convert biofuel into energy and achieve a positive economic effect.

Traditional energy companies face extensive challenges related to energy transformation. It is especially related to the use of alternative types of fuel, which help green energy to be extracted. One such type of fuel can be municipal waste. Municipal solid waste (MSW) is a solid waste that is commonly described as trash or garbage that is generated daily by households, commercial establishments, industries, and others. It is regarded as an inevitable and valueless by-product of community activities. MSW is one of the main waste source streams in addition to commercial and industrial waste and construction waste [14]. Responsible management of municipal waste is one of the main indicators that segment developing and developed countries. Municipal waste can be managed in several ways. In one case, they can be burned to produce heat or electricity. Otherwise, if they are buried in landfills, the gas is extracted. In the latter case, new innovations are observed, allowing us to produce a larger amount of energy. Landfill methane is a potential resource, but allowing its release into the environment has a lot of environmental implications [15]. Municipal waste management can be linked to the creation of so-called eco-cities. This concept is related to the maximum reduction in pollution in agglomerated areas. In eco-cities, it is possible to localize the sources of waste, use them more efficiently for recycling, and from the rest, efficiently extract the energy needed to meet the needs of the city. However, this concept is still fairly new and carries some risks. It is also noted that "eco-cities", often created as implementations of experimental technological solutions for adaptation to the phenomena of global warming, are also places where, under the guise of the need for "green growth", social inequalities are often deepened. As a remedy for this situation, support is most often indicated for individual eco-enterprises and sustainable lifestyles, i.e., developing (broadly defined) mechanisms for resilience to external crises and dwindling resources [16].

The concept of eco-cities is very similar to the concept of a smart city. In the latter case, the synergy of urban planning and IT solutions is emphasized. Investments in IT solutions in cities can create conditions to save resources and increase the level of ecology in the most polluted areas. Previous research by scientists has shown that smart-city management can be based on big data management for energy prosumption in residential buildings and EV. Furthermore, secondary data could be employed to show the applications of the developed IT solutions in promoting energy prosumption. Findings suggest that the IT architecture provides interoperable open real-time, online, and historical data in facilitating energy prosumption [17]. The use of big data is one of the main components with which it is possible to carry out energy transformation in municipalities. Since renewable resources cannot yet ensure uninterrupted energy production, smart grid management can assist the distribution of energy correctly to consumers, and demand-side management would reduce pressure on energy producers.

One of the main trends in renewable energy is the development of power-to-X technologies [18]. In this case, hydrogen is extracted from different renewable energy technologies, which can later be used for different directions in manufacturing, consumption, or energy balancing. According to the information presented in Figure 2, there are a large number of different ways to use the energy obtained by electrolysis.

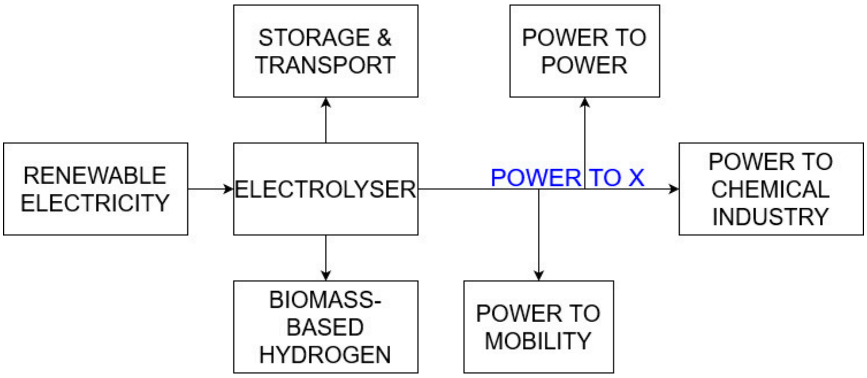

Figure 2. Possible applications of green hydrogen (Reprinted from Ref. [19]).

Previous studies of the economic impact on emissions were characterized by abstraction and the confirmation of a certain fact [20]. Foreign direct investment can play an important role in the transformation [21]. In some cases, they can stimulate investment; in other cases, as consumption grows, there is a need to produce more energy. As quick results are sought, energy production capacity can be developed using fossil fuels. Previous research has revealed the effects of different aspects of transformation [22,23]. Using several indicators of financial development, the empirical results reveal that financial development measured using broad money, domestic credit to the private sector, and domestic credit to the private sector by banks increase carbon emissions while FDI, liquid liabilities, and domestic credit to the private sector by the financial sector do not affect carbon emissions [24,25]. The results show that none of the financial development indicators exert a significant nonlinear effect on carbon emissions. The results further indicate that FDI moderates economic growth to reduce carbon emissions but does not moderate energy consumption to affect carbon emissions [26]. The relationship between financial development and environmental pollution is presented in Figure 3.

Other scientific studies have analyzed empirical aspects to obtain answers to fundamental questions. For this, different statistical methods are used, which allow finding causal relationships between the analyzed phenomena. In one case, results based on a panel Granger causality test showed a unidirectional causality running from energy prices, GDP, the quadratic term of GDP, and trade to CO_2 emissions. The results further revealed no evidence to support the causal relationship between renewable energy consumption and CO_2 emissions; however, renewable energy consumption was found to indirectly affect CO_2 emissions through its direct effect on energy prices [27–29]. This justifies the direct link between GDP dynamics and CO_2 emissions. Other studies describe abstract aspects that are poorly supported by analytical information [30,31]. Since financial development improves environmental quality, it can play a constructive and important role in improving environmental quality around the world, as increased development of the financial sector can encourage further borrowing at lower cost (as the nation's financial institution is controlled by commercial banks, whose main aim is to give loans to both the private and public sectors for various development projects), including for investment in environmental programs [32–34]. The lack of analytical directions encourages further research, which would allow the expansion of scientific knowledge in evaluating the energy transformation and the effects it creates [35–37]. The collected scientific information, as well as the elaboration of previous research, allows us to single out the main groups of data and sources that would help us to study the possibilities of energy transformation:

- Volumes of sewage sludge formation (from water treatment companies);
- Annual energy potential of biomass;
- Power of wind and solar power plants by region;
- Volumes of communal waste generation;
- Amount of unprocessed municipal waste;
- Free power in electrical networks;
- Volumes of green purchases.

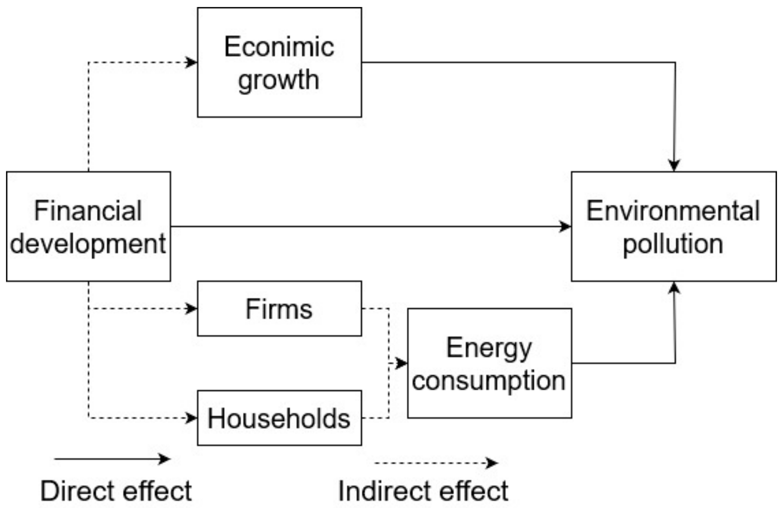

Figure 3. Connections between financial development and environmental pollution (Reprinted from Ref. [26]).

The indicated data groups will allow us to assess the perspective of each region to contribute to the strengthening of the country's energy system using different renewable energy sources. Currently, there is a lack of information, which is presented in the form of data groups, because the process of energetic transformation is not yet precisely defined. These datasets are related to the regional dimension, as the regional waste dynamics are assessed, as well as the share of regional budgets for green initiatives. This group of data covers the interface between economic and environmental factors, thus aiming to explore the possibilities of developing new ecological activities in the regions strictly based on the principles of sustainable development.

In conclusion, with the right political will and mobilization of resources, the energy transformation goals can be achieved in terms of infrastructure. The variety of energy production methods allows adaptation to climatic or geographical conditions while simultaneously extracting energy. In order to achieve the energy transformation, it is important not only to change the infrastructure but also change the governance. Investment management based on industrial methods is no longer relevant, as the current aim is to involve society and protect the environment. The following data group consists of social and governance indicators that are significantly related to economic activity. It allows us to ensure the profitability of the projects, the speed of execution, and the creation of a positive impact.

2.2. The Importance of ESG Indicators for Regional Transformation

Investments in renewable energy are inseparable from the application of environmental, social, and governance (ESG) principles. This type of investment can assist us to quote green bonds for sustainable projects—investment in companies and governments that the investor believes best hold to values of importance to the investor. These include the environment, consumer protection, religious beliefs, and employees' rights, as well as human rights, among others. These areas of concern can be summarized as "Environmental, Social and Governance" and is referred to as ESG investing (environmental, social, and governance). In addition, socially responsible investing includes shareholder advocacy and community investing [38]. ESG investments have attracted wider attention from both investors and customers worldwide. These investments largely follow a triple-bottom-line approach that combines financial returns with environmental and social norms. In addition, it emerges from the analysis that companies have performed relatively better in policy disclosure and governance parameters of ESG integration than in environmental and social factors [39]. Compliance with ESG criteria ensures that the investment project will fulfill social needs, be economically profitable, and protect the environment. The management dimension allows for the continuous, sustainable support of the investment in the future. ESG risk management is becoming an increasingly important aspect of the economic agenda. In order to secure public trust and orderly revenue growth, an ESG component is included in risk assessment plans. ESG risk is currently one of the leading risks in terms of its impact and probability of occurrence. Practical actions to reduce ESG (environmental, social, and governance) risk are necessary because the link between ESG risk and financial performance has been documented [40]. Recently, ESG application actions are clearly visible in the energy sector. This sector is going through two transformations—infrastructural and corporate. It creates the conditions for qualified business model development.

In order to assess the influence of ESG on energy transformation, it is necessary to distinguish the responsibilities of the energy sector. The energy sector is on the path of decarbonization—investments are being made in clean environment solutions, while creating new areas of activity. It is a global trend. The information presented in Table 1 confirms that the implementation of these components significantly contributes to the development of ESG. However, these indicators are quite difficult to measure and express numerically—only some indicators are suitable for objective assessment.

Table 1. Areas of responsibility in the energy sector (Reprinted from Ref. [41]).

Social Responsibility	Environmental Responsibility	Economic Responsibility
1. Personnel's welfare, skills and motivation; 2. Open interaction with stakeholders; 3. The quality of energy supply; 4. Good practices of business and cooperation with the stakeholders, networking with other companies; 5. Correct price for energy.	1. Measuring of environmental impact; 2. Awareness of and reduction in environmental impacts of energy production and transfer; 3. Minimization of use of fossil fuels; 4. Reduction in pollution and emissions; 5. Development of renewable sources; 6. Controlling systems for waste and pollution.	1. Cost-effective operations; 2. Fair prices and good service; 3. Investing in new technologies; 4. Reliability of energy supply; 5. Financial risk management.

Previous studies by [41] have examined different alternatives for ESG assessment. It is generally agreed that the application of ESG principles ensures ethical and environmental interests for future generations. The management component enables the development of human resource intelligence, thereby increasing economic performance and social impact [42]. The need for the environmental, social, and governance–firm value (ESG-FV) relationship is gaining momentum in Asia, as investors believe that firms following sustainable practices are good for value creation in the long run [43]. This is especially important when it comes to strategic planning and risk management. The energy sector is one of the most important users of ESG principles, as the sector is undergoing transformation. Business integration with the internal and external world is gaining momentum in the light of environment, social, and governance factors (ESG score) linkage to corporate financial performance (CFP). However, the impact of the ESG–CFP relationship varies across economies, industries, and institutional frameworks because of varying legal and social structures and expectations from stakeholders [44]. This is especially visible when comparing developed and developing countries. ESG (environmental, social, and governance) factors have, in recent decades, gained attention from different investors and investment strategies. As a result, asset managers are considering and incorporating the financial materiality of ESG factors (including environmental factors such as risk of climate change, greenhouse gas emissions, biodiversity, pollution of water, and waste, social factors such as human rights and safety in the workplace, and governance factors such as ethics, bribery, and corruption) in the investment management process [45]. However, this strategy has so far been applied mostly at the private or public level. At the level of municipalities, where there is a lack of qualified human resources, these ideas hardly make their way. This situation is continuous—the application of ESG requires constant monitoring and accountability to social partners, as well as the application of the latest environmental protection ideas. It requires constant financial resources and control. Smaller municipalities often do not consistently implement the necessary actions, which is why they avoid ESG projects. However, the application of ESG in the case of renewable energy would ensure a reduction in environmental pollution and an increase in the income of the local population. The most straightforward motivation for ESG investing comes from a preference function that loads positively on the goals of a given ESG fund [46]. ESG also forms the prerequisites for the longevity of companies. The sustainable development spheres are interconnected to create a circular value chain of supply in the company [47]. Balancing the positions creates the greatest positive impact on the environment and society.

In the previous work of researchers, an ESG index was created, with the help of which possible investment risks are assessed when investing in this type of company. This index can also be used to assess the possibilities of investing in harmonious business units as an alternative direction of investment. Authors segmented the detailed dependence structures into four groups (ESG/The Wilder Hill New Energy Global Innovation Index; ESG/The Wilder Hill Clean Energy Index; ESG/The S&P Global Clean Energy Index; ESG/The European Renewable Energy Total Return Index) and compare their performances compared with merely investing in the renewable energy index (as the current renewable energy index fund/ETF). Overall, the results suggest that investors could trust the ESG index in hedging investment risk and increasing the profitability level in fund management [48]. However, the ESG index cannot fully assess the element of transformation when aiming to orient the energy system toward self-sufficient production using renewable resources. Reference [49] conducted research to investigate the correlations between certain topical phenomena. The results showed that there was a positive correlation between stakeholder-oriented governance practices and financial performance measures, such as accounting measures for both financial and nonfinancial companies. In addition, shareholder protection policies have a negative impact on accounting performance measures, especially for nonfinancial industries, while the corporate practices that are referred to board of directors and public disclosure vary between financial and nonfinancial entities. Balanced management of energy companies will speed up energy transformation, as expanded competences will allow municipalities to make the necessary decisions. Improving governance based on ESG principles will both save monetary resources and increase the pace of transformation.

Based on the collected scientific information, clear weaknesses in information evaluation have been identified. There is a lack of research that would enable the evaluation of organic production volumes, sustainable use of the environment in agriculture, and the management of municipal enterprises. It creates a situation in which the results of the conducted research are superficial and focused on quantitative assessment, thus excluding important qualitative aspects. The following data groups are distinguished, which are relevant for the evaluation of the energy transformation in terms of social/environmental aspects:

- Number of employees in the renewable energy sector in the regions;
- Production of biological fertilizers;

- Number of boards in municipal companies;
- Approval of ESG plans in municipal companies;
- Areas of organic farms, ha.

In conclusion, the application of ESG criteria is inseparable from the success of the implementation of the energy transformation. The application of ESG principles enables the implementation of projects that would allow the production of green energy at the lowest costs. This is a huge difference compared to fossil fuels or nuclear power, where projects can take decades and exceed planned budgets. Lithuania can be considered an example of energy transformation in the heat sector, as it created a completely new biomass energy sector in a couple of years. In 2022, economic and political unrest created an incentive to invest in other types of energy as well, strengthening electricity production. In both cases, the intentions of the regions to progress by initiating new activities that are important for the climate and social structure have a huge influence.

3. Materials and Methods

3.1. Case Study Analysis

The results of the study are significantly related to the analysis of the Lithuanian sample. Changes made in the heat-energy sector during the global financial crisis (2008–2011) significantly increased energy self-sufficiency and reduced the level of social problems (Figure 4). However, there are some problems in electricity production. Lithuania's electricity generation is predominantly fueled by natural gas, with a smaller portion coming from renewable sources such as wind, solar, and hydropower. The country has significant potential for wind energy, particularly in offshore wind farms in the Baltic Sea, and several large-scale wind-energy projects are currently under development.

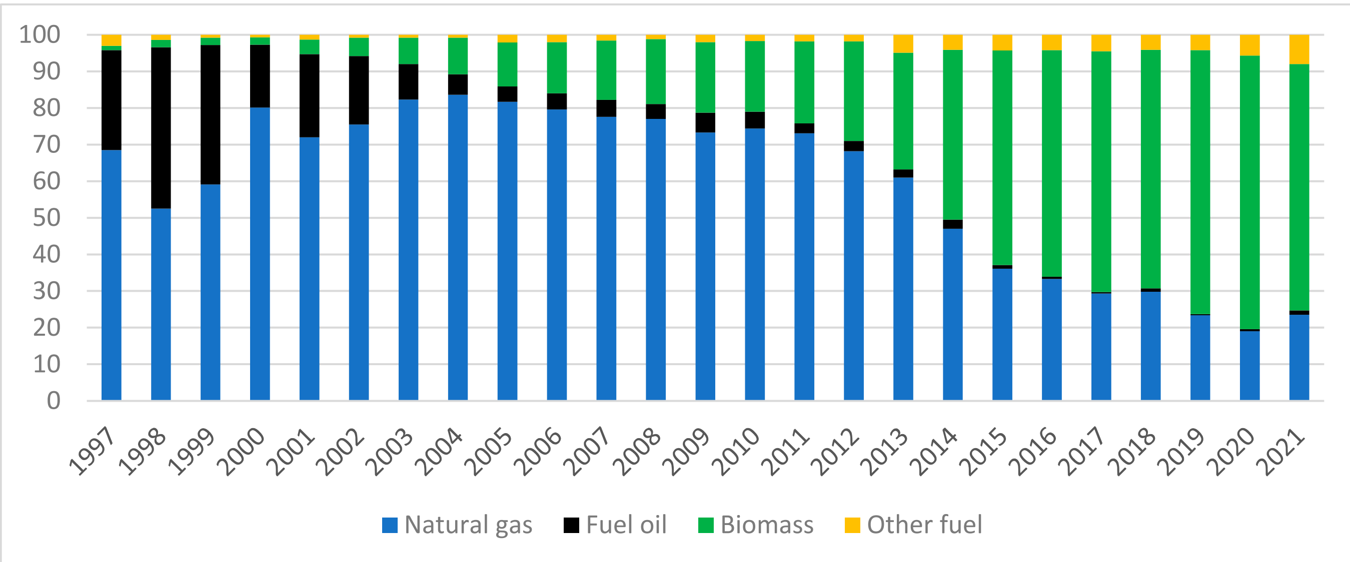

Figure 4. Lithuanian heat-energy balance 1997–2021 (Reprinted from Ref. [50]).

Lithuania has made significant progress in improving energy efficiency in recent years, particularly in the building sector. The country has implemented energy efficiency standards for buildings and has invested in retrofitting older buildings to improve their energy efficiency.

Lithuania was heavily reliant on energy imports, particularly from Russia. To reduce its dependence on Russian energy, the country has diversified its energy sources, investing in renewable energy and building interconnections with neighboring countries to facilitate energy trade. Lithuania's energy policy is focused on achieving energy independence and reducing greenhouse gas emissions. The government has set ambitious targets for renewable energy and energy efficiency and has implemented policies such as feed-in tariffs and energy performance standards to incentivize the adoption of renewable energy and energy-efficient technologies.

Lithuania has a history of nuclear energy, with the Ignalina Nuclear Power Plant being a major source of electricity until its closure in 2009. The government has expressed interest in developing a new nuclear power plant, but this has been met with opposition from environmental groups and concerns over the cost and safety of nuclear energy. However, the government has set a goal of achieving 100% renewable energy by 2050, and significant investments are being made in renewable energy sources such as wind, solar, and biomass.

The country's transition to renewable energy sources was catalyzed by actions taken in the past. The negative example is the abolishment of DH networks after independence. At that time, the price for heating using gas boilers was much higher than for individual gas boilers. A massive reconstruction project was undertaken by replacing DH with individual natural gas and electric boilers. However, the development of this plan has turned against users because, after a decade, the price for natural gas and oil has increased dramatically, and consumers have started to reconstruct natural gas heating systems and replace gas boilers with biomass boilers [51]. This millennium has seen a clear progression in the use of biomass. One can notice the significant progress that has been achieved in implementing RES and energy efficiency improvement targets by all Baltic countries. For example, in Lithuania, the use of biomass doubled during the 2004–2013 period [52]. Almost all the fuel used to produce energy is local; wood and industrial waste extracted from forests, soilless areas, and the wood industry were used. This situation made it possible not only to manage waste but also to turn it into a product with financial value. The need to convert the country's energy system significantly served the breakthrough of biomass utilization in Lithuania. The reasons for the conversion to biomass were unambiguous. Such a result seems to be logical, as a biomass power plant using renewable energy sources plays an important role in ensuring the country's autonomy in energy generation potential, as well as these technologies being efficient and attractive from the environment protection point of view [53]. The country's need to switch to cheaper fuel in this case was perfectly aligned with the goals of sustainable development. During this period, biomass was the main renewable source used for energy production in Lithuania. Ref. [54] studied the effect of using different fuels on electricity production. The results of the conducted research showed that the lowest electricity generation costs are for new nuclear power plants, followed by biomass- and hydropower plants. Otherwise, the biomass could also be used to fulfil other needs of industry and citizens. Wood and biofuel are the two most prospective fuels with renewable energy potential [55]. The national energy independence strategy contains clear principles where the Lithuanian energy system must be improved. The development of RES in Lithuania must be carried out in accordance with the following principles [56]:

- Gradual integration of RES in the market;
- Affordability and transparency;
- Proactive participation of energy users.

The Lithuanian energy system has achieved great progress in the field of heat production. However, there is a lack of electricity production capacity, and the potential of biogas is also underutilized. The development of renewable energy resources encourages the adoption of complex solutions that would allow the combining of energy production capacities. This paves the way for a fundamental transformation of the energy sector. When exploring the possibilities of transformation, first, cooperation is undertaken with innovative Lithuanian municipalities, which tend to follow the path of transformation. In this way, objective criteria will be approved, which will later allow the comparing of municipalities with each other.

3.2. Methods

The research is conducted based on the "research by design" formula. In this case, it builds on good practice from previous research, while identifying key areas for improvement. The selected data groups will enable the creation of a database, which will enable the comparison of the regions of the countries. Research by design is any kind of inquiry in which design is a substantial part of the research process. In research by design, the design process forms a pathway through which new insights, knowledge, practices, and products come into being. Research by design generates critical inquiry through design work that may include realized projects, proposals, possible realities, and alternatives. Research by design produces forms of output and discourse proper to disciplinary practices, verbal and nonverbal, that make it discussable, accessible, and useful to peers and others [57]. In the case of energy transformation research, knowledge will be collected about the resources available to municipalities, the possibilities to manage projects, and information on loans and borrowing. Energy systems are changing, and it is important to quantify and assess those variations, measuring the progress toward the established goals. Indicators can be a useful tool to achieve that purpose. Indicators can analyze energy systems globally, such as the energy mix for a given country, considering the different sources of energy: fossil (fuel, coal, and gas), nuclear, biofuels and waste, renewable (hydro, solar, wind, geothermal, etc.), or parts of the energy system (renewable energy sources). Another indicator is energy dependence, which is important because it can significantly affect the development of countries since it increases their vulnerability to price instability and supply ruptures. The share of renewable energy in the gross final energy consumption is an important indicator since it can represent the pathway to lower carbon energy systems [58]. At the same time, specific solutions will be sought to achieve a positive impact on energy with the lowest costs. Finally, the investment plans of municipally run companies will be reviewed in order to bring them closer to the principles of sustainable development.

The team of researchers are currently cooperating with four Lithuanian municipalities, which are provided with consultations on energy transformation issues. Communication was carried out in February–December 2022. During the consultations, specific transformation plans were drawn up, which included specific solutions that promote the growth of green energy. This is related to increasing the efficiency of asset utilization, applying new technologies, and improving governance in municipal enterprises. At the same time, the main disturbances in the transformation process, which prevent municipalities from accelerating the pace of change, were analyzed. The disturbances will later be standardized to find correlations between municipalities. This will be followed by an assessment of the impact of disruptions in monetary terms, as well as the impact of certain transformation decisions on individual territories. When drawing up transformation plans, there is communication with the management of the municipal administration, the boards of municipally managed companies, and public associations. This is aimed at extracting the expectations of all interested parties, then evaluating them according to economic, social, and environmental logic. The initial results revealed the main aspects of the energy transformation analysis, as well as the main obstacles to the development of green energy in municipalities.

4. Results and Discussion

4.1. Preparatory Aspects

Energy transformation implies major changes both in the municipal infrastructure and in changing public life. In order to achieve optimal investments, it is necessary for institutions, financiers, and society to focus on a common goal. The energy transformation in Lithuania is hindered by the lack of cooperation between science and business, low competences of the public sector, and the influence of interest groups. Working with innovative municipalities and company boards allows the application of scientific knowledge to strengthen regions and solve social problems. At the same time, it allows for the identification of the main directions of change, which can later be used to promote the development of economically weaker municipalities.

The first discussions with stakeholders formed the problem of the situation. There is a clear divide between the previous, post-Soviet management and the new corporate culture. The latter enables all employees to propose relevant ideas, the decision-making process is decentralized, and the influence of the board is proactive, promoting progress. This is fundamentally different from the centralized, post-Soviet governance, where assumptions of corruption are possible. During the discussions, indicators were singled out that will allow us to assess the current state of the municipality, as well as the prospects for transforming unused assets into sources of energy production. Municipal companies are engaged in the following services, which are relevant in the energy transformation process:

- Heat production;
- Water supply and sewage treatment;
- Transportation of passengers by bus;
- Waste management;
- Housing and environmental care.

In principle, all these areas either use or have the potential to use renewable resources. Some sectors generate waste that can be used as fuel (wastewater treatment, waste management, and environmental care). This situation makes it possible to search for joint activities and carry out circular economy activities in the municipality. Since these companies are made up of municipal capital, proper corporate governance is a prerequisite for the success of the processes. The problems of the management of municipal enterprises formed the initial assumptions of the research. The main directions of the researchers' assessment are related to the following aspects:

- How could companies, managed by municipalities, contribute to energy transformation?
- What synergies could be possible between the activities carried out in the municipality?
- How is the organic waste generated in the municipality used?
- How could the management of municipal companies influence the pace of change?
- How are assets used by the municipality and its companies?

During the communication with the municipalities, clear areas for improvement emerged, to which the management's attention and investments must be directed. These directions will allow the generation of the necessary data, thus creating a comparative base with other municipalities. All the investigated municipalities are managed by companies that are engaged in the previously mentioned communal activities. Management of municipal activities allows us to obtain standardized answers about the prevailing situation in municipalities. When studying the municipalities of Lithuania, these main problems were encountered:

- Assets of municipalities related to energy activities are managed through municipal companies. While studying these companies, it was noticed that some of the companies do not have a board. This reduces the accountability of company managers and creates conditions for inefficient project management or corruption. The absence of boards stifles innovation, creating the risk of a slower pace of change.
- Synergies between water treatment and heat production companies are not yet sufficiently exploited. The resulting dried sewage sludge is not sufficiently used as a renewable fuel. In addition, not all sludge is properly dried, so it cannot be used either as fuel or as fertilizer.
- The municipality has not always approved specific plans, specifying which areas are priorities for the development of renewable energy.
- The majority of municipalities do not undertake energy efficiency projects that would allow them to produce electricity independently, and heat-saving projects are implemented at a slow pace.
- There is not enough synergy between private and public business, e.g., biogas from agricultural waste is not used for city buses or heat production and supply.

4.2. Determination of Energy Transformation Priorities in the Regions

Complex challenges are faced in order to transform regional energy systems. In one case, it is necessary to secure the necessary financing for the installation of new facilities.

Otherwise, human competences are required for the successful implementation of projects. However, the most important component of energy transformation is prioritization. Resource constraints make it difficult to complete all the necessary projects at once. Mitigation scenarios focusing on wind and solar power are more effective in reducing human health impacts compared to those with low renewable energy, while inducing a more pronounced shift away from fossil and toward mineral resource depletion. Conversely, non-climate ecosystem damages are highly uncertain but tend to increase, chiefly because of land requirements for bioenergy [59]. In working with municipalities, the following main priorities were established in the tactical period (1–3 years):

- Changing management structures (professional boards with a majority of independent members);
- Approvals of energy transformation plans;
- Electricity production for own needs is increased up to 100 percent;
- Solar power parks are being created to serve municipal entities;
- Specific energy transformation plans are being developed in the heat, water, and utility sectors.

The impact of renewable energy is unique, in that the first steps can already be taken in the tactical period. This applies to the assessment of solar energy—the design of solar parks is much simpler than in the cases of wind, biomass, or biogas. In this case, a stable supply of equipment, land, or roofs is required. In Lithuania in 2022, a solar park on a roof, including the necessary permits, was installed in an average of 9 months [60]. Currently, half of the examined municipalities are engaged in the use of solar energy either for their own needs or in the implementation of solar park projects. The change in the situation was prompted by the increase in electricity prices, when in May 2022, the price of electricity per MW on the NordPool Spot exchange was EUR 400. At the same time, the hourly price record was reached—4000 EUR/MWh [61]. The actions of the municipalities to control the sudden rise in prices were quite limited by the lack of free monetary funds. The behavior of municipal enterprises differed because of the types of boards. In the case of political trust boards, action was significantly slower than in professional boards with independent members. In the latter case, specific actions were taken:

- Ordinances have been established to ensure the permeability of electricity networks in the case of new solar power plants;
- New solar power plants are financed by selling unnecessary assets not used in the main activity;
- Energy efficiency projects are carried out, identifying energetically inefficient activity chains.

These specific actions created a dual effect. First, they made it possible to increase the energy independence of companies, while saving the financial resources of shareholders—municipalities. These could have been directed to the solution of social problems, covering part of the electricity prices for budgetary institutions. Second, the energy difficulties made it possible to review the asset structures of companies, discarding unnecessary assets that were not realized for unknown reasons. This made it possible to mobilize funds and order the components needed for solar power plants. In the first quarter of 2023, the studied municipalities had a 700 kW power generation capacity, which allows the production of 750,000 kWh of electricity. Currently, projects are being initiated that would increase the solar energy production capacity by another 3 MW. The use of electricity is most relevant in water treatment companies, which need electricity to service sewage treatment plants and ensure water supply. Due to a sharp increase in electricity prices, all Lithuanian water supply companies in 2022 became unprofitable [62]. Currently, in three of the analyzed municipalities, the installation of solar power plants on the roofs of buildings is being considered; one municipality is planning to install power plants on water production lands where there are large areas of unused land.

Currently, several municipally managed companies have set goals either to produce 100% of the required electricity or to acquire a remote solar park that would meet part or all of the energy needs. At the same time, the possibilities of asset conversion are constantly being investigated, realizing assets that are not needed in the main activity. Synergies with other municipal companies are being sought by combining activities (common waste collection, hot water production, etc.).

During the tactical period, energy transformation actions can be implemented particularly smoothly. Due to the smooth design process and fast delivery of components, the development of solar power plants is significantly faster compared to other types of renewable or fossil fuels. Further stages of the energy transformation include wider infrastructure conversion and better utilization of waste. These processes require significantly longer time, especially because of design and bureaucratic constraints. The latter are related to both municipal and state restrictions and inefficient bureaucratic processes.

4.3. Compilation of the Energy Transformation Plan in the Strategic Period

In the strategic period (5 years), after properly exploiting the opportunities to expand solar energy, necessary decisions related to better utilization of municipal assets are needed. The discussions envisage the pursuit of complex actions—not only the development of infrastructure but also the increase in operational efficiency. For that purpose, it is planned to expand the scope of hybrid work to reduce the number of buildings used in the activity. Funds received for excess premises can be used to strengthen energy independence.

Lithuania has a strong biomass processing sector, which concentrates the entire supply chain from biomass processing to the production of biomass power plants. However, there is a relatively small number of cogeneration power plants in Lithuania. In strengthening energy self-sufficiency, it is necessary to develop biomass cogeneration capacities in medium-sized cities (>20,000 inhabitants). The cycle of biomass power plants is 15–25 years. The peak of biomass energy development in Lithuania was in 2010–2012. Working with municipal companies made it possible to clarify priorities when investing in heat production. The aim is to turn central biomass power plants into cogeneration plants capable of producing heat and electricity at the same time. This would make it possible to reduce the electricity production problems prevailing in Lithuania, while at the same time making better use of biomass.

In addition to the heat production sector, which is relatively developed, the focus is on the further development of other sectors. In the strategic period, it is necessary to increase the contribution of municipal enterprises to the implementation of the European Green Deal. The task plan is established based on communication with municipalities. The financial plan will be determined in future research, when data on potential operating income and incurred costs will be collected. The following challenges of the strategic period have been identified:

- Utilization of synergistic effects (combining different technologies, production of several types of energy, and governance transformations);
- Adaptation of the heat sector to clean production;
- Adaptation of water treatment facilities for sludge preparation;
- Reorganization of the transport system using biomethane, hydrogen, and other sustainable fuels;
- Development of the waste collection mechanism, including food waste;
- Modernization of lighting systems;
- Application of geothermal heating combined with solar energy;
- Appropriate use of electrical power.

Exploitation of synergistic effects is associated with better utilization of energy resources. Currently, one municipality is working on a pilot project in which sewage sludge and urban green waste would be treated in one facility. The extracted biogas would be converted into biomethane, which is then used for city buses. The remaining dried sewage sludge would be used either for fertilizing land areas or as fuel for the only cement factory in Lithuania, replacing coal. In the latter case, the use of fossil coal in Lithuania would be reduced to a minimum. The wider use of sludge as a renewable fuel requires the improvement of legal acts in Lithuania. Likely, different opinions will not be avoided until generally accepted strategic goals can mobilize various stakeholders and unify justification for the transition toward a sustainable energy sector [63].

Another important segment of changes is the improvement of lighting systems in municipalities by installing LED lighting solutions. Several municipalities in Lithuania apply the ESCO model, which allows the modernization of city lighting systems with private funds. An investment contract is concluded between the municipality and a private investor, which stipulates that the municipality will pay the investor the difference between the electricity price paid and the savings received during a certain period. The investor undertakes to invest in municipal lighting systems by installing LED solutions. In this case, energy savings are achieved, thus enabling the installation of smaller power generation capacities.

In addition, it is necessary to develop charging stations for electric cars, using the free power available in the networks at a certain moment. When installing LED lighting, it is possible to install devices on lighting poles that would provide the opportunity to charge a car in a parking lot, on the streets, near public buildings, etc. This would make it possible to make better use of the electricity network and reduce excess investments in increasing the power of certain selected objects. Power management would be undertaken with the help of software. In Lithuania, this technology has already started to be implemented in the capital city of Vilnius, when the power of offices or lighting poles is used with the help of software at a time when this power is not used for the main activity [64].

In order to achieve further synergistic effects, it is necessary to make waste collection more efficient, by producing solid recovered fuel from solid waste, and extracting biomethane from biological waste. Solid recovered fuel is suitable for waste incineration power plants. Of course, to achieve the principles of sustainable development, it is necessary to ensure the largest possible volumes of waste processing. In addition, it is necessary for Lithuania to use the potential of geothermal energy. Lithuania is characterized by large geothermal water resources. In western Lithuania, geothermal water resources up to a depth of 2 km in the mentioned area amount to 1450 EJ [65]. A combination of geothermal energy and solar energy can produce large amounts of green energy for households. By utilizing the available resources, municipalities can fully supply urban areas with energy. In addition, with economic and practical incentives, municipal residents living in nonurbanized areas can switch to using clean and ecological solutions.

5. Concluding Remarks

During the preparation of energy transformation plans in Lithuanian municipalities, there was a lack of certain data, as well as the reluctance of individual municipalities to share strategic development plans. For this reason, for the initial steps of the research, it was chosen to communicate with the most proactive municipalities that are focused on energy transformation, better utilization of available assets, and more efficient work of municipally managed companies. In order to collect qualitative data, the unused volumes of assets managed by municipalities are based on the possible cost of green energy facilities. At the same time, only possible EU investments are evaluated, excluding state support.

The analysis of the scientific literature allowed us to refine the data groups that will be pooled for future quantitative research. The ongoing project will aim to create a universal energy transformation model that will allow fewer active municipalities to make decisions related to increasing energy independence. Communication with proactive municipalities made it possible to verify the theses highlighted in the scientific literature, while supplementing them with relevant practical insights. During the communication, a clear guideline was emphasized—the search for synergistic effects and their implementation. It will take place through the cooperation of municipal companies, budgetary institutions, and the administration of municipality.

The significance of this initial project:

- The main data groups that will be used in future research have been compiled;
- An initial study was carried out, allowing orientation in the variety of technologies; this will create conditions for determining optimal technological combinations for the transformation of municipal energy systems;
- Refined ideas on how to increase operational synergy between different companies managed by the municipality;
- Sources of waste and resources formed in municipalities, which are suitable for green energy production, have been identified.

Novelty and practical value of the obtained results:

- Defining the importance of professional boards at the municipal level;
- Development of a change concept based on the principles of ESG and the use of local resources;
- Extraction of synergistic effects by using local renewable resources;
- Solutions for increasing the efficiency of electricity production and consumption (centralized supply to public institutions and investments in energy-saving solutions).

Major limitations of the study:

- Difficult cooperation with other municipalities because of a fundamental reluctance toward positive changes;
- Limited amounts of change budgets depending on the economic capacity of the municipality;
- Lack of standardization of governance of municipal enterprises;
- Lack of data related to property managed by municipalities in other municipalities;
- Time consumption for data standardization in the investigated municipalities.

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