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Research Directions of the Energy Transformation Impact on the Economy in the Aspect of Asset Analysis

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Abstract: The challenges of climate change encourage immediate solutions by creating the conditions for energy transformation. This process is significantly related to capital investments and the conversion of existing assets to clean energy sources. Due to the need to save resources, workplaces, and public favor, specific studies involving different data groups are necessary. This article presents key data sources for analyzing the impact of energy transformation on Lithuanian regions—governance, potential, and existing power indicators. The economic, social, and governance data combined in the article will allow us to determine the perspectives of sustainable energy transformation in the regions. The article showed that in certain regions there may be major, complex problems that hinder the breakthrough of the energy system. Cluster analysis and a generic system diagram were used for the research, which showed that municipalities have a wide potential for energy transformation. The research emphasizes the governance component as a key success factor. After reorganizing the management of municipal enterprises, further actions can be initiated, since emerging competences allow progress to be made efficiently and with less time spent. The asset analysis methodology presented in the article allows for the identification of the main groups of assets that can be converted in the short term for the purpose of energy transformation, according to sustainable development principles. These decisions provide an opportunity for decision-makers to consistently implement energy transformation decisions.

Keywords: energy transformation; sustainable development; asset analysis

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1. Introduction

The transition to renewable energy fundamentally changes the economic situation of states and their regions. Countries that do not have their own fossil resources have the opportunity to exploit abandoned land areas for solar energy or employ wind power. In the era of zero-waste production, natural biological waste can be converted into heat, electricity, or gas. Energy transformation creates wide economic opportunities, but there are also certain risks. They are most visible in regions rich in fossil resources and in the workplaces created for their extraction. The assessment of the transformation process is particularly important in order to preserve the environment and develop economic volumes. In this case, it is necessary to note that energy transformation is fundamentally inseparable from changes in the economic structure. The transition to renewable resource consumption has a tangible impact on the economy in particular ways. First, the key aspect of energy transformation is energy independence. By relying more on renewable resources like wind, solar, and hydropower, countries can reduce their dependence on non-renewable resources and foreign energy units. This can enhance energy security and reduce trade deficits [1]. Energy independence ensures resilience and energy stability. It can reduce economic vulnerabilities associated with energy supply interruptions [2]. Energy independence, in turn, promotes economic growth. Renewable energy infrastructure projects, such as building wind farms or solar installations, require significant capital investment, which can boost economic activity in the regions where they are located [3]. At the same time, it promotes high-tech development. In the case of developing countries, this can be achieved through the development of solar and biogas technologies, as well as software for power plant management. It forms synergies effects—regions that prioritize renewable energy can attract investment from clean energy companies, financial institutions, and venture capitalists, further bolstering the local economy [4]. Many renewable energy projects are located in rural areas, providing economic opportunities in regions that may have experienced economic decline [5]. The use of renewable energy based on local resources would revive the economic condition of the regions and stimulate social life.

Another important aspect of energy transformation is related to the increase in efficiency and positive impact on the environment. In 2023, USD 1.7 trillion will be invested in energy efficiency worldwide, with almost half of the amount allocated to manufacturing capacity (USD 659 billion). Only 377 billion USD is allocated to efficiency activities [6]. Increasing efficiency would enable the transformation goals to be achieved faster than just the development of new infrastructure. Due to the decrease in energy imports, monetary funds remain within the country and can be used to solve social and environmental problems. Although there are upfront costs associated with transitioning to renewable energy, it can lead to long-term cost savings as fossil fuel prices are subject to volatility, while renewable energy costs tend to be more stable [7]. In addition, there is an important synergy: decommissioning fossil fuels improves the condition of the environment. The transition to renewable energy helps mitigate climate change and reduce air and water pollution. These environmental benefits can lead to healthcare savings and increased agricultural productivity, indirectly impacting the economy [8]. All these elements form the basis for sustainable development based on sustainable energy sector progress.

The transition to renewable energy (RE) is a complex, multidirectional process that includes different components from economic, social, and environmental perspectives. The impact created by the transition towards renewable resources is primarily related to a change in the behavior of consumers and producers. Production capacities are changed, and employees must be retrained for the required positions. The impact on the labor market is one of the key indicators for evaluating the conversion potential of RE. Early research reveals the relevance of this topic. Net employment effects are positive but small if labor markets are rigid and additional workers cannot be easily mobilized from the pool of unemployed. In such a case, additional production is made possible by an increase in productivity. Then, it could be concluded that the net employment effects of renewable energy expansion strongly depend on prevailing labor market conditions [9]. The loss of workplaces or the need for retraining was one of the main reasons for of questioning the possibilities of implementing the energy transformation. Other studies evaluate the conditions that allow the positive effects of RE utilization to be achieved. Positive net employment effects strongly depend on the further growth of global markets and the country's RE exports. Another important factor for employment impacts is expectations of future cost reductions of different RES technologies [10]. The export of technology has allowed certain countries to take a leading position in the supply of power plants using renewable energy sources. However, unlike the use of fossil fuels, each country can have a clear impact on the use of RE technologies, as local resources are used to produce energy.

Previous scientific works analyze causal relationships between different elements—renewable energy and labor market/economic growth/additional income. However, scientific works have not examined the possibilities of better use of local resources and existing infrastructure, as well as the possible contribution of regions to the transformation. Regions are characterized by an abundance of unused resources, and these, converted into energy, can help solve the regions' energy or even financial problems if the energy is sold outside the region. This article emphasizes the impact of energy transformation on regional economies by analyzing different data groups.

The main problem of the article is how to accurately determine the priorities of sustainable energy transformation when the need for investments in the short term is necessary in all directions.

The novelty of this article is related to its clear orientation to the regional dimension. In this article, directions are indicated on how energy transformation activities can be initiated without significant investments. For this, first, changes in governance are necessary, followed by the utilization of internal resources by municipally managed companies. In addition, the focus is on sustainable investments; the aim is, first of all, to make maximum use of existing resources.

The article aims to justify the necessity of utilizing the assets in the regions, thereby reducing the need for borrowed funds. At the same time, opportunities are being sought to use existing infrastructure units, adapting them to the production or consumption of renewable energy. The use of internal resources creates conditions for cost savings as well as a faster transformation process. The aim of the article is to determine the possible directions of energy transformation in terms of managed assets, using different data from economic, social, and political perspectives.

This research is continuous, consisting of four research phases (Figure 1). This article presents the second phase of the study, which analyzes the specific data and looks for the necessary connections. Later, they will be used to create a universal energy transformation model focused on the use of resources in the regions. The first study identified the most important data groups [11], on which the database is focused. The study is based on the case of Lithuania, since the country has been on the path of energy transformation for more than 15 years and is currently in the final phase of transformation. The aim is to encourage sustainable energy production using renewable resources, waste, and energy from water treatment waste, data servers, etc.

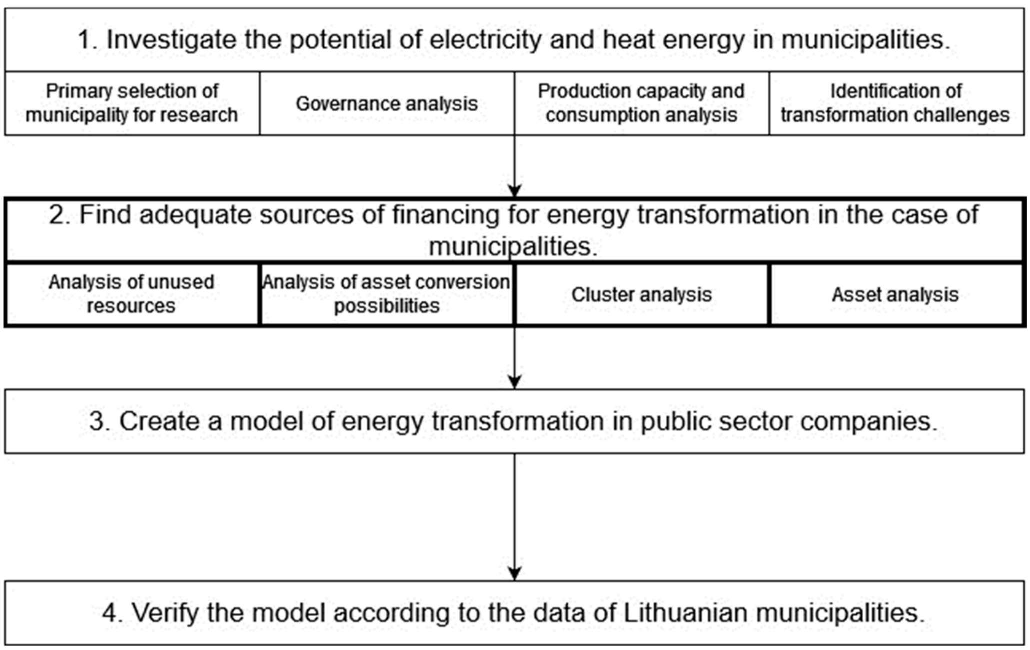

Figure 1. Energy transformation research structure. This article analyzes the second objective.

Next, this article presents the development trends of the energy system, evaluated from the perspective of renewable energy. They are used to find elements that will later be used for cluster analysis. After the analysis, the most problematic municipalities with the greatest potential for energy transformation are identified. An asset management system is formed according to the assets they manage, which will be the axis of future research.

2. Literature Review

2.1. The Potential of Energy System Conversion

In the 20th century, the developed energy system was based on the use of fossil fuels, essentially without limiting the production of energy or the use of resources. In the 21st century, faced with serious challenges caused by climate change, the functioning of the energy system must be fundamentally changed. New concepts such as demand-side management and energy storage in batteries are emerging, and the need for energy system balancing has increased significantly. When looking for opportunities to implement energy transformation, the use of existing infrastructure can significantly contribute to the speed of implementation of the transformation.

The dynamics of the energy system are characterized by extensive connections between different methods of energy production. Renewable energy is no exception; there are clear examples of interaction. In the case of biogas, it can be used to produce electricity or heat, to fuel cars, or to supply main gas pipelines. The use of renewable resources makes it possible to create a multidirectional impact on different branches of business. Overall, the shift toward renewable energy sources can have a tangible impact on the economy by promoting workplace creation, reducing environmental costs, enhancing energy security, and fostering innovation and economic growth. However, the specific economic effects can vary depending on factors such as government policies, market conditions, and the scale of renewable energy adoption [12]. One of the ways to increase the positive impact created by renewable energy is to search for relevant connections. Different types of fuel can be produced from one type of green energy, which would be used to supply the necessary aggregates. Figure 2 shows that interactions between different technologies can enable the energy system to operate dynamically in a competitive environment. In cases of overproduction in one energy sector, the energy produced can be transferred to fulfill the needs of other sectors. The shaded boxes demonstrate the key technological changes required.

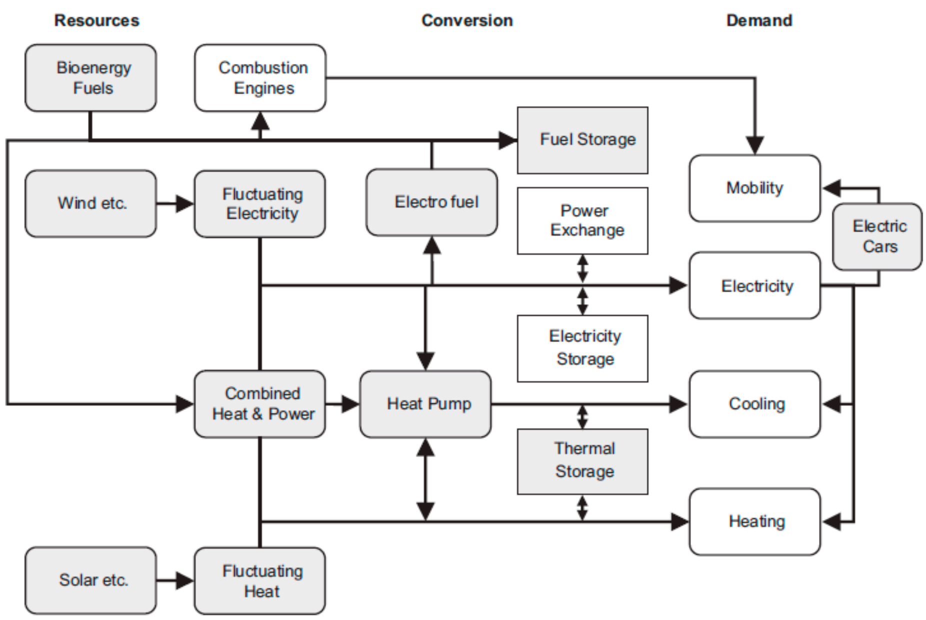

Figure 2. Interaction between different technologies in the energy system (reprinted from ref. [12]).

The potential of energy conversion is inseparable from successful political implementation. Political will is inevitably necessary to achieve the most effective implementation of transformation projects. When implementing policy decisions, potential synergies must be sought, as well as key factors that save taxpayers' funds. The policy decisions to accelerate the energy transition will need to be aligned with the development of enabling infrastructure. More attention is needed for emerging infrastructure issues such as smart charging of EVs, distribution grid reinforcements, and the role of shifting demand and smart grids. In addition, important synergies exist between higher energy efficiency and higher shares of renewable energy; both solutions should therefore be pursued jointly [13]. Due to the specifics of energy production, it is necessary to look at the transformation process in an extremely complex manner. When correcting one part of the energy system, it is necessary to consider other parts as well, since this can lead to the potential of saving energy and financial resources. Energy efficiency is inseparable from the success of the transformation process; infrastructure development to meet current needs is pointless and costs significant financial and time resources. Meanwhile, the negative consequences of climate change are already being felt. The expansion of renewable energies for power generation is a key element on the development path to combine low costs with low emissions. In the industrial sector, emission reductions in high-temperature heat generation exclusively require electrification, whereas for medium- and especially low-industrial heat generation, biomass can be a vital part of possible decarbonization pathways. In the transport sector, battery-powered passenger vehicles and electric overhead freight trucks are gradually replacing conventional combustion engines. The electrification of the transport sector is also reflected in the expansion of electric rail transport [14]. In the case of rail transport, greater synergies are possible—instead of sound-absorbing walls, vertical solar modules can be installed to provide energy to the railway system [15]. The reduction of pollution caused by industry and transport will essentially define the success of the energy system transformation process, since these sources of pollution have a particularly negative impact on the quality of the environment.

In addition, there are certain risks associated with implementing the energy transformation process. Conversion potential varies across countries and continents. This may hinder the faster development of the consumption of renewable resources, despite the positive political will. The need for conversion using existing assets is recognized at a global level. However, in order for decisions to be made smoothly, it is necessary to manage all the necessary processes. Clearly, the differences in energy conversion efficiency cannot be neglected. In some regions (e.g., Africa), such differences go up while the overall trend is downward. However, through the implementation of pertinent measures, there could still be scope to reach greater convergence toward a higher efficiency level in energy transformation [16]. Increasing energy efficiency would reduce the pressure on the budgets of countries and regions, while accelerating the pace of investment implementation. The importance of conversion is particularly visible in the international documents that have already been adopted. The Kyoto Protocol and the Paris Climate Change Agreement clearly regulate the actions that must be taken to avoid a climate catastrophe. The first period, according to which the achieved global progress of the energy transformation will be evaluated, is the year 2050. Today, the directions of the future transformation are already known. The energy system of the future will be based on electricity consumption. The greening of electricity production will be an essential condition for energy transformation. Figure 3 shows that, based on conservative estimates, the transformation of the electricity and heat sectors would ensure the implementation of the essential goals of the transformation. It is intended that these projects will be implemented under market conditions. A subsidy system was used for new projects at the beginning of this century. Today, the subsidy system is no longer such an effective tool, with negative effects in some cases. The system of feed-in tariffs stifles competition among renewable energy producers and creates perverse incentives to lock into existing technologies [17]. As there is clear opposition from countries developing conventional energy, the promotion of renewable energy can hold back projects. In addition, promotion directions may not necessarily be chosen for those technologies that would have the greatest positive impact on society. In order to develop new concepts, it is necessary to look for unused resources of state or regional enterprises, the conversion of which would allow the development of new innovations, especially in electricity production.

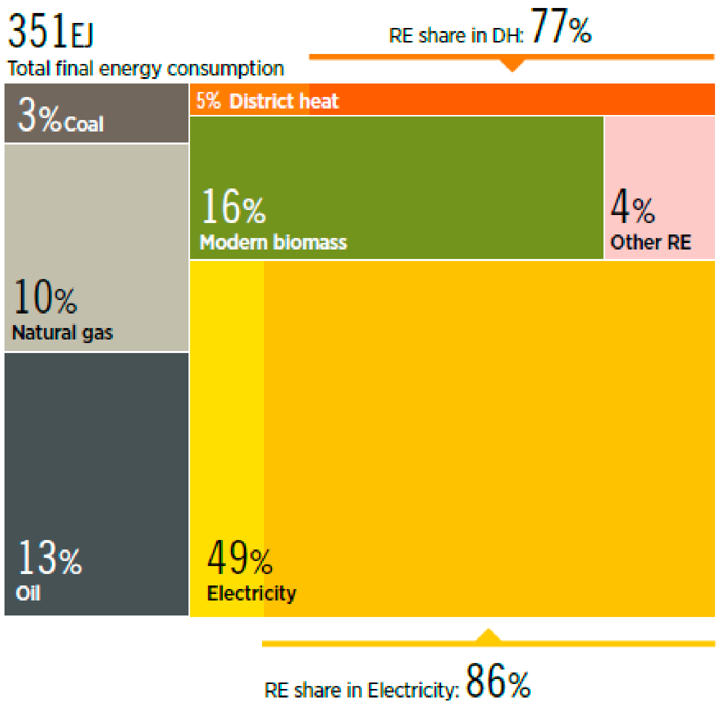

Figure 3. Total final energy consumption breakdown by energy carrier (%) system, projected in 2050 (reprinted from ref. [18]).

The necessity of the energy transformation is presupposed by the fact that it is fundamentally necessary to stop using fossil fuels. For now, it is based on the hope that it will be possible to develop productive and cost-effective electricity generation technologies. This process can take decades, so today it is necessary to act "from below" by initiating regional changes. Energy transformation based on the use of renewable resources creates a clear and calculable impact on different economic structures. In this case, it is necessary not only to establish the directions of positive impact, but also to show solutions that allow for the practical benefits of using renewable energy.

2.2. Impact of Energy Transformation on Different Economic Directions

The use of renewable resources fundamentally changes the economic situation of countries and the competitive advantages that have arisen. Early innovation creates more synergistic effects that contribute to economic growth. The impact on the economy can be assessed both numerically and qualitatively. However, the current progress in renewable energy is insufficient due to the negative impact of climate change. In order to achieve a breakthrough in energy transformation, the possibilities of further strengthening the leading branches of energy must first be evaluated and only then engaged in the development of new concepts.

One of the main positive effects of renewable energy production is the creation of new jobs. Jobs in renewable energy are related to the maintenance of power plants, the supply and cultivation of biomass, the collection of biological waste, as well as the development of new technologies. Renewable energy technologies are significantly more complex than the technologies of thermal power plants and biomass boilers. Their development requires deep knowledge of human capital, as well as the work of scientific institutions. The impact on countries transitioning to renewable energy is assessed from various perspectives [19]. investigated the contribution of renewable investment and job generation in the Czech Republic. The findings suggested the resilient dependence of employment enhancement on investment in the renewable industry of the Czech Republic. The Czech Republic is characterized by its own coal resources, but the country has a clear goal of transforming the energy system towards the use of renewable resources. Workplace creation within a country creates multi-scale impacts that are felt both regionally and nationally. Benefits occur when workers spend part of their income in the local economy, generating spin-off benefits known as the "multiplier effect". This increased spending creates economic activity (jobs and revenues) in other sectors such as retail, restaurants, leisure, and entertainment. The number of jobs also depends on how many stages of production are carried out in the region, as more jobs will be created if the materials and technologies are processed and manufactured locally [20]. Over time, the importance of workplace creation has increased as more opportunities have become available to produce energy at a competitive price. As the payback of new energy capacity accelerates, the pace of workplace creation has increased significantly. The largest workplace growth is recorded in the power plant design, construction, and maintenance sectors. The example of the Netherlands is also relevant for workplaces creation. This country makes a significant contribution to environmental protection by developing new, climate-friendly technologies. Renewable energy has the potential to stimulate growth and jobs in the Dutch economy. Other scientists expect that an additional 0.85% of gross domestic product will be created by 2030 as a result of the shift towards a renewable energy mix, with the largest effect seen in investment growth. In terms of job creation, the projection is around 50,000 new full-time jobs by 2030. This positive impact is explained by the relatively higher labor and capital intensity of wind and solar technologies compared to gas and coal plants. This creates growth opportunities primarily for domestic, but not imported, products [21]. Also, countries that excel in renewable energy technology can export their expertise and products to the global market [22]. Trends increasing the use of renewable energy resources are visible around the world. Recently, the volume of production of components using renewable resources has increased rapidly in Asian countries. These countries have favorable conditions for renewable energy; the population is growing rapidly, and the existing energy system is not yet strong enough to meet the current needs of the population. Renewable energy in Asian countries is stimulating different directions. Gross fixed capital formation, renewable energy consumption, and the labor force are valid determinants of economic well-being in Malaysia. Consequently, it can be argued that gross fixed capital formation, renewable energy consumption, and the labor force play a significant role in enhancing economic well-being in Malaysia. Renewable energy consumption enhances energy efficiency and encourages growth through upgraded technology transfer and resource distribution [23]. In the case of Malaysia, consistent decisions are being made to reduce the impact of fossil fuels while making better use of available local resources. The goal is to increase the use of solar energy by installing modules on buildings. This avoids the use of land for energy needs. Other Asian countries, especially China, have concentrated solar panel production capacities and competencies. The impact on the labor market is an important catalyst for the development of renewable energy and the energy transformation. The renewable energy sector creates a substantial number of workplaces in manufacturing, installation, maintenance, and research and development. These workplaces often offer stable employment opportunities and can stimulate local economies [24]. However, in certain countries, e.g., in coal-rich Poland, the energy transition has the potential to create a short-term decline in unskilled workplaces. Due to the avoidance of this condition, retraining solutions or the promotion of parallel businesses (biomass energy, agroforestry) are necessary [25].

The impact of renewable energy use can also be described using more general elements. One of the most important is the connection between renewable energy and economic growth. In order to justify the huge expenditure on renewable energy, the element of economic growth is one of the essential arguments. Several studies have been conducted that point to a general relationship between renewable energy and economic growth. In one case, the results provide evidence of the nonlinear impact of renewable energy consumption on economic development under different country risks (composite risk, political risk, financial risk, and economic risk). Countries with a lower composite risk have a more stable environment, and renewable energy consumption has a greater promotional effect on economic development. Similarly, a stable political environment helps renewable energy consumption play a larger role in promoting economic development [26]. An abstract conclusion is formed that there is a positive relationship between these two elements. In this study, the components of the political situation are distinguished. Politically unstable states can discredit energy transformation projects, thus undermining the development of this idea around the world. In other countries, combined studies have been conducted, investigating the synergy between different economic and social elements. In the case of Morocco, the overall figures for the economic impact on GDP range from 1.21% to 1.99% at the end of the forecasting period covered (2040), with a full-time equivalent employment effect of between 269,252 and 499,000 jobs. In conclusion, the alternative that produces the most benefits in terms of impact on GDP and employment growth would be the installation of windmills, whatever framework of exports and imports is observed [27]. Specific directions for energy transformation allow for better performance results. In the case of Morocco, energy production is possible both onshore and offshore. In the case of developed countries, similar studies have been carried out, which provide a general overview of the essential advantages of renewable energy. The cases of OECD countries also show clear causal relationships. Estimations indicate that a 1% increase in renewable energy consumption will increase GDP by 0.105% and GDP per capita by 0.100% while a 1% increase in the share of renewable energy to the energy mix of the countries will increase GDP by 0.089% and GDP per capita by 0.090% [28]. Another aspect is related to environmental pollution from using biomass or other bioenergy products. It is not uncommon to try to justify the negative effects of using biomass because burning biomass releases CO_2 that was previously recorded in trees. In the case of biogas, CO_2 is also released, but it comes from burning the even more polluting methane gas. For the production of biomass, low-value wood is used, which does not have a high oxygen production potential. This situation makes it possible to obtain positive environmental and economic effects. The statistics illustrate that bioenergy production, biomass production, energy import, energy export, and economic development have a negative association with the carbon emissions of ASEAN countries. The results show that bioenergy production, biomass production, energy import, energy export, and economic development have a negative association with carbon emissions or a positive association with the environmental quality of the ASEAN countries [29]. The use of biomass is relevant in heat production, while biogas can be converted into different types of energy according to demand.

Combining energy transformation measures can significantly reduce the consequences of climate change while supporting economic growth. This fundamentally contradicts the hitherto prevailing narrative that only the use of fossil fuels can ensure the satisfaction of economic needs. The lack of political will and the need for professional project management are holding back the breakthrough of renewable energy. At a time when it is necessary to focus resources as consistently as possible, primary research is essential. They must be focused on the problem points that, together, have the greatest potential for transformation. A clear focus on problem regions would allow resources to be concentrated, thereby maximizing economic, social, and environmental benefits.

3. Materials and Methods

To explore the potential of the regions, data related to the current situation in the regions and future prospects are used. The research is based on the principles of sustainable development, as it aims to base the impact of energy transformation on all these dimensions. First, data groups are selected that represent the energy and management activities taking place in the regions, as well as the opportunities to develop such activities on a larger scale (Table 1). The information presented in the table will allow you to find out objective directions where it is possible to achieve the fastest positive impact by utilizing the resources available in the regions.

Table 1. Research indicators [30–37].

Social Indicators	Environmental Indicators	Economic Indicators
Number of boards with independent members Approval of ESG plans of municipal companies	Forest coverage projects, ha Unused lands, ha Forestry sector incomes, thousand EUR, Area of organic farms, ha Biomass potential, toe. Sludge potential, t.	Wind and solar power plants, MW Municipal wastes for energy needs, t. Free power in electricity grid, MW Biomass consumption, % Electricity production incomes, thousand EUR

In order to assess the potential of regions, cluster analysis is used. During the analysis, the regions will be grouped according to the identified characteristics to explore their potential for the first stage of transformation. In this article, the clustering method will be able to effectively identify regions that have energy system problems. Based on this, short-term investment decisions can be made. Such regions require primary attention. The efficiency of identification is directly related to the quality of the selected indicators. Cluster analysis does not allow for econometric estimates but is designed to group objects in the space of selected indicators [38]. Cluster analysis has a wide range of applications, depending on the available data and the purpose of using it. This is related to the specifics of cluster analysis. Clustering is the process of grouping a set of objects based on some similarity measure. Each group of partitioned objects is known as a cluster. The partitioning is performed by clustering algorithms. Clustering algorithms can be categorized into partitioning methods, hierarchical methods, grid-based methods, and density-based methods. Clustering techniques are widely used in data mining, information retrieval, classification, pattern recognition, and data analysis, etc. [39]. In addition to these basic methods, there are several alternatives for performing cluster analysis. One of the main alternatives is K-Means analysis, which helps group different elements into groups according to previously selected parameters. K-Means Clustering is a method that attempts to partition existing data into two or more groups. This method partitions data into groups (clusters) so that data with the same characteristics are included in the same cluster and different data are grouped into other clusters. The iterative concept of the FCM method is the same as the K-Means method, which is based on minimizing the objective function [40]. The application of cluster analysis will enable the grouping of municipalities according to their possible energy transformation potential and speed, thus creating a basis for further transformation research.

Data from 60 Lithuanian municipalities are used for cluster analysis. According to the data in Table 1, which represent the main characteristics of municipal enterprises, the aim is to group municipalities in such a way that it is possible to identify directions of immediate impact. According to the wide data coverage, the objective direction of the primary transformation actions is determined since it focuses on those regions where the short-term potential will be the highest. Potential is assessed not only through physical indicators but also through governance and ESG dimensions. This will project the speed of implementation of changes and determine the reasons why changes are not happening at this time. The data analysis aims to identify the guiding directions where the energy transformation model should first be applied. After forming the core of the investigated municipalities, the main characteristics of the municipalities will be systematized. According to this, a universal energy transformation model will be developed, which will allow municipalities to move towards the use of renewable energy faster and more sustainably. The purpose of the cluster analysis in this case is to identify the municipalities that have the most obstacles to the implementation of the transformation, and based on their example, to create a financing mechanism for the transformation. The most relevant, 2022, is used for the study data, arguing that today's energy sector environment is extremely volatile. It is pointless to use older data because, during 2015–2022, the country invested more in purchasing building permits and equipment. Data are drawn from different databases as they cover a wide range of items.

With cluster analysis data, asset analysis is undertaken. Asset analysis in prospective municipalities will allow us to find out the possibilities of financing as well as asset conversion. Financing of the energy transformation will be carried out from the own funds of entities in municipalities (by converting assets or developing profitable activities) and borrowed funds (by taking loans, issuing bonds, etc.). The asset analysis method is useful to systematize the structure of the entity's assets while investigating borrowing possibilities. Asset structure illustrates the amount of assets that can be used as collateral [41]. In this article, asset analysis is used for a specific task: to identify unused assets of municipalities, inefficiently used energy production plants, as well as borrowing potential. This is considered the basis of the energy transformation since the efficiency of the structure of the assets in the regions allows for reducing or even eliminating the need for state investments. In the selected regions, a detailed analysis of the assets of municipally managed utility companies is carried out, identifying the strengths of the companies and the assets that can be converted into new energy production units.

Asset analysis is a less frequently used research method focused on very clear and specific goals. It is suitable for analyzing the asset structure of both the private and public sectors. Asset analysis is a critical process in financial management, involving the evaluation and assessment of various assets to make informed investment decisions. This analytical approach employs quantitative and qualitative methods to gauge the potential risks and returns associated with different asset classes. The primary goal is to optimize portfolio performance and achieve specific financial objectives. Asset analysis extends to various asset classes, including stocks, bonds, real estate, and commodities. Each asset class has unique risk and return characteristics, necessitating tailored analytical approaches. In the case of municipalities, based on the principles of sustainable development, the focus is on the search for convertible assets and the utilization of borrowing potential. These actions would allow the energy transformation processes to be significantly accelerated with the smallest capital investments.

Asset analysis is significantly related to asset management. This practice is particularly used in the private sector, but responsible asset use practices are also seen in cutting-edge municipalities and states. One of the most important rules is the constant review of available assets and the assessment of the efficiency of their use. At the same time, other factors are also important. Tangibility (asset structure) is an important factor in corporate funding decisions because tangible assets act as collateral, provide guarantees for lenders in the event of financial difficulties, and provide a comparison between fixed assets and total assets [42]. Considering these factors, it is possible to create an adequate asset structure that allows the implementation of energy transformation ideas [43–45]. Property reviews in selected municipalities will be conducted based on public data. The focus is on municipally managed companies, their infrastructure, and their borrowing potential.

After the formation of certain asset groups, a structure is finally created that allows controlling the energetic transformation processes of this stage. The structure is created based on a generic system diagram. It includes key performance aspects such as external and internal factors, action tactics, and value creation [46]. This diagram will outline opportunities and challenges that occur during the energy transformation in problematic regions of the country. Because the diagramming approach is systematic, it allows for a more accurate prediction of possible risks and possible directions of impact [47]. This diagram will serve as a basis for further research, allowing for an empirical assessment of the potential of energy transformation.

4. Results and Discussion

4.1. Cluster Analysis

2022 are used during the cluster analysis. data summarizing 60 Lithuanian municipalities. The R package is used for analysis. Since the data groups are sufficiently different, the indicator values are converted according to the Z-Score to unify them. By unifying the values of the indicators, distortion of the results will be avoided. When performing cluster analysis, an important result is achieved: municipalities are evaluated not only through the economic definition of sustainability, but at the same time, the social and environmental impact of sustainable initiatives on the regions is consistently presented. This solves an important scientific problem: sustainability is often evaluated only according to the economic form, without emphasizing the importance of social aspects or the public's interest in living in a clean and transparent environment. Figure 4 presents the main results of the cluster analysis, expressed according to the regions of Lithuania, showing a clear regional distribution and direction of activity priorities.

Figure 4. Results of cluster analysis in the case of Lithuania.

The figure shows that all municipalities are divided into three clusters. Cluster 1 includes municipalities that are characterized by a relatively well-developed heat economy sector, but there are unexploited opportunities to develop electricity production (based on the data on free power in the electricity grids). These municipalities have relatively smaller governance problems; most of the municipal enterprises have boards with independent members. In the cluster, municipalities have above-average forest resources and relatively small areas of abandoned land. The energy progress of these municipalities is largely related to the development of their own electricity generation, especially in terms of solar and wind energy.

Only one municipality participates in Cluster 2, the city of Vilnius. It is a capital city municipality characterized by high energy consumption and other opportunities to develop its own energy capacities compared to other clusters. In this municipality, there are no large vacant land areas for solar and wind energy, as well as abandoned lands and forests. However, this municipality has fundamentally different possibilities for energy transformation. Building roofs and walls can be used for local energy production. In addition, political projects are already being developed in the municipality that allow for the recovery of heat from the sewage network. There are various energy-saving options related to power balancing, heat utilization of servers, and the development of cooling networks. The municipality of the second cluster has an exceptional corporate culture; all companies in this municipality have independent board members, and ESG plans are prepared and strictly followed. The waste generated in the municipality already meets a significant part of the energy needs. A greater development of green cogeneration would enable faster achievement of energy self-sufficiency goals.

Cluster 3 municipalities have a huge perspective for the implementation of short-term energy transformation goals. The third cluster shows concentrated problems, the solution of which would create a positive impact on the whole country. First, most municipalities still use imported fossil fuels for heat production. The municipalities of the cluster have all the conditions to provide themselves with local biomass—the forest cover of the municipalities is higher than the national average, and the amount of abandoned land is 5–7 times higher than the indicators of the rest of the country. In the latter case, it is possible to exploit biomass resources that are not useful for industry. In these regions, there are fundamental governance problems: municipal companies either do not have boards or do not have independent members. ESG plans are also not in place. Due to the complex negative situation, electricity grids are not fully utilized, and thus wind and solar energy are not developed. The number of organic farms in the cluster is higher than average, but their potential to produce biogas is not fully exploited. These complex problems basically prevent the municipalities of the cluster from achieving an energy breakthrough and solving current social problems. The unexploited potential of internal resources leads to the fact that, in the long term, cluster municipalities will lose competitiveness in the context of the entire country. Energy transformation initiatives should be focused on these municipalities since the elimination of problems in this cluster would provide valuable experience for solving problems in other regions or countries. In this and the following studies, the focus will be on solving the problems of municipalities belonging to the third cluster. This action will allow us to focus on a clear sample and study the complex positive impact on the regional economy and social cohesion.

In the future, focusing on energy transformation actions in Lithuania, two-speed transformation plans must be drawn up. The municipalities of Cluster 3 must implement the transformation faster, as they have complex infrastructure and resource use problems, as well as management problems. As the solution to the problems of the third cluster progresses, it is possible to start solving the problems of Cluster 1 related to the production of local electricity. Cluster 2 (Vilnius) must have a separate energy transformation plan focused on housing efficiency projects, decentralized production, and better utilization of local waste.

In the next phase of the research, the focus is on the municipalities in the third cluster, which have structural development problems. In order to identify opportunities for financing and expanding the use of renewable energy, an analysis of assets managed by municipalities is carried out. The purpose of this analysis is to identify opportunities for short-term energy transformation initiatives, while creating a basis for long-term actions. Carrying out the transformation based on the principles of sustainable development creates the need to first analyze not the development of new production volumes but to study greener alternatives for the use or conversion of existing assets. The study of the property structure of the most energetically inefficient municipalities will create conditions for understanding the extent of the efficiency of the energy system and finding even single possible cases of the use of inefficient assets.

4.2. Asset Structure Analysis

Asset analysis is focused on assessing the asset structure of problematic Lithuanian municipalities (Cluster 3). In this case, the possibilities of converting existing property units are analyzed, alongside with investing and using borrowed capital. Asset conversion involves the realization of unnecessary infrastructure as well as the sale of unprofitable municipal enterprises.

The structure of the analyzed Lithuanian municipality properties is quite similar. It consists of real estate managed by municipalities, shares in municipal companies, movable units, and other smaller groups of assets. This is a grateful situation for evaluation, since these municipalities are characterized by a similar area, number of inhabitants, and problems. Analyzing the financial statements of companies managed by municipalities shows that the income from assets is relatively low. When examining individual cases, it was noticed that municipal companies not only have a lot of depreciated assets but also assets that are not related to the main activities of the companies (apartments, recreation rooms, etc.). This allows for significant asset conversion potential.

The initial stage of asset analysis consists of the identification of assets suitable for energy transformation. After reviewing the public data of the municipalities, it can be seen that the potential for using the existing assets is high, and the existing assets can be put to good use. Figure 5 presents the main actions that would accelerate the potential of transformation in problematic municipalities. These actions are condensed into action groups, according to which a specific asset management plan will be developed. The scope of the first task (SELL) includes the sale of all possible redundant assets. These assets are of a particularly wide spectrum; they can be unused equipment, unused premises, old power plants, unsuitable for conversion, or other assets not used in direct activities. A concrete and objective review of the assets of companies managed by municipalities would allow for the formation of sustainable initial capital for further sustainable investments. These assets must be immediately realized at the moment when the investment plan is prepared. Realization is recommended to be carried out through public electronic auctions. Another group (CONVERT) is directly related to sustainability; the possibilities to convert or improve the existing infrastructure are analyzed to switch to green energy production. This can include the use of old coal power plants or upgrading gas power plants by building facilities suitable for storing and burning biomethane. Another option is also possible: the use of existing foundations for new construction after they have been substantially strengthened. However, the conversion of energy production will not be fully successful without a large-scale renovation program. With its assistance, ecological insulation materials could be used, and more efficient houses would consume less energy. In addition, other alternatives (FINANCING) are necessary, related to the distribution of shares of municipally managed companies and better use of borrowing potential. This would allow for the attraction of additional capital, which would be invested exclusively in renewable energy. This will be guaranteed by the distribution prospectus of shares or bonds and approved investment plans.

According to these tasks, a plan for the use of existing assets is prepared, including the use of borrowed capital. The plan is created based on a generic system diagram. When creating an asset management plan, internal and external factors are included that affect the scope of asset utilization and, at the same time, the timing of the start of the energy transformation. Connections are formed between the components. This will allow you to focus on the most important tasks while identifying the areas of greatest change. The plan presented in Figure 6 is complex, but its implementation requires consistency; without mobilizing all available resources, transformation activities may be delayed, thus further contributing to higher levels of environmental pollution.

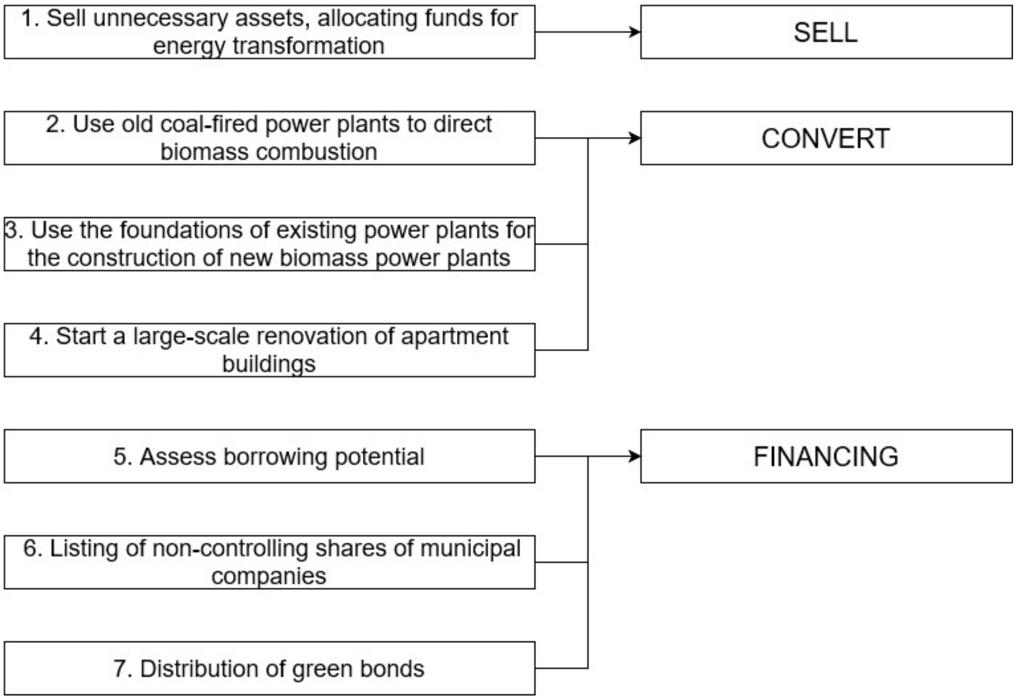

Figure 5. Tactics that enable the formation of the potential for the use of assets by municipally managed enterprises.

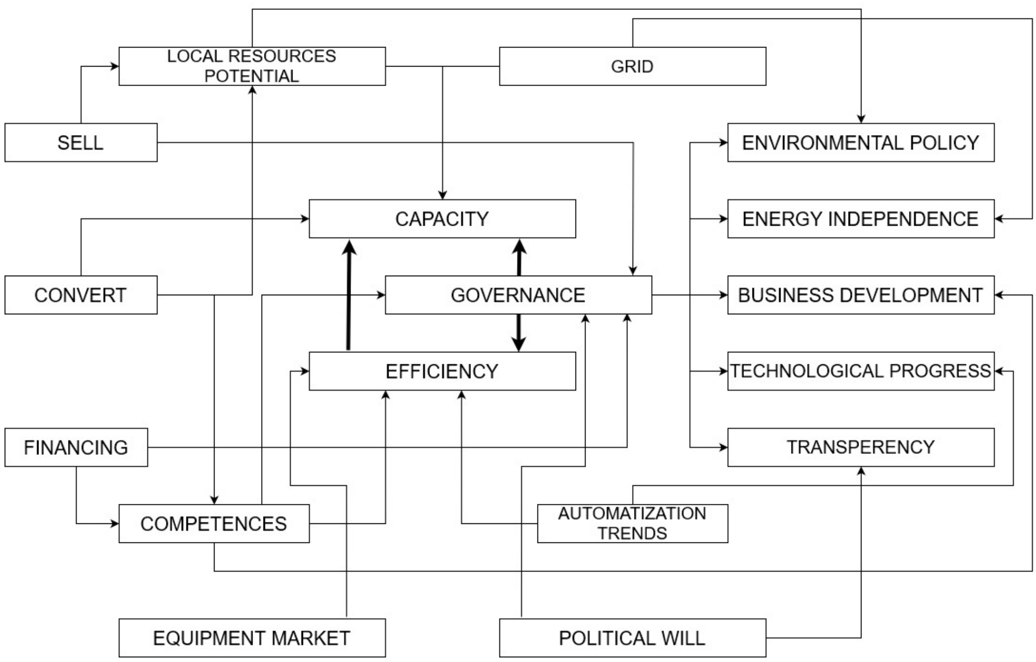

Figure 6. The asset management system in Cluster 3 municipalities.

Based on the asset management tactics selected in Figure 6, an asset management system is created, including three internal factors: capacity, governance, and efficiency. Bold lines show relationships between internal factors, while lighter lines define relationships between all other factors and their directions. In this case, it is considered that proper governance can help achieve the goals of energy transformation. Cluster 3 municipalities do not lack unused assets, have excess energy production capacities, or have adequate opportunities to finance projects. They are also rich in local resources and energy production competencies. The main obstacle to better progress is the governance of municipal companies, the improvement of which would allow both achieving the primary goals of energy transformation and extracting synergistic effects. The phenomenon of governance can also lead to an increase in efficiency, and governance can also affect capacity (well-managed municipal companies can expand to surrounding regions or companies, supplying them with energy). Important external factors—local resource potential and grid—are related to the possibilities of developing renewable energy activities in the municipality. Automation trends can further accelerate transformation activities. The equipment market significantly affects construction and development prices. Competences located in the regions can be used both to transform the energy system and to talk about new future activities. Political will from the municipal administration can lead to changes in governance. At the same time, it allows for the monitoring of the entire transformation process, removing possible administrative obstacles.

Property transformation in municipalities creates a complex effect that is not only economic. First of all, the perception is formed within the municipalities that the property must be used efficiently, and if there are no opportunities for its use, it must be converted. In addition to business development and emerging technological progress in municipally managed companies, there are more directions for positive impact. Environmental progress is perhaps the most important of these—when the burning of coal and natural gas is abandoned, the state of the environment improves. If biogas energy is developed, particularly harmful methane gas will not enter the environment. Another element that is particularly relevant for countries without fossil fuels is energy independence. Decentralized energy systems will make it possible to supply energy to customers more efficiently and reduce energy transmission losses. At the same time, it will be a safe measure to avoid cyber or physical incidents. Ultimately, good governance practices will ensure transparency, thus preventing opportunities for corruption and the waste of resources. The developed model is universal and can be applied to a wide range of regions. Internal factors and created benefits are not finite; in the case of both positively and negatively evaluated municipalities, achieving these aspects would allow for the creation of analogous benefits.

Cluster and asset analysis showed that the initiation of change must start in those regions with the greatest energy problems. Focusing on these regions allows us to distinguish objective action tactics, internal and external factors, as well as possible positive effects on the transformation of the energy system. According to the selected municipalities, after the analysis of their assets, clear directions for transformation were formed. Their final results are presented in the newly created asset management system. Further stages of energy transformation will be formed on the basis of this system. It is necessary to emphasize that the transformation process has many directions, which in turn can create additional synergistic effects. This would allow us to further expand the transformation potential, thus strengthening the regions and improving their environmental status.

4.3. Discussion

The solutions for determining the directions of energy transformation presented in this article will allow decision-makers to structure the process and argue the initial directions of the transformation. Without optimizing the existing asset structure, the transformation will take more time and require greater financial resources. In addition, it is necessary to emphasize the fact that the transformation must comply with the principles of sustainable development. The destruction of convertible infrastructure must be avoided, and the use of secondary raw materials and waste must be focused on, as this will reduce the need for expensive technologies. The use of existing resources will allow for reduced intervention in new areas of land when they are prepared for wind or solar energy needs. Although these species are compatible with the principles of sustainable development and sustainable farming, the sale or conversion of redundant assets will have a greater impact on the sustainable transformation of already existing infrastructure. The directions presented in this article clearly focus on better utilization of existing infrastructure, existing assets, and the existing business environment. Once these steps are completed, it will be possible to objectively assess the possibilities of further development.

This work differs from other works as it clearly links the sustainability component and regional economic development through energy business development. Due to the centralization of the energy business, not every region is suitable for conventional energy activities. Renewable energy enables each region to contribute to the strengthening of the country's energy independence by using available renewable resources for energy activities. This creates conditions for improving municipal businesses and empowering communities to engage in the business of fuel supply and environmental management.

Energy transformation will form clear directions of influence. First, it will empower the regions. This is related to both economic and social changes. The role of independent boards is particularly important; this can not only help enrich the regions economically but also stimulate the progress of the education system, since responsible management would become a good example for the progress of the regions. Strengthening the economic condition of the regions will reduce grants from the national budget and allow for the solving of long-standing problems related to unused and undemanded assets, lack of alternatives, and non-transparent management.

Key original research findings:

➢ **An algorithm for implementing sustainable internal operational efficiency is developed.** Due to a lack of knowledge, insufficient political will, and, in many cases, the absence of a clear national direction, it is not clear how best to start transforming the energy system. This article proposes a clear algorithm for the implementation of sustainable energy transformation based on improving internal efficiency and better use of internal resources. The algorithm is based on the use of concrete data and can be used both at the national level (identifying problem areas) and at the regional level (identifying sustainability-based efficiency priorities). The solutions presented in the article allow the measurement of both quantitative and qualitative indicators related to green energy production, regional economic viability, and governance transparency.

➢ **A clear focus on achieving mid-term results.** While the world's countries, enterprises, and organizations are working hard to develop the latest technologies, the challenges posed by climate warming are getting worse. The commercialization of the latest technologies may lead to a situation where this milestone is reached too late. The solutions proposed in this article highlight the urgent need to address the challenges of energy transformation in the electricity and heat generation sectors. The emphasis on the regional level ensures speed of decision-making, as key decisions would be taken at the local rather than national level. Once the pollution problems in the electricity and heat sectors have been solved, in the near future, the commercialization of the latest technologies will make a significant contribution to solving the problems in the transport sector.

➢ **Emphasizing governance as a central axis in the mid-term energy transformation processes.** The article highlights the fact that, despite the abundance of resources available in the regions, it is first of all necessary to depoliticize the municipally owned companies, allowing them to be managed by professionals. This must be done both at the level of the management team and the board. This will make it possible to implement all the transformation measures set out in the article, which are intended to cover an intermediate period until cost-effective mass production technologies are developed.

Comparing this study with the opinions of other authors, the lack of intermediate solutions becomes apparent. Other research by scientists focuses on conceptual solutions that will create huge positive impacts in the future. The most talked about is hydrogen technology and its influence on future energy [48,49]. A common opinion is that the transition to hydrogen will happen directly—fossil fuels will be immediately replaced by hydrogen production [50]. However, cost-effective hydrogen production has not yet been achieved, and this process may take time. Until then, environmental pollution will not be stopped, and the elimination of the consequences will only become more difficult. This article proposes intermediate solutions until the breakthrough of hydrogen technology, which would significantly solve environmental pollution problems in the short term. In addition, some conceptual hydrogen projects do not talk about wastewater but about the use of groundwater. This would go against the principles of sustainable development. The solutions proposed in the article for the beginning of the energy transformation correspond to the principles of sustainable development in all aspects.

Although other studies talk about empowering communities [51], in this case the focus is on regional policy changes, encouraging the more efficient functioning of municipal enterprises. This would allow us to catalyze the energy transformation since, unlike in the case of communities, municipal entities have many unused assets that can be invested in the energy sector. Existing studies on regional aspects of transformation are incomplete, either focusing on resources within the region [52], on financing issues [53], or on a single transformation technology [54]. The lack of integral solutions makes it difficult to identify the benefits of using intermediate solutions in the energy transformation process. Decision-makers, especially at the regional level, lack the information and arguments that are needed to understand that they are a key part of the whole energy transformation process. This article clearly identifies this problem and proposes integral and coherent solutions to initiate the energy system transformation.

Governance in energy transition processes is perhaps the least addressed topic. This article proposes a rather novel approach, not in terms of recommendations for adjusting governance but in terms of the fundamental necessity of this action for achieving the goal. Previous studies have mainly examined governance through the prism of sustainability [55–57]. These studies have looked at changes in governance that would lead to improvements in the achievement of the SDGs. However, the directions for change they provide are prescriptive. Moving on to governance aspects, specific regional examples are used, and inter-institutional cooperation structures are presented [58]. There are studies that analyze the prospects for European governance [59]. There is a dearth of research in the scientific field that proposes concrete solutions to the issue of governance and points to the clear role of governance in energy processes. This article establishes the importance of governance in energy transformation, distinguishing it from other relevant processes.

Another aspect of the transformation is subsidies. Although renewable energy solutions have become significantly cheaper, the impact of subsidies is still emphasized. This is to encourage energy transformation initiatives. Previous research has emphasized the impact of subsidies on the transformation until 2050 [60], as well as the theoretical implications of innovation [61–64]. This article focuses on avoiding subsidies, especially in the short term. Starting the transformation based on efficiency would allow better use of public finances instead of distorting the free market. The solution proposed in the article would be better in line with the principles of sustainable development—excess funds that would be allocated to subsidies can be directed to promote other sustainable development initiatives.

Suggestions for municipal policymakers:

- ➢ Promotion of professional and independent corporate boards,
- ➢ Quotation of shares of municipal companies on the stock exchange,
- ➢ Sale of shares of non-priority municipal companies,
- ➢ Enlargement of municipal companies in at least one direction—by consolidating companies from one municipality or by consolidating companies operating in the same sector of different municipalities.

5. Conclusions

Research directions for energy transformation have various aspects that must be evaluated. Incorrectly chosen transformation priorities can not only not bring positive results but also discredit the idea of energy transformation in general. For that purpose, it is necessary to find out the problematic points at the national level from which active transformation actions could be started. In this article, the analysis of Lithuanian municipalities is chosen since the country is currently actively transitioning towards renewable energy. When analyzing problem areas, cluster analysis was used, for which different data proving sustainable development were used. Cluster analysis identified those municipalities that have difficulties transitioning to green heat and electricity production. Based on this, the groups of assets they have that can serve to achieve less polluting energy production were analyzed.

The asset analysis made it possible to form an asset management system, which will be used in future research. When investigating problematic municipalities, it was established that improving governance standards in municipally managed companies would create conditions for unfolding the potential of transformation. In the absence of appropriate management competencies, critical thinking, and the desire to change the nature of activity, energy transformation is not possible. The axis of the newly created asset management system is ensuring internal governance factors. With the help of this action, it will be possible to achieve both energy and environmental goals. Expanding energy (especially electricity) production within the region creates economic incentives to increase operating income and profitability. The profit obtained would be invested in the further development of the municipality, thus solving the current economic, social, and environmental problems.

The limitations of the research are related to the disclosure of appropriate information about the managed property, management deficiencies of municipal companies, and a lack of their will to accept objective information. Some municipalities have disclosed more information about idle assets by agreeing to cooperate. An analysis of public sources was carried out in the remaining Cluster 3 municipalities. Unused assets are a particularly important catalyst for short-term energy transformation; their realization allows the transformation processes to start faster while at the same time reducing the costs of the administration of such assets. Converted assets contribute to the achievement of sustainable development goals, as such assets are reused by other owners, and their sellers can invest funds in green energy production technologies.

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