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Review

Renewable Energy for Sustainable Development: Opportunities and Current Landscape

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Abstract: Energy is often described as the lifeblood of a nation's economy, and the world energy trilemma calls for collaboration and innovative solutions at the national level. This is where Education for Sustainable Development (ESD) plays a crucial role, helping integrate the achievement of the United Nations Sustainable Development Goals (SDGs) while addressing the challenges posed by the energy trilemma. Europe's strong commitment to transitioning to sustainable energy is evident in its response to geopolitical changes and climate targets. Notably, the Baltic States have taken decisive action in response to the war in Ukraine, choosing to completely halt electricity imports from Russia and Belarus. This shift was supported by increased energy imports via interconnectors from Finland, Sweden, and Poland, with electricity imports rising to 13,053 GWh—an increase of 2.6% in 2023 compared to the previous year. Latvia, which holds the highest green energy potential in the Baltic Sea region, has nevertheless lagged behind its Baltic counterparts in terms of implementation. In 2021, Latvia ranked third among European Union (EU) countries for renewable energy share in final energy consumption, with 42.1%, significantly higher than the EU average of 21.8%. However, further progress is needed to meet Latvia's 2030 target of 14% renewable energy use in transport. The Baltic States aim to produce 98–100% of their electricity from renewable sources by 2050. The Baltic States should be regarded as a unified energy system, with a coordinated strategy for achieving sustainable energy development through collaboration and joint planning. This analysis highlights the complexities of managing energy markets amidst global and regional challenges, emphasizing the importance of well-designed public interventions to secure long-term benefits. The study concludes with a call for enhanced interagency cooperation to reform ESD and create a new interdisciplinary sector dedicated to "Sustainable Development".

Keywords: energy trilemma; renewable energy; education; Baltic states; sustainable development goals

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1. Introduction

UNESCO defines sustainability science as "science about sustainability, to understand how complex physical, biological, and social systems function; and it is science for sustainability, to support sustainable policies and positive social transformations" [1]. The topic of sustainable development is frequently discussed in various publications, and the educational content and approaches in sustainable development studies evolve over time, including new trends brought by technological progress and political policies [2–6].

Like education aimed at fostering sustainable development, the United Nations' Sustainable Development Goals (SDGs) serve as benchmarks for society as it seeks to tackle a variety of urgent issues.

It is important to highlight that one cannot speak in isolation about one specific Sustainable Development Goal. Sustainable Development Goal 7 (SDG7) calls for "affordable, reliable, sustainable, and modern energy for all" by 2030, with the following target areas: SDG 7.1—access to energy, SDG 7.2—renewable energy, SDG 7.3—energy efficiency [7,8].

Balancing energy security, energy equity, and environmental sustainability is essential for enhancing energy sustainability and facilitating a clean and fair transition to a new energy system. Each country needs to navigate the three critical components of the energy trilemma—affordability and accessibility, energy security, and environmental sustainability—to establish a strong basis for prosperity and competitiveness.

The relevance of the topic is underlined by the fact that the Baltic countries have the potential to become a significant player in the European energy market, being able to cooperate and create a common Baltic energy hub that would integrate renewable energy from both land and sea sources, while ensuring stable transmission capacity for Central Europe. This can be considered a gap in this study.

Regarding the contributions of other authors to this topic, this article does not aim to revisit the questions of whether renewable energy is sustainable or its impact on each Sustainable Development Goal (SDG) [9,10]. Instead, based on the research and theoretical insights of others, the focus will be on examining potential scenarios for advancing renewable energy through Education for Sustainable Development (ESD), specifically within the context of the Baltic States and the 2024 World Energy Trilemma Index publication [5,11–13].

The ongoing energy crisis, exacerbated by Russia's actions in Ukraine, has highlighted the urgent need for the EU to reduce its dependency on Russian fossil fuels. Diversifying and securing energy sources, while prioritizing cleaner alternatives like renewable energy, is now more critical than ever. Additionally, the EU's commitment to leading the green transition in response to the climate emergency is paramount [14].

The Renewable Energy Directive, a central component of the Green Deal [15–19], emphasizes the importance of leveraging the experiences of others to extract valuable insights for improving the energy economies of countries and regions.

The World Energy Council's Energy Trilemma framework has become an essential tool for policymakers and stakeholders navigating the energy transition [17–19]. The framework evaluates countries across three dimensions [20].

- Energy Security: Ensuring reliable, stable, and resilient energy supply amidst global and regional disruptions.
- Energy Equity: Ensuring affordable energy access for all socio-economic groups, particularly vulnerable populations.
- Environmental Sustainability: Reducing greenhouse gas emissions and environmental impacts by promoting renewable and low-carbon energy sources.

The 2024 Trilemma Report emphasizes how recent geopolitical conflicts have highlighted vulnerabilities in Europe's energy security. In response, European nations have implemented strategic measures to reduce reliance on Russian natural gas, ramp up renewable energy production, and enhance grid resilience. However, these measures have also led to short term challenges related to affordability and grid stability, intensifying issues of regional energy equity. The report provides a valuable baseline for assessing progress in sustainable development and SDGs.

The research framework includes the following questions for exploration:

- RQ1: Bibliographic analysis of Education for Sustainable Development (ESD) vs. World Energy Trilemma.
- RQ2: The role of renewable energy in sustainable development and the renewable energy policy and transition in Europe.
- RQ3: Developing the World Energy Trilemma Index for the Baltic States.

- RQ4: The potential for positive change through Education for Sustainable Development.

This study is part of a series that advocates for the establishment of the Science of Sustainable Development. It seeks solutions for integrating Sustainable Development Goals (SDGs) and ESD in academic curricula. The research continues with an in-depth review of key industries and introduces a methodology for an open-access index that enables rapid comparisons of nations' positions on the energy trilemma (energy security, energy equity, and environmental sustainability). This index will serve as a foundation for comparative case studies within the Baltic Sea region.

By exploring the latest literature and data, this paper aims to identify strategic pathways for promoting renewable energy adoption while addressing barriers to a sustainable energy future. It also underscores the interdisciplinary nature of sustainable development. The findings are expected to be valuable for a wide audience, including educational program developers, educators, policymakers, and industry practitioners.

2. Theoretical Framework

To gather evidence supporting the establishment of a field of sustainable development science, a research sequence, outlined in Figure 1, was developed. The first step involves conducting a bibliometric analysis of the World Energy Trilemma, both at the global and regional levels.

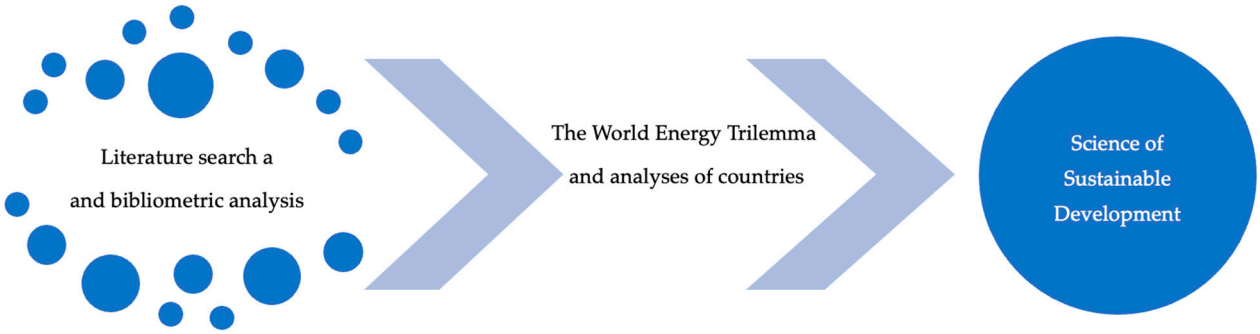

Figure 1. Graphical representation of research.

Based on the literature identified through the bibliometric analysis, a comprehensive description of the situation will be developed. Secondary data from existing studies will serve as the foundation for understanding the connections and disparities between the Baltic region and the global context. This approach will enable an informed assessment of future efforts within specific countries, using data relevant to our own nation.

An important element of this work is the use of the Global Energy Trilemma framework, which includes three key components: energy security, energy equity, and environmental sustainability. However, the substantive application of this approach has proven to be superficial, requiring in-depth analysis and a broader understanding of these concepts in the context of the Baltic region.

Energy equity was considered mainly through the lens of energy affordability, which is an important aspect but requires a more detailed approach. Energy equity encompasses a much broader range of issues, such as regional disparities, social inclusion, and the impact of energy policies on vulnerable groups. In the context of the Baltic States, these issues are particularly relevant, as the region is characterized by significant differences in development levels, economic situations, and social structures. It is important to consider how different population groups, including the with low incomes, may be affected by the energy transformation and rising energy prices.

In order to more accurately and comprehensively assess energy equity in the Baltic Sea region, it is necessary to include data on the social and economic context, as well as on measures aimed at supporting socially vulnerable groups, in the analysis. As for environmental sustainability, this aspect is presented in a rather limited context. Sustainability requires not only a transition to renewable energy sources, but also taking into account the geopolitical, enhanced, and environmental context of the Baltic Sea region, including the impact of climate change, the transformation of energy infrastructure, and the possible impact on biodiversity. It is important to analyze how these factors may affect environmental sustainability in the long-term and what measures can be taken to minimize them.

The geopolitical situation in the Baltic Sea region, especially in light of events such as the war in Ukraine, requires special attention to energy security issues. The instability of supplies from Russia threatens not only energy security, but also the energy sustainability of the entire energy system of the region. This requires comprehensive solutions that ensure not only energy independence, but also a balance between economic efficiency, environmental safety, and social justice.

2.1. The Methodological Approach to Bibliometric Analysis and Its Improvement

The choice of data analysis methods in this study is justified by the need to comprehensively explore the interrelationships between renewable energy, the Global Energy Trilemma, and the broader Sustainable Development Goals (SDGs) in the context of the Baltic States. In order to effectively address the research questions and fill the identified research gaps, the selected methods provide robust tools for analyzing both qualitative and quantitative aspects of the topic. The rationale for the selection of the key methods used in this study is as follows:

1. Bibliometric analysis was chosen as the main method due to its ability to systematically analyze the vast amounts of academic literature and identify trends, key themes, and knowledge gaps in a given field. This method is well suited to understanding the evolution of renewable energy, energy security, and sustainable development research over time, especially in the Baltic States. It also allows the identification of research clusters and interrelationships between different topics, which is crucial for linking the energy trilemma to the SDGs. By focusing on scientific articles, it provides a comprehensive understanding of what was already studied and what still needs further research.

2. VOSviewer (Version 1.6.2.) was used to visualize the results of the bibliometric analysis and create keyword co-occurrence networks as well as citation relationships. This method is particularly useful for identifying emerging trends, frequency of relevant terms, and key areas of research that intersect with renewable energy and the SDGs in the Baltic States. The tool's ability to visualize complex relationships between concepts in a clear way helps to uncover potential interdisciplinary links between energy policy and other SDGs, such as poverty reduction, education, and gender equality.

3. Secondary data analysis was included to use existing reports, indices, and publications, in particular from authoritative sources such as the World Energy Council, EU reports, and Energy Trilemma indices. This method complements bibliometric analysis by adding contextual depth, enabling comparison of academic findings with real-world energy indicators and policy reports. Secondary data are particularly useful for assessing how the Energy Trilemma framework applies in real-world contexts such as the Baltic region and understanding the impact of energy transitions on energy security, equity, and sustainability.

4. Qualitative content analysis was used to examine policy documents, reports, and academic articles to highlight themes related to energy justice, sustainability, and security. This method ensures that the research captures the nuanced perspectives of different

stakeholders, including policymakers, researchers, and community representatives, on the challenges and opportunities of renewable energy transition in the Baltic region. Content analysis also helps to identify context-specific issues that are not fully captured by quantitative methods, such as regional disparities, social justice issues, and the interconnectedness of the SDGs.

For a more in-depth analysis of research in the field of sustainable development and renewable energy sources, an important element is a methodological approach, including bibliometric analysis. In this work, keywords such as "World Energy Trilemma", "Sustainable Development", "Renewable Energy", and "Sustainable Development Goals" were used to search for relevant publications in databases such as Scopus and Web of Science. However, several shortcomings in the application of this approach were identified in the early stages of the study, which required improvement.

First of all, it is necessary to justify the choice of keywords and data selection in more detail. The previously used terms, although relevant, required additional explanation, as they are directly related to the purpose of the study—the integration of sustainable development principles into energy policy. These keywords were chosen in order to identify the relationships between the global sustainable development goals and real energy trends. Thus, improving the validity of the choice of keywords allows us to make the research more transparent and substantiated.

As a result of the revision of the methodological approach, changes were made that allow us to clearly identify the connection between the analyzed terms and current trends in the energy fields, such as energy security, energy justice, and environmental sustainability, which are central components of the World Energy Trilemma concept. This approach allows us not only to study trends, but also to offer practical recommendations for the development of a sustainable energy strategy.

The second important step was to improve the connection between bibliometric results and strategic recommendations for energy policy, which allows us to move from the description of existing problems to specific solutions. In particular, several directions were proposed for increasing the sustainability of the energy system in the Baltic countries, using a deeper integration of the principles of sustainable development into the national energy sector.

Furthermore, the analysis showed the need for a more integrated approach to developing recommendations, including technological innovation, strategic government regulation, and enhanced international cooperation. This provides a more comprehensive understanding of how challenges related to energy transformation and the integration of renewable energy sources in the Baltic States can be overcome.

Thus, the reworking of the methodological approach allowed us to improve the quality of the analysis, making it more relevant to the current political and practical aspects of sustainable energy development.

To mitigate climate risk, comprehensive assessments of energy systems and strategies for a sustainable energy transition and sustainable development are gaining importance in academic research. The topic of green transformation is becoming increasingly relevant in the public debate. Climate neutrality policy goals were set globally and in Europe—dependence on imported fossil fuels must be reduced, the use of local resources must be promoted, and energy security and supply stability must be increased. It is important to be aware of the readiness for change and to find out what research is already available and what examples of experience were already published.

To obtain a more detailed perspective on the concepts related to the topic, bibliometric analysis is often utilized. Bibliometric analysis is a research method that has increasingly been used in recent years for selecting and analyzing literature sources. Typically, bibliometric studies focus on analyzing networks of documents, keywords, authors, or journals within a specific period. Mapping and clustering methods are usually applied to provide insights into the network structure and to reveal certain correlations between the keywords used [21,22].

First, the dynamics of the development of the topic in previously conducted studies and publications were studied in order to determine the connections for the presentation of the topic. Therefore, the decision was made to work with previously verified data from Scopus, because it includes peer-reviewed publications from all over the world and is compatible with VOSvieer.

VOSviewer is a complimentary software application designed for the construction and visualization of bibliometric networks. These networks may consist of academic journals, researchers, or specific publications and can be organized based on keywords, citations, bibliographic coupling, or relationships of co-authorship and collaboration. VOSviewer allows users to create and visualize co-occurrence networks of significant terms derived from scientific literature databases [22,23]. Bibliometric networks are made up of nodes and connections. Nodes can represent various entities, such as publications, journals, researchers, or keywords, while connections illustrate the relationships between pairs of nodes. The most frequently examined types of relationships include citation relationships, co-occurrence of keywords, and co-authorship connections. Typically, bibliometric networks are weighted networks, meaning that connections not only show whether two nodes are related but also represent the strength of their relationship [22,24].

By investigating the articles' contents and analyzing their distributions over time, researchers can identify key trends and outline a path for advancement in this critical field [25–27].

In this write-up, an examination of studies on renewable energy sources as a whole and specifically in the Baltic States was undertaken, using information from the Scopus and Web of Science databases. At the outset of this data analysis, the following five key terms associated with sustainability and resource management were selected: "World energy trilemma", "Sustainable development", "renewable energy", and "Sustainable development goals". These terms were employed to locate pertinent research articles in the Scopus database, a comprehensive repository of scholarly publications. The materials were chosen from the timeframe of 2018–2024 within the Baltic States. The results from the search were refined to pinpoint the most pertinent studies. The chosen papers were examined to extract information regarding when and where the research took place. The data were exported into a CSV format and then visualized using a tool called VOSviewer 1.6.20 to create graphical depictions of research trends. Through the visualization of these data, researchers can obtain a clearer insight into the present landscape of research and discern potential gaps or areas for further investigation.

The choice of keywords stems from the purpose of the work and the achievement of the result. To search for a set of keywords on the topic, first look at Figure 2 with the result obtained by searching sources for the following keywords: "World energy trilemma". The visualization clearly shows that the most frequently used keywords are "sustainable development", "energy security", "energy", and "energy policy".

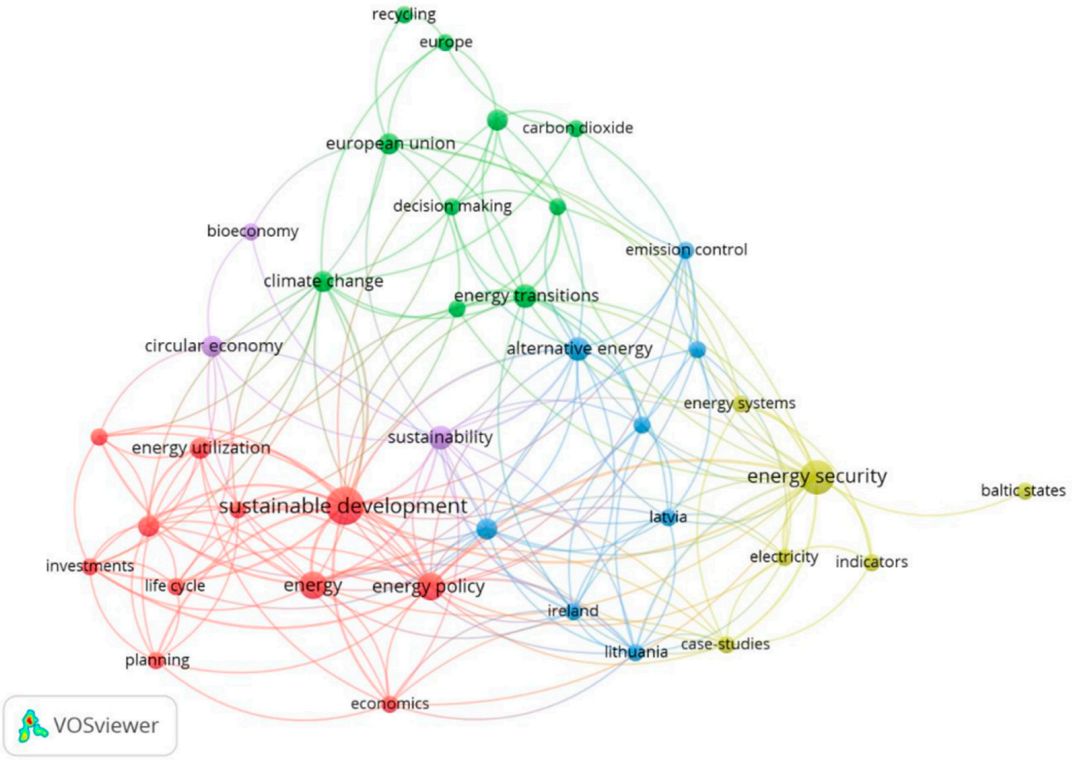

Figure 2. Keywords: "World energy trilemma" (36 documents found—period 2018–2024 in the Baltic States) [24].

To specify the research set, the next sample set is shown in Figure 3, selecting documents using the following keywords: "World energy trilemma", "Sustainable development", and "Renewable energy".

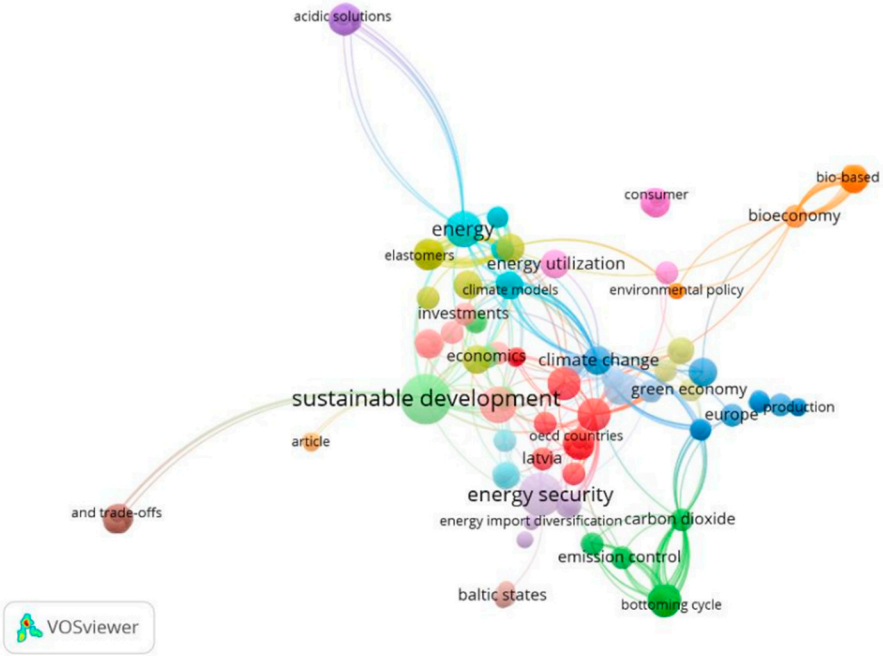

Figure 3. Keywords: "World energy trilemma", "Sustainable development", and "Renewable energy". (The figure shows the author's analysis, via VOSviewer. Thirty-one documents were found—period 2018–2024 in the Baltic States).

In Figures 4 and 5, when selecting documents, a set was already specified using the following keywords: "World energy trilemma", "Sustainable development", "renewable energy", "Sustainable development goals", or, respectively, "World energy trilemma" and "renewable energy". The number of articles and the frequency of citations reveal the connections with related topics to be analyzed further.

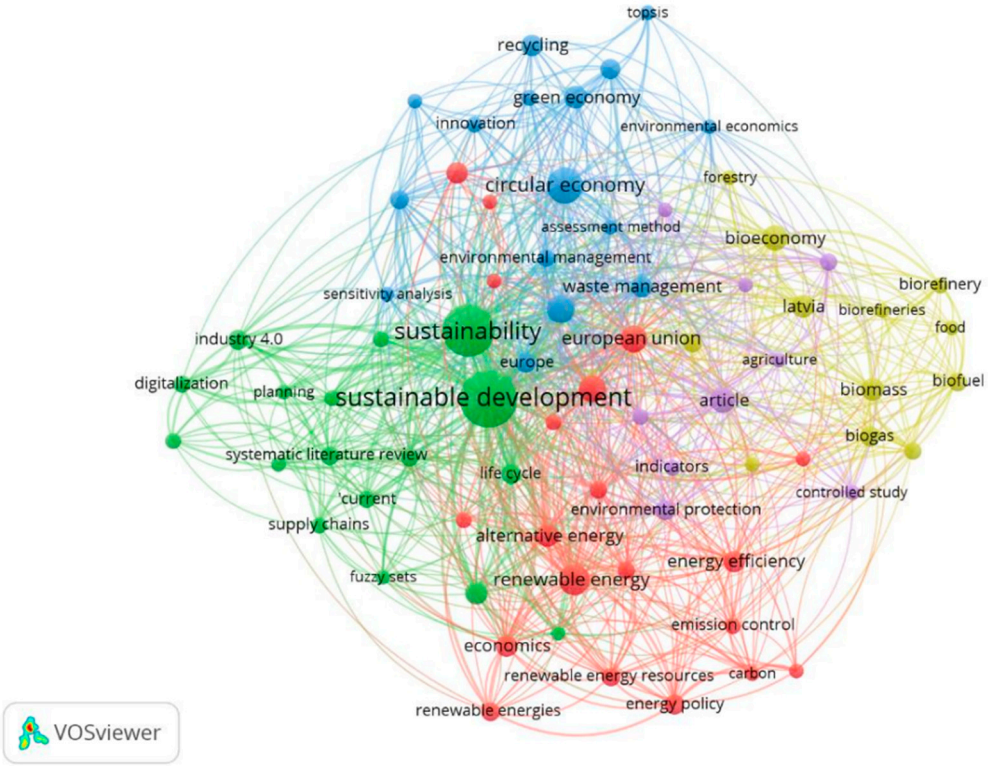

Figure 4. Keywords: "Sustainable development", "renewable energy", and "Sustainable development goals". The figure shows the author's analysis, via VOSviewer (223 documents were found—period 2018–2024 in the Baltic States).

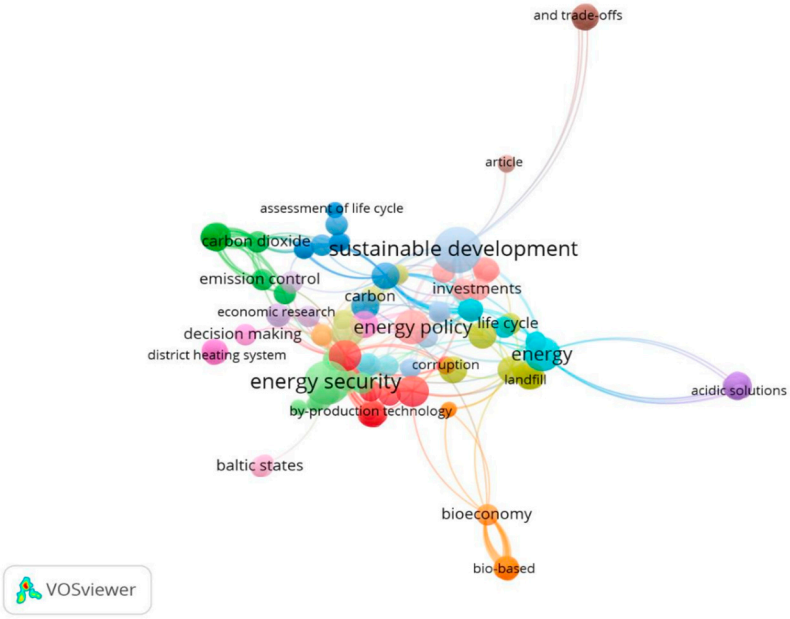

Figure 5. Keywords: "World energy trilemma" and "Renewable energy". The figure shows the author's analysis, via VOSviewer). Thirty-two documents were found—period 2018–2024 in the Baltic States [24].

The bibliographic research of the literature confirms that the transition to renewable energy in Europe, especially in the Baltic States, is motivated by global and regional commitments to mitigate climate change and promote sustainable development. Central to these efforts is the concept of the World Energy Trilemma, which emphasizes the balancing of three interrelated goals: energy security, energy equity, and environmental sustainability. In the European context, these principles are essential to achieve the ambitious goals of the European Green Deal, which includes achieving net zero greenhouse gas emissions by 2050 and increasing the share of renewable energy to 42.5% of total energy consumption by 2030. The following sections explore the main frameworks and challenges of renewable energy development in Europe and the Baltic region, with a particular focus on Latvia's unique opportunities and obstacles.

The energy trilemma is crucial for long-term planning as it helps prevent the tendency to focus on one energy dimension at the expense of others. Just as energy is often considered the lifeblood of a nation, the energy trilemma can be seen as the backbone of energy strategy. It serves as a key tool when formulating energy policies. Cooperation is essential in identifying both strengths and weaknesses, enabling the development of a unified energy strategy within the Baltic region. Education acts as a vital connector, facilitating public engagement, communication, and research activities. Consequently, further investigation into the situation was conducted, and secondary data were thoroughly analyzed.

2.2. A Description of the Situation

Renewable energy resources are natural resources or energy sources that are available in relatively infinite quantities and are renewed as a result of natural processes. They are used to produce electricity, heat, and fuel. The most widely used types of renewable energy resources are solar radiation, wind, water, and biomass. In 2015, 195 countries in the world approved the first legally binding global climate agreement—the Paris Agreement. As part of it, countries must reduce their greenhouse gas (GHG) emissions, which are mostly generated by the combustion of fossil resources. The European Union has reinforced this goal with an ambitious plan—the European Green Deal, which stipulates that by 2050 it will become the first climate-neutral part of the world, or to balance the amount of GHG emissions generated in the European Union with the emissions it absorbs. Generating energy from renewable energy sources does not produce GHG emissions, which makes them a more environmentally friendly way of generating energy than fossil resources. Promoting the use of RESs will allow for a further reduction in emissions worldwide. In order to promote the use of renewable energy, a large number of countries around the world have also set ambitious goals for the decarbonization of the energy sector [28–30].

In order to track how effectively commitments are being achieved and to compare the performance of countries, it is essential to analyze performance systematically and obtain objective information. The World Energy Council offers the Energy Trilemma Online Tool, which not only provides an interactive display of the current World Energy Trilemma results, but also analyzes at regional and country levels, breaking down performance across three dimensions: energy security, energy equity, and environmental sustainability [31,32].

Although the overall index ratings still position European nations as leading performers, it is essential to recognize the difficulties encountered and the solutions being pursued in response to the initial consumer-driven energy crisis triggered by the invasion of Ukraine [31]. As shown in Figure 6, the tool presents the latest World Energy Trilemma Index rankings, measuring a country's overall performance, which can be seen by the colors and analyzed in relation to previous periods. The coloring on the map is uniform, with the highest scores for both the Nordic countries and all three Baltic States, indicating good potential. Countries that excel in the World Energy Trilemma Index regularly rank

highly in Sustainable Development Goals (SDGs) assessments as well, showcasing their effectiveness in energy sustainability, commitment to sustainable development objectives, and preparedness for the energy transition. The Nordic countries are particularly notable for their consistent results across all indices, demonstrating their robust strategies for energy sustainability and effective policy frameworks. The impressive scores of the Nordic countries also illustrate their commitment to tackling wider socio-economic and environmental issues. The Baltic States are usually compared with each other, but the idea of a Baltic trilemma index tool suggests viewing the Baltic States as a single region, as we have similar climates, economic indicators, and related energy infrastructures.

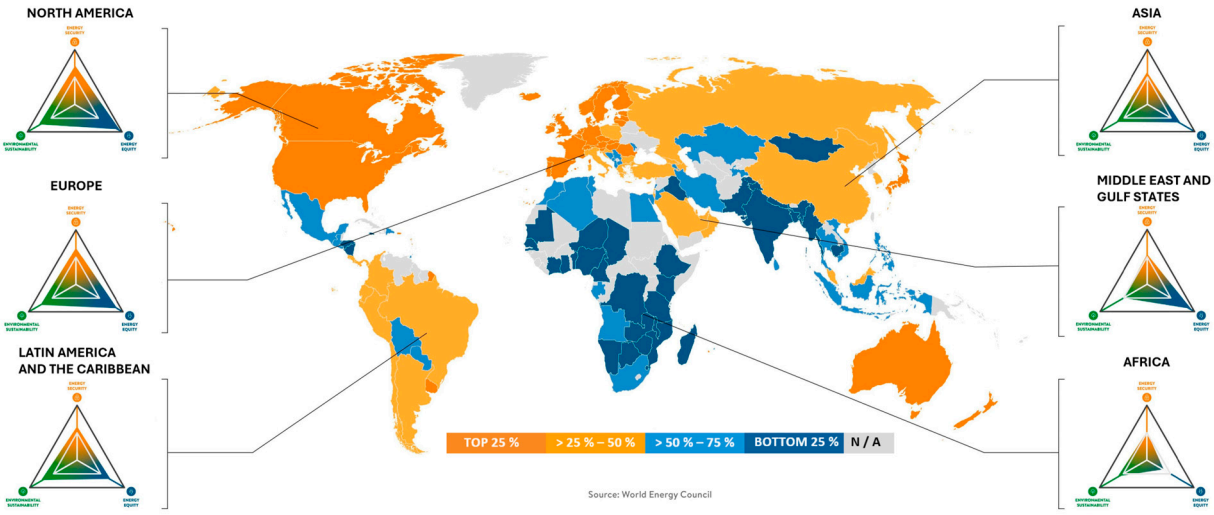

Figure 6. Countries' performances according to the World Energy Trilemma Index 2024 [31].

The amount generated from renewable sources continues to grow every year, both in the world and in the European Union, including the Baltic States. The growth in the share of renewable energy worldwide is relatively small, only 4% in the period from 2004 to 2019. The growth rate is different in each region and country of the world [32].

With the adoption of the Paris Agreement, the global community committed to transitioning to a low-carbon future. The European Union has established bold climate objectives, and to reach our long-term decarbonization targets, renewable energy sources need to supply at least 55% to 75% of our energy requirements by 2050. This is of course difficult to achieve, but with strong actions and measures it is not impossible [33–35]. In addition to geopolitical uncertainties, fossil fuels incur significant external costs to society, particularly concerning health and environmental harm [36,37].

Although sustained low oil prices might influence the economic viability of renewables, the future outlook for these sources remains quite bright. Renewable energy technologies have become significantly more competitive. In numerous regions, renewable energy sources are already effectively competing with the market prices of fossil fuel technologies. Moreover, if energy costs could help lessen the environmental impacts of energy production and consumption globally—such as emissions affecting air, water, and climate change—renewable energy sources would clearly surpass traditional technologies [28,38].

While many countries are adopting low-carbon and renewable energy strategies, Europe, particularly the European Union (EU), continues to lead the way with ambitious policy measures and frameworks. Nevertheless, the implementation of an effective and sustainable transition still faces obstacles in various dimensions that require balanced analysis and strategic decision-making [39,40]

Important attention was also paid to the assessment of sustainability in the energy sector to achieve a balanced transition. Challenges to the energy transition are multidimensional and include financial, regulatory, and infrastructural barriers that require integrated approaches with knowledge, and how to integrate Sustainable Development Goals and sustainable solutions [41–45].

The Baltic Sea has substantial potential not only for onshore, but for offshore wind power, as well as with competitiveness varying across the region due to wind conditions, connection costs, and market values. The Southern Baltic Sea, in particular, offers high-value sites for wind generation. Regional cooperation could enhance the efficient use of these prime locations. Market and grid modeling indicates that by 2030 offshore wind power at optimal sites could already be competitive, contributing significantly to the Baltic Sea's energy transition under the EU's decarbonization strategy aligned with the Paris Agreement.

Cross-border renewable energy (RES) cooperation on offshore wind projects can yield economic benefits by achieving renewable energy targets more cost-effectively. Regional grid planning that includes all renewable energy, not only offshore wind power, could further optimize investment efficiency, particularly through the early integration of grid development with wind deployment. Advanced offshore hubs linking wind power to multiple member states also merit exploration for added benefits.

Effective deployment of Baltic offshore wind resources requires addressing national administrative and regulatory barriers, such as inefficient licensing and limited maritime spatial planning data. Essential cooperative solutions include harmonized tendering, grid connection cost-sharing, and integrated regional grid planning. For efficient, coordinated development, a shared long-term vision is necessary to guide critical investments in generation and grid infrastructure, along with targeted measures and incentives to support them [38,46].

The map in Figure 7 shows the "green" electricity potential of the EU countries, and the situation of the Baltic States looks acceptable, even compared to the Scandinavian countries. Solar and wind energy are now considered to be the dominant energy sources in the European Union, with solar and wind energy exceeding fossil fuel energy for the first time in the first half of this year. This change occurred despite a 0.7% increase in consumption. The initial analysis was conducted at the NUTS2 (nomenclature of territorial units for statistics) regional level and was subsequently aggregated and reanalyzed at the NUTS0 national level to facilitate a more comprehensive evaluation of the potential for green energy and associated techno-economic factors. Key findings indicate that RES electricity potential exceeds national electricity demand, including hydrogen production, in all analyzed countries. Most European regions possess an adequate amount of renewable energy sources (RESs) potential for self-reliance, but densely populated areas and major hydrogen-producing hubs pose challenges to meeting electricity and green hydrogen production demands.

The Baltic region demonstrates significant renewable energy potential, particularly in wind (both onshore and offshore) and solar energy, which could support green hydrogen production and energy self-sufficiency. However, despite this potential, the region may face challenges in scaling up infrastructure to meet both current energy demands and future green hydrogen production targets.

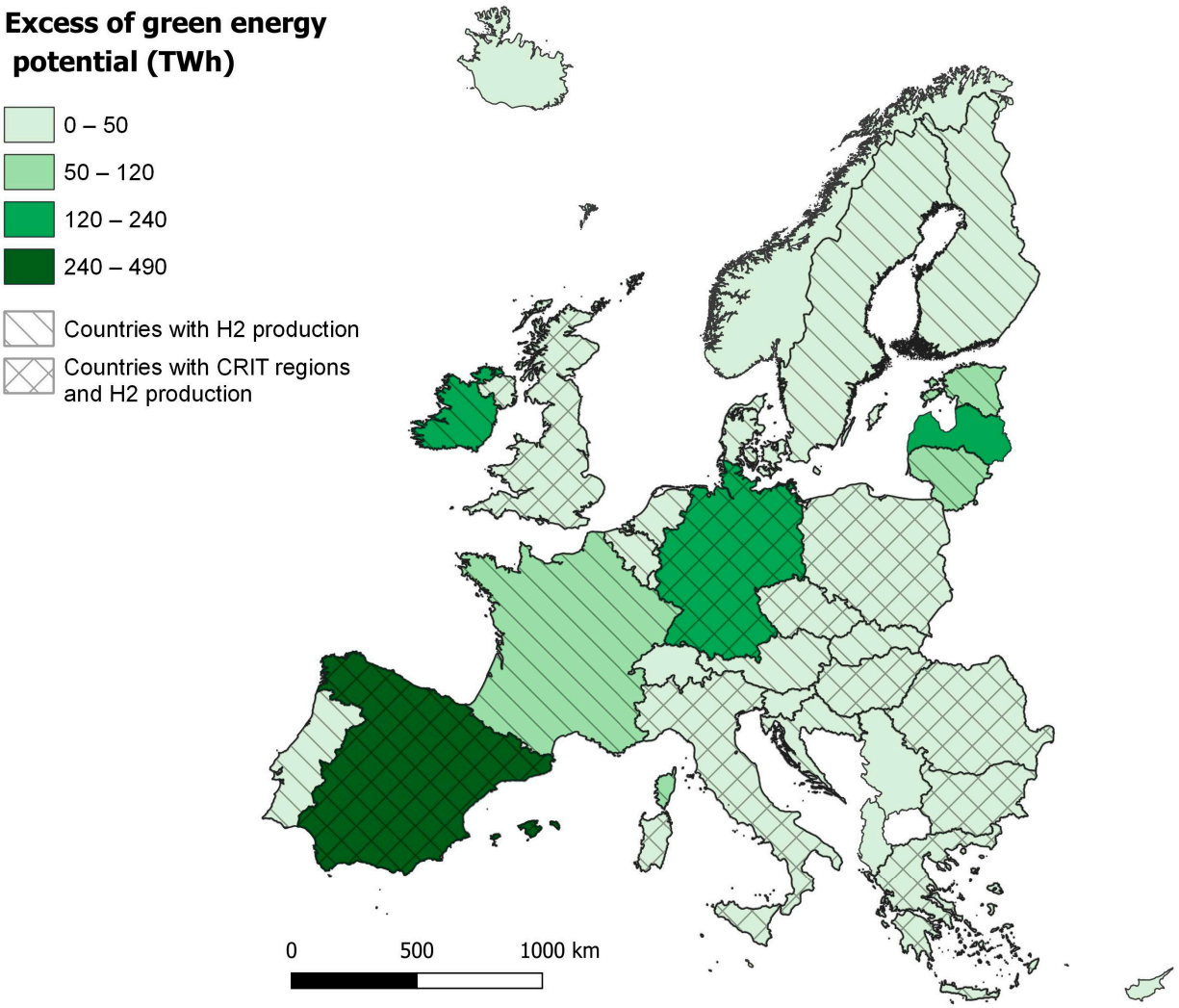

Figure 7. The "green" electricity potential of the EU countries, based on [47].

The Baltic States have exceptional potential for offshore wind energy, the numbers do not lie, but it must be honestly admitted that, for example, Latvia has relatively the highest green energy potential in the Baltic Sea region, but lags in implementation. If the neighboring countries (Estonia and Lithuania) hurry to implement significant wind and solar energy projects first, it may create a situation where it is no longer economically useful to implement such projects in Latvia and they will become net importers for at least a 30-year period, reducing our GDP and de facto sponsoring of the development of neighboring countries (Figure 8).

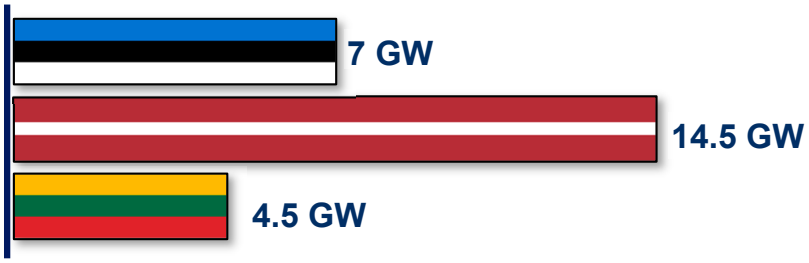

Figure 8. Offshore wind potential in Baltic States [48].

The Baltic States should be viewed as a single energy system; it is planned that in 2050, 98–100% of electricity in the Baltic States will be produced using renewable energy

resources, specifically wind and solar energy [48–50]. The map in Figure 9 presents details regarding the wind turbines located in the EU, Great Britain, and Norway, along with the proportion of renewable energy in their overall energy usage, with a specific focus on the Baltic States.

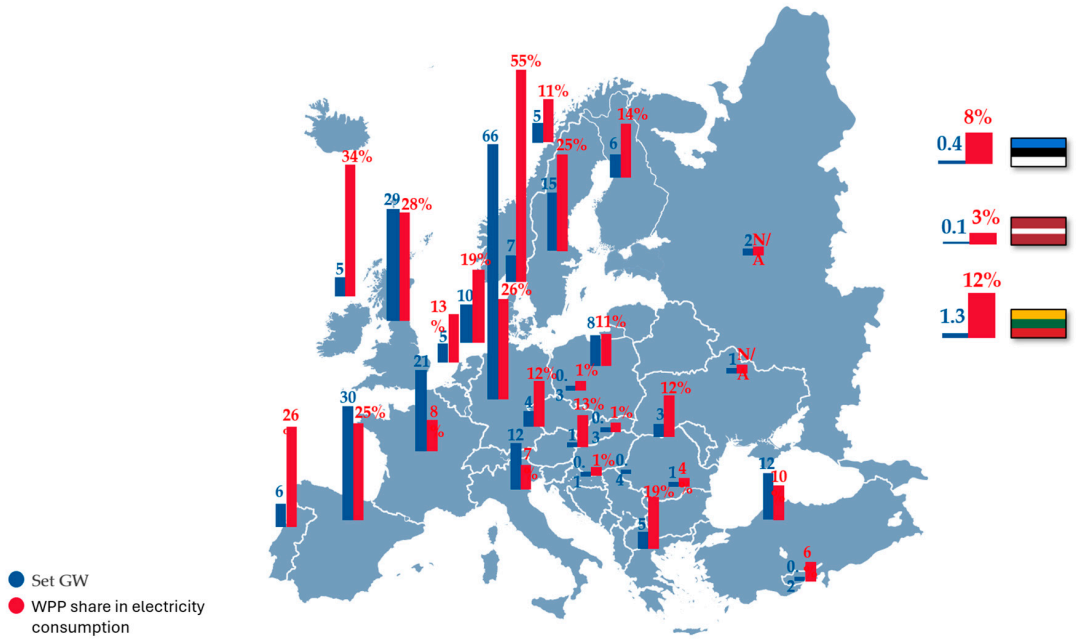

Figure 9. WindEurope Q2 2024 renewable energy performance data, based on [51].

The World Energy Trilemma Index evaluates and ranks the energy performance of 127 nations based on three key aspects: energy security, energy equity, and environmental sustainability. By utilizing this index, countries can pinpoint their difficulties in achieving a balance within the Energy Trilemma and recognize potential areas for enhancement in fulfilling present and future energy needs, economic prosperity, and sustainable development objectives. Figure 10 shows in which categories the Baltic countries' performances differ globally.

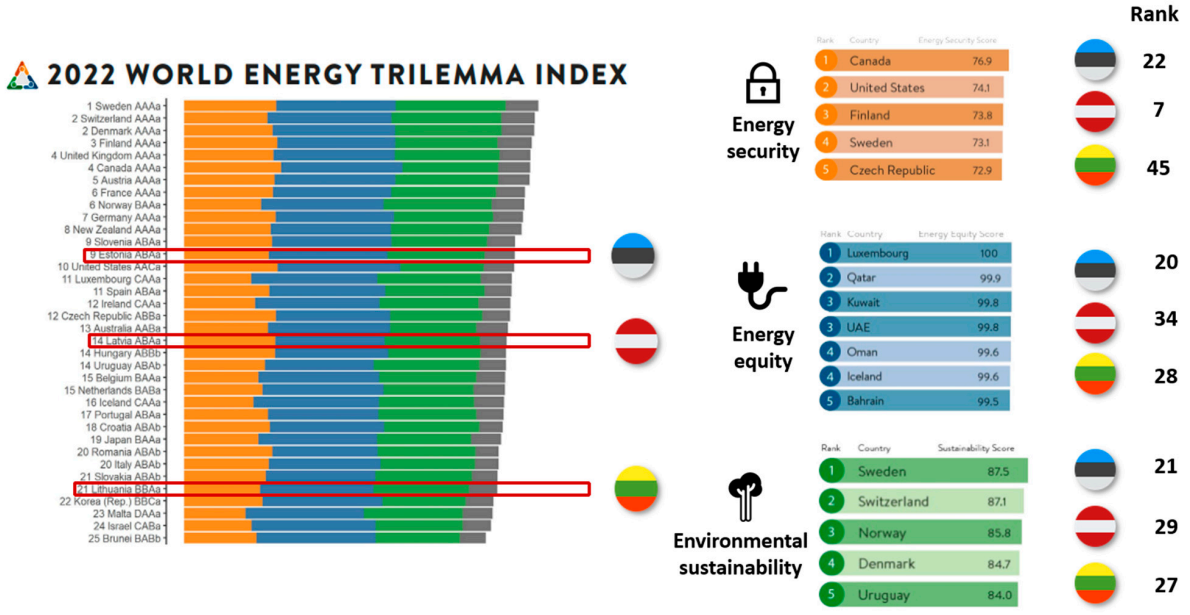

Figure 10. Baltic countries' performances in the World Energy Trilemma Index, and comparison across sections energy security, energy equity, and environmental sustainability, based on [52].

Latvia, Lithuania, and Estonia are usually compared to each other; however, in many aspects of development we fail to miss looking at the Baltics as one region, to reach larger goals together. Using various sources of information and databases, a new Baltic energy trilemma model is being developed—it is tailored to the Baltic situation—with the goal of this study being that all three countries must be evaluated as a whole, rather than separately.

Also, it demonstrates the region's collective strengths and weaknesses. For example, when Russia invaded Ukraine in 2022, we saw the Baltics' fossil fuel dependence, particularly on natural gas, the need for new renewable energy generations, and grid-related questions become as important as ever before. We also included new indicators related to electrification, grid connection, and biodiversity, taking into account future trends and the importance of it in the future.

2.3. Considerations and Trends on the Development of Renewable Energy in the Baltic States

The Baltic States have already demonstrated good efforts to ensure energy independence, including independence from energy imports, energy and carbon intensities, and the contribution of energy products to trade, taking into account their potential impact on the economy. The Baltic States underwent an energy transition in the 1990s following their independence from the Soviet Union in 1991. Due to various economic factors and political shifts, total energy consumption dramatically declined (by nearly 50%) and there was a move towards the use of local renewable resources. Notably, their accession to the European Union in 2004 played a significant role in the sustainable development of their economies and adherence to EU policies [45,53]. Figure 11 illustrates the overall energy share during the recent period, showing the situation of the Baltic States in comparison to the European average.

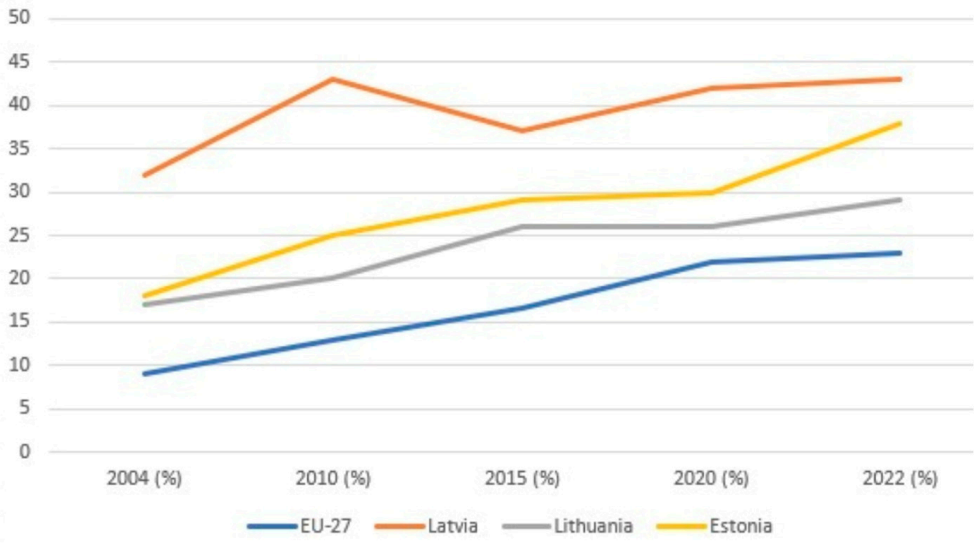

Figure 11. Percentage of energy derived from renewable sources, 2004–2022 (% of total final energy use), based on [54].

Despite the Baltic region having a shared historical background and a long-standing tradition of collaborative governance along with aligned national policies in accordance with EU guidelines, the distinct structural characteristics of their energy and economic systems, as illustrated in Table 1, result in varying attributes in primary energy supply and planning.

Table 1. Differences between Baltic States [38,55–61].

Country	Description of the Situation
Estonia	Estonia intends to eliminate oil shale energy production by 2040 and increase the proportion of renewable energy sources in its energy portfolio, focusing especially on offshore wind and solar power.While the country boasts a high percentage of renewable energy in its final energy consumption and the lowest energy dependence levels, it still faces challenges with high energy intensity and carbon intensity across its economy and individual sectors. Nevertheless, notable reductions in both energy intensity and carbon intensity were observed in the energy sector during the analyzed period.
Latvia	Latvia demonstrates a relatively low level of political dedication to the energy transition, which leads to limited incentives for the utilization of renewable energy. Despite a significant proportion of renewable energy sources contributing to electricity generation and overall energy consumption, this is largely due to favorable climatic conditions, well-established hydroelectric power plants, and improved metrics of energy efficiency and carbon emissions, as well as better figures for specific energy and carbon intensities in various economic sectors. However, the country has the poorest energy dependence metrics, including those related to trade.
Lithuania	Lithuania exhibits a strong national political commitment to renewable energy, aiming to attain full energy independence by the year 2050. Comprehensive policies are essential to enhance energy efficiency, promote the utilization of renewable energy sources, and diversify fuels thereby lowering energy dependence and minimizing vulnerability to fluctuations in energy prices; the impact of energy trade on external product imbalances is significant.

The World Energy Trilemma framework, emphasizing energy security, equity, and environmental sustainability, offers a useful lens for understanding and managing these complexities. It can be concluded that strong cooperation and understanding of the solutions and possible measures of the situation are needed between the parties involved [57–59].

The Baltic States are rich in natural resources and have enormous potential to produce green energy, providing lower prices for citizens and businesses, ensuring the region's competitiveness, and becoming a stable and sustainable energy export partner for Europe. The Baltic governments have agreed on a joint study to assess the potential of establishing a Baltic energy hub—a central point that would integrate renewable energy from both onshore and offshore sources, while providing stable transmission capacity to Central Europe, which could provide the Baltic States with a significant contribution to achieving Europe's decarbonization goals [58,59]. The transition to renewable energy in Europe, especially in the Baltic States, shows the complex interrelationship between security, justice, and sustainability. The World Energy Trilemma framework emphasizes that achieving a balanced approach to energy requires not only technological innovation, but also strategic policy-making that considers economic, environmental, and social dimensions. Future efforts in the Baltic region will benefit from a complex of measures, such as policies that improve grid resilience, promote local production, and address social justice in energy access. Promoting regional energy independence is essential to promoting green energy production, accelerating exports, and attracting energy-intensive industries that want to receive green energy at a competitive price, as well as to produce new energy products, such as green hydrogen and its derivatives, on a large-scale and at affordable prices [58–60]. In the Baltic States, the progress of the development of the Baltic National Energy and Climate Plan, as well as the Baltic Energy Policy Goals until 2040, and infrastructure resilience, is being developed and discussed at the government level, and a unified dialog is being ensured on common challenges of the Baltic States, particularly in relation to energy security and the growing importance of renewable energy.

3. Discussion

3.1. Education for Sustainable Development as the Tool for Changes

The issues described in the previous chapter regarding the World Energy Trilemma and the performance of the Baltic countries in the World Energy Trilemma Index are closely related to the overall movement towards sustainable development at various levels.

The European Commission (2023) approved [62]'s implementation, which requires companies across Europe to report on their impacts, risks, opportunities, sustainability efforts, successes, and future goals. This has raised the issue of understanding sustainability, the practical application of knowledge, and the compliance of educational programs within the time requirements. The new ideals cannot be realized by maintaining the educational methods and traditions of the 20th century. Therefore, it is essential to transform education through a comprehensive institutional approach to teaching, learning, research, and community involvement. Universities and other educational institutions must embrace experimental and practical learning strategies for "education for sustainable development" (ESD) to equip learners to tackle the significant socio-ecological issues of the 21st century.

Sustainability and sustainable development are among the most frequently debated subjects [63–65]. Sustainability is generally divided into three fundamental components: economic, environmental, and social. These components are collectively referred to as ESG (Environmental, Social, and Governance).

ESG represents the criteria used to evaluate how effectively a company manages its environmental impact, ensures fair treatment of its workers, and conducts its operations responsibly. In the context of business, sustainability often aims to protect natural or physical resources, ensuring their availability for future generations. The United Nations (UN) offers a widely recognized definition of sustainability within the sustainable development framework. Sustainability involves fulfilling the needs of the present without jeopardizing the capacity of future generations to meet their own needs. [66] It underscores the significance of responsible resource utilization, environmental conservation, and fair development to secure a better future for everyone. For over four decades, sustainable development (since the introduction of the term "sustainable development" as a global priority in 1980 in the World Conservation Strategy [67]) has been a collective objective of humanity and was extensively studied by the broader research community.

It is important to note that the connection between sustainable development, the quality of educational, scientific endeavors, and socio-economic progress was recognized only two decades later with the adoption of the Millennium Development Goals (MDGs) in the United Nations Millennium Declaration.

Advancements of sustainability and sustainable development pose significant challenges for society in the present day [68–70]. Education for sustainable development [70] in the broadest sense is meaningful education. At its center are questions of identity and values, justice and responsibility, inspiration for curiosity and creativity, a call to be open, courageous and sensitive, and an encouragement to use one's social, emotional, cognitive, and physical resources in building a hopeful future [71]. In 2019, the UNESCO General Conference adopted the global action program "Education for Sustainable Development 2030" [72]. Which calls for a closer connection between education and the Sustainable Development Goals and highlights the importance of education in achieving all global goals. It continues the UN's Decade "Education for Sustainable Development" (2005–2014) [73] and the Global Action Program "Education for Sustainable Development" (2015–2019) [74]. Higher education institutions are essential in facilitating the knowledge needed for the transition to Sustainable Development Goals (SDGs) through their teaching efforts, while also reskilling professionals to meet the evolving sustainability requirements. To avoid monotonous tasks, educators must adopt technology to enhance efficiency and

achieve better learning outcomes. Sharing experiences allows us to refine our academic programs [75–77].

The Sustainable Development Goals (SDGs) outline the 2030 agenda aimed at transforming our world by addressing various challenges that humanity faces to promote well-being, economic growth, and environmental stewardship. Unlike traditional development agendas that focus on a limited range of areas, the SDGs offer a comprehensive and multidimensional perspective on development. Therefore, interactions between the SDGs may lead to conflicting outcomes [78].

UNESCO [74] highlights the role of knowledge creation and science in solving today's most pressing economic, social, and environmental challenges and in achieving the UN Sustainable Development Goals. UNESCO's goal in the field of science is to strengthen cooperation between scientists, national governments, and entrepreneurs, between higher education institutions, research laboratories and society, which would promote not only the transfer of knowledge, but also peace. To support the field of science more effectively in the world, UNESCO implements its activities through natural sciences and social sciences and humanities programs, where each sector has its own basic tasks and goals. The aim of natural science programs is to promote the contribution of science to sustainable development. Social sciences and humanities programs aim to address ethical challenges, as well as to promote local cultural and social environmental research [79,80].

Every four years, each nation provides an update on how well they are implementing the Sustainable Development Goals (SDGs). Energy system security refers to the ability to satisfy present and future energy demands. Although the Baltic region performs well on the WEC Energy Security Trilemma Index, even brief and targeted issues (such as interruptions in gas supply or a shortage of regional generating capacity) can significantly impact overall energy security and future growth since the global energy security index emphasizes oil and other fossil fuels. Thus, it is crucial to prioritize and intentionally enhance concerns regarding energy security.

In February 2025, Estonia, Latvia, and Lithuania are set to sever their electrical connections from the Russian and Belarussian systems (BRELL). The desynchronization process, which has spanned nearly 20 years, will reach its conclusion, with all three Baltic countries integrating into the Continental European (UCTE) grid. Recent incidents in the Baltic Sea, including damage to gas and electricity infrastructure in 2023 and 2024, highlight the importance of focusing not just on cybersecurity, but also on the physical protection of critical infrastructure [81]. The idea of a Baltic Trilemma Index Tool may serve as an innovative regional adaptation of the World Energy Trilemma Index, specifically tailored to address the unique challenges and conditions faced by the Baltic States—Estonia, Latvia, and Lithuania.

3.2. Obstacles, Barriers, and Expected Results

A research gap identified in the current study is the under-exploration of the relationships between renewable energy, the Global Energy Trilemma, and the broader Sustainable Development Goals (SDGs), especially in the context of the Baltic States. Although there is considerable research on renewable energy policy and its impact on energy security, sustainability, and equity, limited attention has been paid to how these elements are interconnected in regional contexts and how they can be effectively implemented in practice.

In the Baltic States, which face unique geopolitical and economic challenges, the application of the energy trilemma—balancing energy security, equity, and environmental sustainability—remains under-explored. Existing research has mostly focused on individual aspects of the trilemma, without fully integrating issues of social justice (such as regional disparities and social integration) or critical sustainability issues, especially in

relation to the specific geopolitical context of the Baltic region. Moreover, the link between the transition to renewable energy sources and other SDGs, such as poverty reduction, education, and gender equality, is often overlooked.

This gap highlights the need for a more integrated, interdisciplinary approach that combines energy policy, sustainable development, and social aspects. It also highlights the need for region-specific strategies tailored to the Baltic States, taking into account both their unique challenges and untapped potential in renewable energy production. Closing this gap will provide policymakers with a clearer understanding of the complexities of energy transitions in the Baltic region, guiding more effective decision-making and facilitating cross-border cooperation to achieve sustainable development.

This study therefore aims to bridge these gaps by offering a comprehensive analysis of how the energy trilemma and the SDGs can be intertwined to shape a more sustainable, sustainable, and inclusive energy future for the Baltic region.

In connection with the practical implementation of the Sustainable Development Goals, it is important to look at the existing obstacles and challenges.

Table 2 lists the most common obstacles to the development of solar and wind power plant projects in EU countries, which were compiled within the framework of the "PowerPlant" project initiated by Eurelectric. The aim of the project is to identify the factors hindering the development of RES, develop recommendations, and compile examples of good practice and ideas for more successful integration of RES, taking into account biodiversity, optimal territorial planning, and public interests.

The most common obstacles to the development of solar and wind power plant projects in the EU.

For residents, one of the most important indicators is price, but with this trilemma tool, you can create an understanding of how important safety and accessibility also are. Looking at electricity prices for households in Baltic States (Figure 12), we can see why both Lithuanian and Estonia are ranked higher by WEC in energy equity. So, the WEC index can indicate particular countries or states compared to rest of the world, but it does not provide a clear view on particular country's progress, nor does it provide information which could be used to analyze what should be conducted to improve the situation.

Table 2. The most common obstacles to the development of solar and wind power plants in the EU [55,58,81–87].

Energy	Type of Restrictions
Renewal energy	• Although various indices exist for measuring the energy trilemma, there is a lack of quantitative tools for assessing the discursive side of the energy trilemma. • The Baltic States compete with each other for the construction of RES, but the infrastructure they are using is the same.
Solar energy	• Lack of a definition of "the dual use" at EU level uncertainty. • Non-digitalized and lengthy process of harmonization and obtaining permits. • Regulatory variability, affecting current and future investments for the public to financially engage in the project. • Lack of or low availability of environmental information, which is critical for environmental studies of projects. • Deficiencies in the cadastral/digital mapping of territories suitable for RES projects at the national level. • Negative attitude of the public towards the inclusion of solar photovoltaic cells in the landscape. • Lack of initiatives in the field of agriculture, promoting the optimization of agricultural land use, including combining different types of land use.

Table 2. *Cont.*

Energy	Type of Restrictions
Wind energy	• Change and uncertainty of legal framework. • Inconsistent investment approach in the environmental impact assessment process. • Administrative restrictions for local communities to financially engage in the project. • Complex and lengthy project coordination process. • Lack of inter-institutional cooperation. • Lack of cadastral/digital mapping of territories suitable for RES projects at the national level. • Unclear land status, resulting in changes to the plan/study. • Complex process of developing territorial plans, overlapping with other processes. • Overlapping land use purposes and legal obstacles to combining them. • High proportion of protected areas (which will be increased by the upcoming EU Nature Protection Law). • Limited transmission network availability, unclear capacity reservation process, and complicated coordination process for new infrastructure facilities. • September 2024 infringement package prepared for 26 countries—because the RED III directive was not transposed into local regulations—as a result, no go-to zones for RES, etc. measures were defined to accelerate the receipt of permits for the construction of new RES; this is especially painful for wind projects.

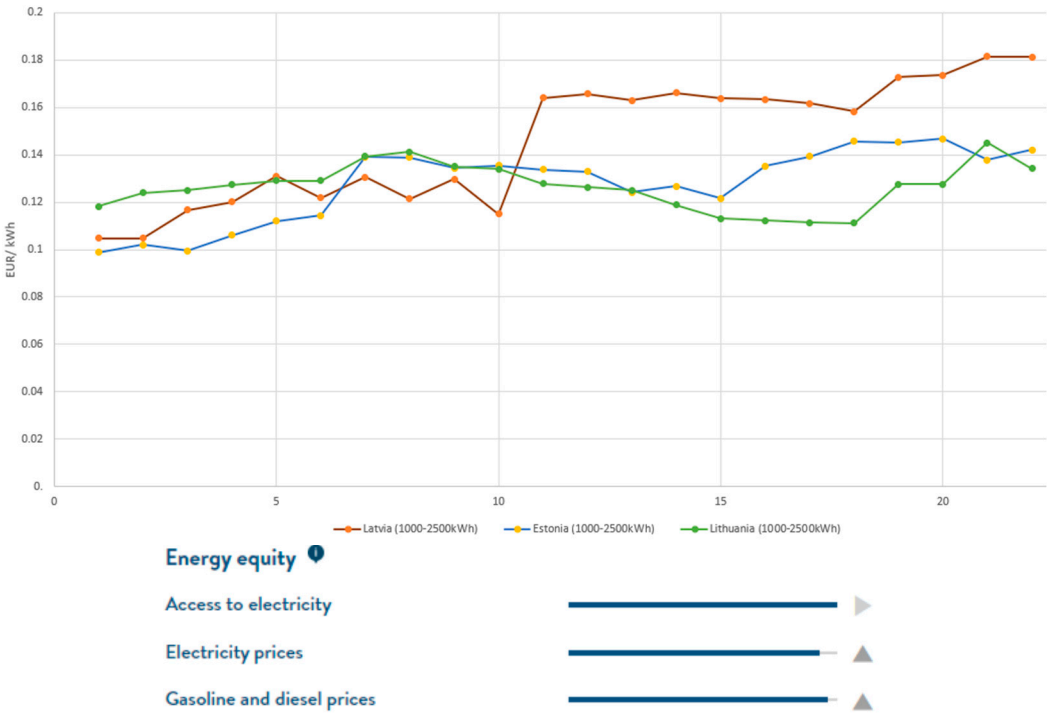

Figure 12. Electricity prices in Baltic countries [88].

A successful case is Estonia, where the Estonian Energy Policy Development Plan uses its position in the World Energy Trilemma Index as a key performance indicator (KPI). The plan reflects current challenges in terms of sustainable development, in particular due to the country's dependence on oil shale. The Baltic trilemma is a vital guide for policymakers, shedding light on the challenges and opportunities for improving energy systems and achieving energy goals across the region. Although Latvia, Lithuania, and Estonia are often compared, there is a tendency to overlook their joint regional efforts towards broader energy goals. The Baltic trilemma tool is crucial for strengthening regional cooperation, promoting joint infrastructure development, and creating a unified strategy for the energy sector. This updated Baltic Energy Trilemma tool offers valuable information on

the performance of energy systems in the region, considering all aspects both individually and together [89,90].

Energy equity is essential for economic growth. It is important to know that our area has had 100% technical access to electricity for decades. The primary objective of this study was to add and evaluate future scenarios, keeping in mind that electrification, EVs, and microgeneration are becoming part of our daily lives and are no longer just for a small group of enthusiasts. In this situation, the cost and competitiveness of energy resources, as well as the price and availability of new connections for households and producers, are very important. New, adjusted indicators were made to measure the competitiveness of the Baltic region, so that each country can reach its own plans and also work towards a larger goal.

Baltic Energy Trilemma is a convenient and transparent tool, which highlights Baltic States' strengths and weaknesses. Figure 13 shows the trilemma as a foundation for a new cooperation and science. It shows the prerequisites for how, based on the trilemma index of the Baltic States, to further ensure energy independence. The next step would be to plan sustainable development measures.

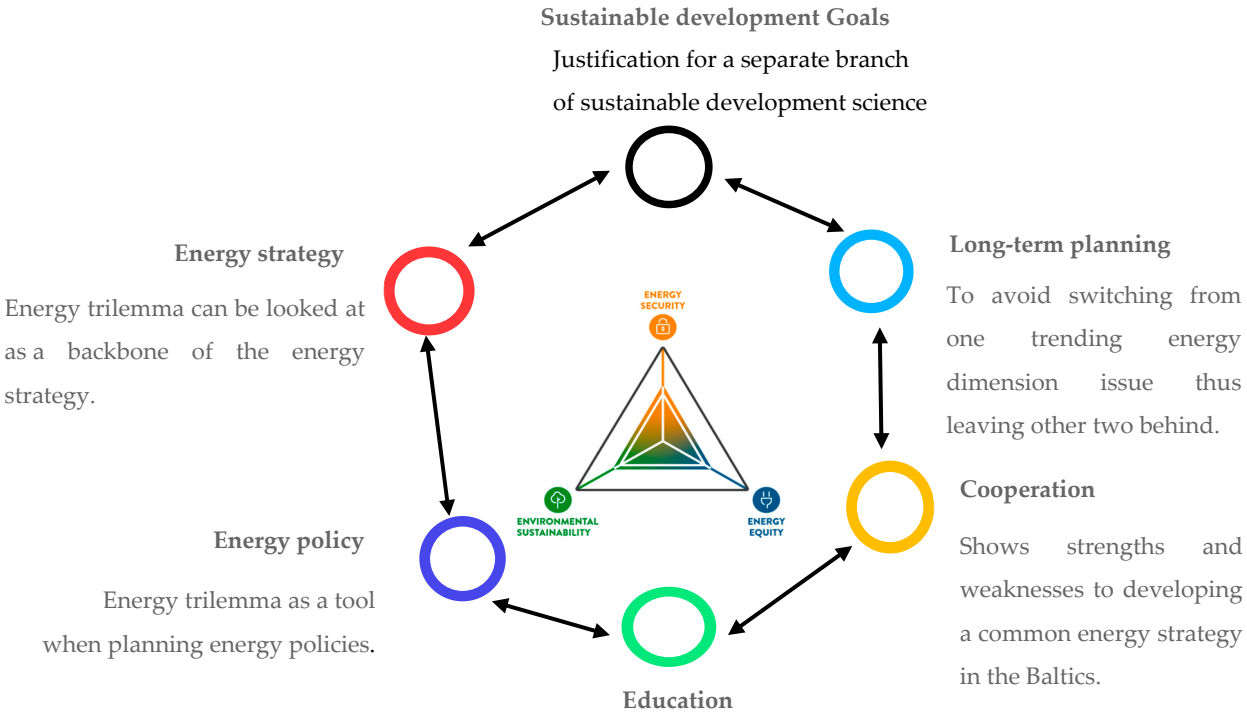

Figure 13. The trilemma as a foundation for a new cooperation and science.

The Baltic Energy Trilemma tool highlights the Baltic States' strengths and weaknesses in each dimension. Kites fly best against the wind, not with it, so it is critical to boost regional cooperation and collaborate on infrastructure development to achieve a unified approach to energy sector strategy.

The author strongly believes that this adjusted Baltic Energetic Trilemma tool provides insights into the Baltic region's relative energy system effectiveness in each dimension and together.

As a subsequent step, it is crucial to develop guidelines for managing and regulating the quality of educational and scientific research systems in alignment with the Sustainable Development Goals. Previous experience and research show that the quality of education is

one of the key factors in achieving the Sustainable Development Goals. Several studies have highlighted that curriculum and educators can play a huge role in creating awareness of the concept of sustainability in practice [91–96]. This should be further promoted through the educational process, diverse course offerings, encouraging research-oriented studies, and fostering connections with industries.

This paper emphasizes the importance of expanding regional cooperation, but in fact, the recommendations lack specific mechanisms and steps for implementation. Future research and recommendations should detail specific actions, such as the following:

Creating interstate energy hubs that will combine renewable energy sources from different countries in the region to ensure the stability of the energy supply.

Developing uniform regulations and standards for the integration of green technologies into existing infrastructures, taking into account the needs and characteristics of each country.

Financing and subsidizing local projects for the introduction of renewable energy sources in small- and medium-sized enterprises will ensure a decrease in the cost of energy and the development of an environmentally friendly economy.

On the other hand, the article should expand the analysis of interdisciplinary connections, combining the issue of energy sustainability with other Sustainable Development Goals (SDGs). For example, when promoting renewable energy sources, it is important to consider the following:

- Poverty reduction by ensuring access to clean energy for vulnerable groups and creating jobs in green sectors of the economy.
- Education aimed at raising awareness about the importance of switching to renewable sources and implementing educational programs on sustainable energy practices.
- Gender equality by creating equal opportunities for women in the energy sector, stimulating their participation in technological and engineering initiatives.

These specific recommendations will allow policymakers and stakeholders to be more clearly guided towards practical steps to realize a sustainable energy future for the region.

4. Conclusions

The world is experiencing turmoil due to global energy disruptions resulting from the intersection of crises: climate change, COVID-19, and conflict. The interplay of these crises leads to cascading and uneven effects on energy that are experienced across all segments of society. The energy trilemma provides a framework for understanding the benefits and drawbacks of increasing decentralization in the energy system. The variations in performance across the trilemma dimensions and contextual factors highlight the unique and complex energy challenges faced by each country. A perspective that transcends national boundaries is necessary because of the global nature of environmental issues and energy markets.

The investigation into the World Energy Trilemma and sustainable development has rapidly gained prominence, leading to a marked rise in annual publications. Global collaborations among researchers have delved into various sustainability themes with considerable depth and breadth by concentrating on the social, ecological, economic, political, and cultural dimensions of sustainability.

This study examines the challenges and opportunities of renewable energy in Latvia and the surrounding Baltic Sea region. The transition to renewable energy is an important step not only to achieve sustainability, but also to minimize dependence on imported fossil fuels, and to increase energy security in a rapidly changing geopolitical landscape. Building on the World Energy Trilemma, which advocates for the integration of energy security,

energy justice, and sustainability into energy policy and planning, would greatly assist Latvia in its efforts to create a sustainable and equitable energy system of the future.

Latvia's strategic location in the Baltic Sea region also opens up opportunities, including hydropower and biomass, as well as a growing share of wind and solar energy. Thus, Latvia has good potential for renewable energy. According to the latest data, Latvia was able to meet approximately 38% of its total energy consumption from renewable sources, with wind energy accounting for 12%, solar energy for 5%, and biomass and hydropower for 21% of the energy balance. However, infrastructure, financial resources, and a regulatory framework are needed to fully develop this potential. The Latvian authorities, through national strategies and other documents, aim to address both behavioral aspects to increase energy efficiency in the short term and the introduction of modern technologies in the long-term. These strategies are consistent with the principles of energy equity, providing tangible benefits for households and businesses from efficient energy use in the short term, while long-term development reduces overall energy consumption.

The performance of the Baltic countries in the World Energy Trilemma Index, along with a comparison of the categories of energy security, energy equity, and environmental sustainability, highlights areas where initiatives can be implemented through education for sustainability. For example, Latvia scores 77.4% for energy security, 69.2% for energy equity, and 68.5% for environmental sustainability, compared to regional averages of 75%, 70%, and 66%, respectively. As shown in Figure 13, strong cooperation between stakeholders will lead to increased performance.

A diversified energy strategy that combines renewables with modernized infrastructure and storage solutions is essential for Latvia to ensure a stable energy supply, reduce carbon emissions, and achieve EU goals. Energy policy priorities in Latvia should include incentives for investments in renewable energy, modernizing the network of public–private partnerships, and regional cooperation with neighboring countries to ensure a strong interconnected energy system. A bibliographic review of the literature confirms the relevance of the topic, and references for building cooperation indicate that the Global Energy Trilemma needs to be considered alongside other policy actions.

Education for sustainable development can effectively address the implementation of the Sustainable Development Goals and highlight their interrelationships. Latvia's path to a sustainable energy future will depend on the successful implementation of energy efficiency strategies, diversification of renewable energy sources, and an approach that balances economic, social, and environmental considerations. Through strategic policy measures and continued commitment to the principles of the Global Energy Trilemma, Latvia has the potential to make significant progress in creating a green, sustainable, and inclusive energy system that meets the needs of both current and future generations.

The Baltic Energy Initiative embodies a shared vision for sustainable growth and energy security in Northern Europe. By combining renewable energy capacity with a large-scale transmission system to the continent, the Baltic States will strengthen their resilience, contribute to Europe's climate goals, and create a roadmap for cross-border energy cooperation.

By combining renewable energy capacity with a large-scale transmission system for the continent, the Baltic States will not only strengthen their resilience and contribute to Europe's climate goals but also promote the development of the Baltic Energy Trilemma framework, which can serve as a blueprint for cross-border energy cooperation. This initiative positions the region as a hub for innovation, fostering dynamic collaboration between academia, industries, and governments to advance cutting-edge technologies that support a low-carbon economy, enhance energy efficiency, and create sustainable economic growth opportunities for the region.

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