

The Role of Green Energy in Minimising the Effects of Global Warming

Tetiana Gutsul*

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Abstract. The development of greenenergy is essential for minimizing the effects of global warming. The purpose of this study is to analyze the current trends in the use of greenenergy at the global level and to determine the potential of its implementation in Ukraine to combat climate change effectively. To achieve the goal, several analytical methods were used; in particular, thanks to an abstract and logical analysis, data was systematized regarding trends in the world in the field of greenenergy; the method of generalization helped to determine the general principles and features of the implementation of greenenergetics, a comparative analysis allowed to interpolate examples of the implementation of greenenergy in EU countries and Ukraine, economic and statistical analysis revealed financial obstacles to implementation, the graphic analysis helped to provide a visual representation of the implementation of greenenergy.

The study showed that the war in Ukraine significantly impacts world policy in the field of greenenergy due to the growing need for energy supply and security, which is caused by the abandonment of dependence on Russian energy resources. Key obstacles to the competitiveness of green technologies in the energy market were identified: lack of investment, high cost, insufficient regulatory and legislative framework, and lack of incentives for business. The results emphasize the importance of overcoming these obstacles by attracting international financial support and improving and implementing legislation and government programs regarding greenenergy.

The conclusions emphasize that Ukraine should focus on improving its energy strategy and adding measures to stimulate the use of greenenergy, infrastructure modernization, and active international cooperation.

Keywords: alternativeenergy, legislation, energy resources, regulatory policy, sources.

INTRODUCTION

Global economic crises, energy disputes, and the struggle for limited natural resources force humanity to rethink its attitude toward the environment from the point of view of economic benefit. This leads to serious environmental problems such as global warming and climate change. Environmental pollution

and the growth of greenhouse gas emissions stimulate the search for alternative energy sources that can help preserve natural resources and mitigate the consequences of environmental disasters.

One of the key measures in the fight against global warming is the transition to green

* Tetiana Gutsul

PhD in Economics, Associate Professor, Associate Professor of the Department of Economy, Faculty of Economics National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine, gutsul_tetiana@nubip.edu.ua, <https://orcid.org/0000-0002-1826-240X>

energy, such as solar, wind, hydro, and geothermal energy. Since the mid-1990s, the European Union has been actively promoting the use of green energy. An important step in this direction was Directive 2001/77/EC, which promotes the development of electricity from alternative sources. Further changes in energy policy, in particular Directive 2009/28/EC, became the basis for the harmonization of energy policy and the increase of the share of "green" energy in the energy balance of the EU (European Parliament & Council, 2009).

For Ukraine, the transition to green energy is important not only from an environmental point of view but also from an economic point of view. This makes it possible to reduce dependence on the import of energy resources, such as natural gas and oil, which is especially relevant in the context of geopolitical challenges. In addition, the introduction of RES promotes the development of innovative technologies, which reduces the cost of energy resources, creates new jobs, and contributes to the development of the national economy (REN21, 2020).

Ukraine has already signed the Association Agreement with the EU and has taken a number of steps toward integration into the European energy market; in line with EU goals, Ukraine is also working on reducing its carbon footprint

Research problem

Two main factors determine the relevance of research on promoting renewable energy sources in Ukraine. First, digitization and the rapid development of industrial automation, together with the emergence of Industry 5.0, are changing the paradigm of interaction between man and machine, which opens up new opportunities for the use of artificial intelligence in the field of renewable energy. This is important for forecasting energy production from renewable sources such as solar energy. Effective forecasting will reduce investment risks and improve the integration of "green" energy into Ukraine's energy balance.

Secondly, the problem of stimulating renewable energy becomes even more urgent in the context of climate change, which is a global problem. Ukraine, as part of the international community, is obliged to work towards achieving the UN Sustainable Development Goals, in particular Goal 7, which concerns the availability, reliability, and sustainable use of

and increasing the share of renewable energy sources in its energy balance.

The main priorities of the modern energy strategy of Ukraine and the EU countries are increasing energy efficiency and replacing fossil fuels with renewable energy sources. This is due not only to the limitation of hydrocarbon resources and dependence on energy imports but also to the need to reduce anthropogenic impact on the environment. Increasing the share of "green" energy will contribute to the reduction of carbon dioxide emissions, which is an important factor in the fight against climate change and global warming (REN21, 2020).

Although the high cost of renewable energy production remains a deterrent to its development, increased government support and economic incentives have contributed to the growth of green energy use. As a result, much of the energy in the EU is now produced from renewable sources, helping to reduce dependence on fossil fuels and mitigate the human impact on climate change.

Thus, "green" energy plays an important role in minimizing the consequences of global warming. The transition to renewable energy is an important step towards sustainable development, reducing greenhouse gas emissions and maintaining the ecological balance of the planet.

energy, and Goal 13, which provides urgent action to combat climate change. Using innovative technologies, such as artificial intelligence, to optimize the production of "green" energy is an essential step towards increasing the efficiency of the energy sector and reducing Ukraine's carbon footprint (UNFCCC, 2021).

Effective forecasting of renewable energy production will allow more rational development of energy policy, increase the competitiveness of alternative energy sources, and ensure stable integration of "green" energy into Ukraine's energy market. It will also help minimize the consequences of global warming and help Ukraine fulfill its international obligations to reduce greenhouse gas emissions.

Research focus

Given the current challenges of climate change and the growing importance of renewable energy sources in the international arena, it is essential to explore the role of "green" energy in minimizing the effects of global

warming. Studying the features of "green" energy, its advantages, disadvantages, and the impact on environmental stability is becoming relevant. Of particular interest is the analysis of the production and implementation of renewable energy in different countries, particularly world leaders in this field, and the possibility of adapting their experience to reduce the carbon footprint and develop alternative energy sources in Ukraine.

Research Aim and Research Questions

The purpose of this work is to study the minimization of global warming using "green"

LITERATURE REVIEW

This review aims to systematize and critically analyze studies highlighting the role of renewable energy sources (RES) in global warming mitigation, including their impact on greenhouse gas emissions reduction and climate stability. All studies analyze the mechanisms of RES's impact on reducing greenhouse gas emissions, but there are gaps that require further study.

Fedun (2020) examines the environmental aspects of cooperation between Ukraine and the EU, focusing on general issues of sustainable development. However, the study does not contain a detailed analysis of the mechanisms for mitigating the impact of RES. For example, the work does not consider specific projects that would demonstrate the successful reduction of carbon dioxide emissions in Ukraine thanks to the introduction of RES.

"Sustainable development and socio-economic relations" Averikhina, et al. (2021) examine the impact of RES on sustainable development, but again, insufficient attention is paid to specific regulatory mechanisms. The lack of clear examples, such as wind and solar success stories, is a disadvantage because it does not demonstrate a concrete impact on emissions reduction.

Globalization and the "Green Economy," Kupalova et al. (2022) emphasize the systemic impact of the 'green' economy on international security. However, specific regulatory instruments to support the development of RES have not been considered. For example, a better understanding of the impact of greenhouse gas emission reductions would be achieved if mechanisms such as tax

energy and assess its impact on reducing greenhouse gas emissions and maintaining climate stability. The study also aims to analyze the opportunities and challenges associated with implementing renewable energy sources to combat climate change.

The following research questions will be considered in the work:

1. How effective is "green" energy in reducing greenhouse gas emissions and global warming?

2. What are the main challenges and risks of implementing renewable energy sources to combat climate change?

incentives for RES investors were explicitly mentioned.

The EU Directive and its implementation Directive 2009/28/EC set mandatory targets for EU countries regarding the use of RES. However, existing studies have not adequately addressed how meeting these targets has affected the actual results of emission reductions. For example, Denmark achieved a 40% reduction in emissions in 2020 by installing wind farms.

The COVID-19 pandemic significantly impacted all sectors of the economy, including the energy sector. Amid global regulatory and economic instability, RES development experienced challenges and new opportunities: according to 2021 International Energy Agency (IEA) data, more than 60% of national recovery programs included a RES support component, indicating shifting policy priorities. The COVID-19 pandemic has had a complex impact on developing renewable energy sources (RES), creating new challenges and opportunities for the industry. Due to restrictions on international transportation and the closure of borders, many companies had to delay the construction of new RES facilities. For example, delays in the supply of components for solar panels and wind turbines have complicated the commissioning of new plants. These disruptions affected global energy markets and led to an increase in the cost of project implementation in the short term. The downturn in economic activity caused by the pandemic has reduced electricity demand and made investing in new renewable energy projects less profitable. Market uncertainty and economic recession made it difficult to finance projects in

the early stages, which discouraged many investors from making new investments.

The pandemic showed weaknesses in traditional energy systems, which sometimes needed to be prepared for the rapid integration of new RES plants. This raised the question of the need for accelerated development of network infrastructure to support renewable energy sources. However, the pandemic has also brought essential opportunities. The pandemic has accelerated the implementation of digital solutions for monitoring and managing renewable energy sources. Remote control of power plants and analysis systems has made it possible to manage energy systems more efficiently and reduce operating costs. Implementing artificial intelligence and automation systems for real-time analysis of plant operations has played a vital role, thereby reducing the dependence on the physical presence of staff. Economic incentives introduced by the governments of various countries have become a catalyst for new investments in "green" technologies.

Countries such as Germany and Canada have introduced new tax incentives for investors to encourage solar and wind power investment. The impact of the pandemic has also brought changes in technological development. On the one hand, travel restrictions and reduced international trade relations have delayed the implementation of several projects in the RES sector. On the other hand, however, COVID-19 accelerated the adoption of digital technologies in monitoring and managing energy systems. For example, using remote control and data analysis in power plants has become more common, increasing the efficiency of RES operations.

Many companies have begun to invest in process automation, reducing their reliance on human resources. As a result, the energy system's resilience to possible future crises will increase.

The effectiveness of supporting renewable energy (RES) depends on using several mechanisms to stimulate investments and technological development. One of the most widely used tools is green tariffs, which provide a guaranteed price for electricity produced from renewable energy sources. Thus, according to the studies of Kaufmann et al. (2020), green tariffs in Germany increased the percentage of renewable energy in the total energy balance from 6% in 2000 to 42% in 2019, correspondingly reducing CO₂ emissions by 27% over this period.

Another important mechanism is the auction system, where companies compete for contracts to supply electricity from RES. According to a study by Van der Veen et al. (2021), wind farms awarded contracts through auctions in Denmark reduced costs by 30% compared to traditional financing methods. This suggests that such an approach can effectively reduce the cost of renewable energy.

The quota trading tools are flawed. According to the European Commission's report (2021), thanks to the trading of quotas in the EU, greenhouse gas emissions have decreased by 38% since 2005. This is an incentive for investors.

Table 1 presents visualizations of the results of the analysis of RES support policies and compares successful examples from different countries, such as Germany, Denmark, Canada, and the USA.

Table 1. Examples of RES support policies

Country	Tax benefits for investors	Financial incentives for the development of VDE	Goals to increase	Challenges	Successes and innovations
Germany	Preferential loans	Greenfund for renewable energy	80% of energy from RES by 2030	High cost of integration into the national network	Innovative program "Energiewende", significant investments in solar and wind energy
Denmark	Tax refunds for investors	The state invests in the development of wind power plants	100% of energy from RES by 2050	Dependence on weather conditions	The world leader in the development of wind energy, a high level of energy sustainability
USA	Tax incentives for RES	Federal subsidies and grants	50% of energy from RES by	Lack of unified energy strategy	The rapid growth of investments in

			2035	among states	solarenergy and the development of the electriccar market
Canada	Tax reduction for producers of greenenergy	State support programs for small businesses in energy	90% of energy from RES by 2030	Difficulties due to climatic conditions in certain areas	The development of hydropower and large investments in the development of wind power plants

Source: authors' own development based on Agnolucci&DeRubeis (2022)

The role of subsidies and subsidies is also important. For example, in the U.S., thanks to the Investment Tax Credit (ITC) program, in 2019 installed PV capacity increased by 167% compared to 2015 (Solar Energy Industry Association, 2020).

Research gaps

Many studies need to analyze the mechanisms of renewable energy sources (RES) implementation. It is worth presenting a detailed description of technologies, such as solar panels and wind turbines, that can significantly reduce carbon dioxide emissions. Research does not always include real examples of successful RES implementation. An analysis of Germany's success in using solar energy can serve as an example. Not enough attention has been paid to the recent political and technological changes that have resulted from the COVID-19 pandemic. It was noted that crises indicate the need to change approaches to energy policy, such as increasing investments in RES during the recovery period.

Research is needed to analyze the

effectiveness of specific renewable energy support mechanisms, such as tariff systems, and their impact on greenhouse gas emissions. It is also important to consider how political stability, and the level of government support affect the development of renewable energy.

Research should also assess the long-term impact of RES on the stability of the energy system, particularly in the context of integrating RES into existing energy networks. This requires a detailed analysis of how technologies supporting the integration of renewable energy sources affect the security of energy supply.

Thus, this study aims to fill critical gaps in existing knowledge about RES and their impact on the climate situation and provide new evidence for improving green energy policies.

METHODS

Data Design

The research is focused on determining the role of "green" energy in minimizing the consequences of global warming and requires the use of various scientific methods. The main approach is a qualitative analysis of scientific sources, including articles from international scientific journals, statistical data, monographs, methodical manuals, collective works, and conference materials.

The research used content analysis, namely the codification of topics and categories. Thanks to this method, it was possible to systematize and classify information from different sources, highlighting critical aspects of the impact of renewable energy sources on reducing greenhouse gas emissions. This method consisted of extracting the main categories such as "economic incentives,"

"environmental consequences," and "technological innovations," based on which further analysis was carried out.

In order to ensure the objectivity and reliability of research results when applying content analysis methods, clear criteria for selecting information sources have been introduced. In particular, sources from countries whose governments actively use renewable energy policies for domestic and international propaganda were excluded. These incorporate nations where government data is sporadic or centered on purposeful publicity.

Sources related to companies with coordinated commercial interfaces in renewable energy were also avoided to maintain a strategic distance from distorting or overstating the benefits of particular innovations. Sources that do not meet logical benchmarks were also prohibited, particularly those containing wrong or oversimplified gauges and the need for straightforwardness in inquiry about strategies or

data control.

Preference was given to well-known international organizations (International Energy Agency (IEA), Intergovernmental Panel on Climate Change (IPCC)) and research institutions with a good reputation in the international arena. The data is based on proven methods and is therefore considered objective. To ensure that the research is relevant to the current situation in the RES market and current political and technological trends, sources published within the last 3-5 years have been selected.

This allowed for a deeper understanding of the interrelationships between political, economic, and technological factors affecting the development of "green" energy and provided a basis for formulating practical recommendations for its implementation.

Data selection

The collection of scientific literature was carried out in several stages, which made it possible to create a systematized list of sources for further analysis. The first stage included a search for publications in scientific and metric databases such as Elsevier (Scopus), Web of Science, and Google Scholar. Keywords used included: "green energy," "renewable energy,"

"global warming," "climate change," and "energy policy." At this stage, 355 results were obtained.

The second stage consisted of excluding duplicates and editions from countries with possible bias, particularly Russia and Belarus. This made it possible to reduce the list to 149 articles. The exclusion was based on an analysis of the journals in which the articles were published and on the authors' reputations.

The third stage included a thorough analysis of abstracts of scientific articles to exclude those that did not contain relevant information about green energy. This reduced the number of articles to 107. The exclusion criterion was the irrelevance of the topic or the need for a clear link to climate change.

The fourth step was determining the research year range, including works published after 2018. This is critical to the relevance of the topic, and a further 41 articles were excluded at this stage.

The fifth stage involved applying additional selection criteria, including the availability of information on green energy policy, its impact on global climate goals, and development in each country. As a result, 30 works that met these requirements were selected. Three papers based on previous studies that met the search criteria were also included.

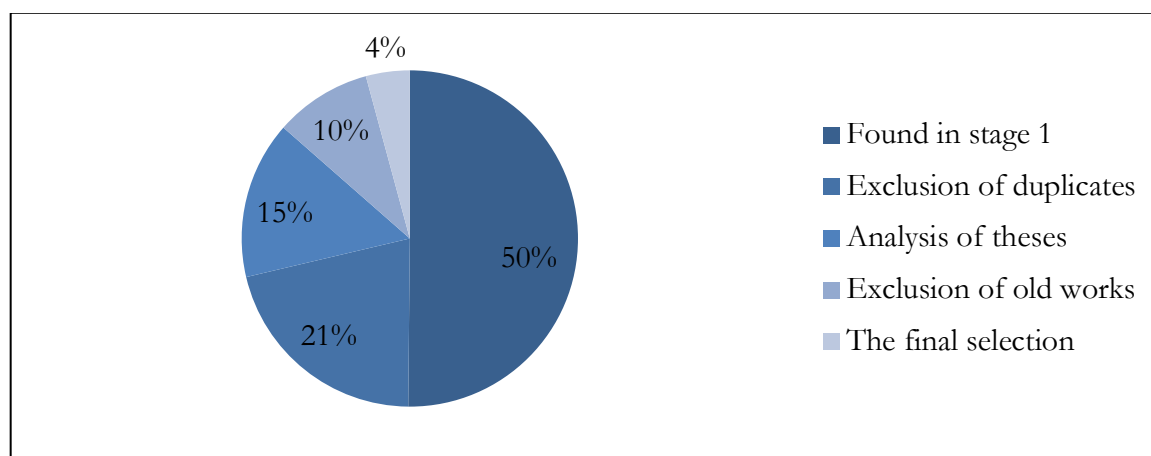


Figure 1. The process of selection and analysis of scientific sources for research
Source: authors' own development

The source selection process included an assessment of credibility and relevance based on factors such as journal impact factor, peer review, citations, and topic relevance. The result was a list of reliable sources relevant to the study of the role of renewable energy sources in the context of global warming.

Data analysis

Using the methods mentioned above, the scientific literature was analyzed to identify the main trends in the development of green energy, their impact on global warming, and the role of various political and economic factors. The analysis of scientific literature was carried out using several main steps, which ensured a qualitative approach to selecting and evaluating sources.

First, clear criteria were used for the selection of sources, such as relevance (publications in the last five years), scientific reputation of the publications (impact factor or peer review), as well as the expertise of the authors (the availability of relevant academic degrees and experience in the field). Second, the sources were assessed for reliability, considering scientific methodology, statistical data, and clear presentation of conclusions. A detailed consideration of the impact of specific government measures on the development of green energy deepened the analysis of political factors.

Analyzing subsidies for renewable energy sources provides a significant reduction in the costs of their production, which stimulates demand and infrastructure development. For example, in Germany, the system of subsidies for solar and wind power plants led to a rapid increase in their share in the country's energy balance. However, one of the disadvantages may be an increase in the tax burden on other sectors of the economy or the need to reduce spending on other social needs.

After researching the tax incentives, I found that they stimulate investments in the green sector, allowing companies to reduce the costs of installing renewable energy sources. In the US, the Investment Tax Credit (ITC) for solar energy investors has contributed significantly to the growth of the solar panel market. However, depending on government decisions, these benefits may be reduced, which will affect the development of the industry.

Having analyzed the environmental regulations, it is worth noting that using hydrocarbons contributes to the transition to clean energy sources. For example, in the EU, introducing carbon dioxide emission limits has encouraged companies to use greener technologies. However, it has also increased production costs, which can lead to higher electricity prices.

Several economic factors were also analyzed, namely the reduction in the cost of technologies such as solar panels and wind

turbines that have made renewable energy competitive with traditional fossil fuels. For example, over the past ten years, the price of electricity from solar panels has decreased by more than 80%, significantly increasing the share of green energy in many countries. It also lowers barriers to entry for new players in the market. The general level of investments in the green sector depends on political and economic stability and the predictability of regulatory policy. For example, countries with stable economies, such as Denmark, attract significant investment in wind energy, which has allowed them to become a world leader in this field.

On the other hand, instability or frequent political changes create risks for investors and can slow development. The analysis also includes credit and financing programs that encourage citizens to switch to clean energy sources, such as providing low-interest loans to install solar panels on private homes. These programs contribute to increasing the share of green energy in the overall energy balance and reducing greenhouse gas emissions at the individual level. However, in some cases, the high costs of administering such programs may reduce their effectiveness.

Ethics

Several measures were taken to ensure ethics and protect the rights of participants in the research. All personal data of the participants are anonymous, and the study's results are presented in an impersonal form. Names and other identifiers have been excluded from all reports and publications.

Research data is stored in a secure electronic format on an encrypted server, ensuring access only to authorized persons. All data will be stored for a specified period in accordance with research ethics requirements, after which they will be destroyed. Table 2 presents the main stages of selecting and analyzing sources for further work on the research.

Table 2. Stages of finding exclusions of scientific sources for research

Selection stage	Number of sources	Actions	Amount after exclusion
Initial search	355	Publications found	355
Exclusion of duplicates	355	Duplicates removed	149
Analysis of essays	149	Irrelevant ones are excluded	42

Determining the range of years	42	Articles up to 2018 are excluded	41
Additional selection criteria	41	Choices for politics and climate impact	30
Additional studies	30	Added 3 relevant works	33

Source: authors' own development

Limitations

The study has certain limitations that may affect its results and conclusions. The study is based on a sample that may not reflect the diversity and complexity of the situation in different countries. This means that the results may not represent the wider population, and their generalizability may be limited. To improve representativeness, future studies plan to expand the sample to include additional countries and regions and take into account diverse political and economic contexts. Because the study focuses on specific countries, its findings may not be relevant to other regions with different

political, economic, and environmental conditions. To overcome this limitation, future studies will conduct a cross-country comparative analysis that will assess the impact of local conditions on the effectiveness of green energy implementation. The methods used may not cover all aspects affecting the results. For example, content analysis may not fully account for changes in the political environment. Conducting further research requires a combination of different methods, such as quantitative and qualitative methods, to get a more complete picture of the situation.

RESULTS

Global climate change has become one of the most pressing environmental issues that the world community has focused on. The resulting rapid changes in temperature, floods, strong winds, torrential rains, hail, droughts, and other dangerous weather hazards are causing significant environmental and economic damage around the world. According to the World Meteorological Organization (WMO), the past three years have been the hottest on record.

Increasingly unpredictable weather conditions threaten food security, and rising sea levels increase the likelihood of natural disasters. According to the Intergovernmental Panel on Climate Change, scientific studies have shown that climate change due to anthropogenic factors since the end of the 19th century is partly related to natural climate change but mainly due to human activities, especially increased concentrations of greenhouse gases in the atmosphere.

The COVID-19 pandemic has significantly impacted green energy policies and changes in the global energy balance. The pandemic has led to a significant reduction in energy demand due to economic constraints, which has caused a reduction in energy production, especially from fossil fuels. This demand reduction has made green energy more competitive, as it is less dependent on fluctuations in raw material prices. Many countries have included measures to support

"green" energy in their anti-crisis plans. The European Union, in particular, introduced programs to support renewable energy sources (RES) as part of the "Green Deal." Government incentives aimed to make the transition to clean energy technologies the foundation for economic recovery after the pandemic.

The pandemic has also prompted countries to rethink their long-term energy strategies, focusing on greener solutions. There is an increase in investment in research and development in the field of renewable energy, particularly in technologies such as solar and wind energy, energy storage, and the use of hydrogen. COVID-19 caused a short-term reduction in greenhouse gas emissions due to shutdowns in industry and reduced transportation. This gave impetus to a more active discussion of climate policy and increased regulation of carbon markets. Countries and international organizations have begun to revise their energy policy priorities. For example, the International Energy Agency (IEA) emphasized the need to invest in clean energy to recover from COVID-19 and improve energy security in the long term. The transition to "green" energy began to affect the global energy balance, accelerated by the pandemic. This is expressed in the gradual reduction of the role of fossil fuels in energy systems, especially against the background of the growth of the share of RES. COVID-19 has catalyzed changes in the global

energy balance, accelerating the transition to renewable energy sources and increasing attention to climate goals. Green energy promotion policies received a new impetus due to anti-crisis packages aimed at ecologically clean recovery of the economy.

Adaptation to global climate change is the process of adjusting natural and human systems in response to actual and projected climate change. This process aims to mitigate the adverse effects of climate change and take advantage of opportunities that arise. In 2015, heads of state agreed in Paris to take action to limit global temperature increase to less than two °C by the end of the century and limit temperature rise to 1.5 °C. 2019 is the year that will promote the global Year of Climate Change Protection, and millions of students around the world participated in the protest “Future Friday,” demanding decisive action on addressing climate change (Tantoh & Ndongmo, 2019).

However, current efforts to curb global warming must yield the desired results. According to the United Nations, instead of limiting global warming to 1.5 °C under the 2015 Paris Agreement, the world will be warming by 3.2 °C by 2100. At the same time, greenhouse gas emissions are increasing. This is because the world's 20 largest countries, which account for about 78% of global greenhouse gas emissions, have implemented few necessary reforms (Stevens & Van de Graaf, 2019).

Developing renewable or “green” energy is a critical component of sustainable development and guarantees the ecological and economic security of individual countries and the global economy in general. Significant reductions in the use of carbon fuels in developed countries will reduce carbon dioxide emissions and slow global warming. Renewable energy sources underlying “green energy” include solar and wind energy, hydropower (including small hydroelectric power plants on mountain rivers), tidal energy, geothermal energy, and bioenergy using biomass (mainly agricultural and food waste).

In the international system of economic relations, synergistic links can be seen between the development of “green energy” and the provision of international economic security. Renewable energy development in the 21st century is becoming a key direction for countries' transition to sustainable development and a strategic priority in the global energy

market. It has become a strategic priority in the global energy market. Thanks to “green energy,” the process of global warming will be slowed down, and carbon dioxide emissions and their associated environmental, social, and economic risks (from increased climate refugees and coastal flooding to increased hunger and poverty) will be reduced.

The insufficient integration of renewable energy sources (RES) into the national energy systems of EU countries has many negative consequences. First, long-term dependence on fossil fuels increases greenhouse gas emissions. For example, Eastern European countries such as Poland consume large amounts of coal and have significantly increased their carbon dioxide emissions, which is at odds with the EU's emission reduction targets. Second, inappropriate investments in renewable energy infrastructure can lead to economic losses, mainly due to rising electricity prices. Hungary did not have sufficient support for the development of solar energy, which lagged behind other countries and negatively affected the energy sector's competitiveness.

Insufficient integration of RES also increases the energy dependence of countries reliant on imported fossil resources. This is especially critical in conditions of geopolitical tension, such as in Ukraine and other Eastern European countries that depend on gas supplies from Russia. The lack of diversity of energy sources hurts energy security, increasing the risks of supply interruptions. For example, in Italy, insufficient integration of solar and wind energy during peak loads leads to high energy system vulnerability.

In expansion, conventional fuel capacity has critical natural impacts, including disruption and water contamination. In Romania, the natural issues related to the extraction of coal and other fossil assets are exacerbated by the need for backup for renewable energy sources. All these illustrations appear to show that the lack of integration of renewable energy sources has a negative effect on the environment, economy, and energy security of EU nations.

Developing “green energy” will lead to new market sectors, production sectors, and services that support international economic security, stimulate economic growth, create new “green” jobs, expand employment, and reduce unemployment. It will contribute to structural and innovative changes in producing goods and services. For example, the development of solar

and wind energy will require the production of solar panels, wind turbines, and batteries, which will stimulate high-precision engineering. There is also a growing demand for energy-efficient solutions, from “smart” devices to building infrastructure for carbon dioxide capture and storage. This creates a multiplier effect of economic growth and provides demand for innovative equipment, information technology, and transportation and logistics infrastructure development, which positively impacts international economic security (Barrett, 2017).

“Green energy” is often developed through a design approach that considers

International cooperation in the development of "green energy" is focused on several key priorities. First, institutional support for the use of renewable energy, which includes legal, organizational, and advisory assistance, is important. Second, increasing access to renewable energy sources, along with technical and advisory support, is critical. The third priority is the diversification of energy supply sources and increasing the share of renewable resources in global energy consumption. In addition, it is necessary to eliminate political and institutional barriers that prevent the development of "green energy" in all countries. Last but not least is the demonopolization of energy markets and the reduction of barriers to entry into global and regional energy markets for environmentally friendly resources used to produce "green" energy (BP, 2022).

economic, social, and environmental aspects and national and international economic security issues. This approach is often financially supported through government programs, tax breaks, subsidies, and grants. The transition to green energy requires significant resources and investment in research and development. It is facilitated by international cooperation supported by organizations such as the United Nations, the United Nations Environment Programme (UNEP), the Basel Organization for Sustainable Energy (BASE), and the International Renewable Energy Agency (IRENA) (Baisakalova, 2015).

Today, the top seven renewable energy-producing countries, which together account for 71.5% of the world's electricity generation capacity (excluding hydropower), include China, the United States, Germany, Italy, Spain, Japan, and India. The total capacity of these countries is 470 GW (The Guardian, 2018).

“Green energy” includes power plants that generate electricity from biomass and biogas and thermal power plants that generate heat from products and waste from the woodworking industry, such as charcoal briquettes, pellets, chips, and pellets. Bioethanol and biodiesel from rapeseed production to make environmentally safe vehicle fuel is also part of renewable energy. The emergence of new forms of “green” energy will occur along with scientific and technological advances and depend on the active implementation of innovative solutions in economic activities.

Table 3. Top-5 Leading Countries in Renewable Energy Production and the Largest Capacities of Renewable Energy Facilities Worldwide

Type and Indicators of Renewable (Green) Energy	1st Place	2nd Place	3rd Place	4th Place	5th Place
Renewable energy (including hydro-)	China	USA	Brazil	Germany	Canada
Renewable energy (excluding hydro-)	China	USA	Germany	India	Portugal
Renewable energy capacity per capita	Denmark	Germany	Sweden	Portugal	Norway
Bioenergy production	USA	China	Germany	Brazil	Japan
Geothermal energy production	USA	Philippines	Indonesia	Mexico	New Zealand
Hydropower capacity	China	Brazil	Canada	USA	Russia
Solar energy production	China	USA	Japan	Italy	Germany
Solar energy capacity	China	Japan	USA	Italy	Greece
Solar energy capacity per capita	Denmark	Ireland	Belgium	Japan	Greece

Windenergy capacity	China	USA	Germany	India	Spain
Windenergy capacity percapita	Denmark	Sweden	Spain	Germany	USA
Heatpump systems capacity	Sweden	Germany	Brazil	Austria	Greece
Heatpump systems capacity percapita	Austria	Cyprus	Barbados	Germany	Greece
Geothermalheat capacity	China	Turkey	USA	Russia	India
Geothermalheat capacity percapita	Japan	Sweden	Ukraine	Finland	Japan

Source: compiled by the authors based on analysis Renewables 2018: Global status report

The data in Table 1 show that as of 2022, the leaders in the adoption and use of "green" energy are countries whose economic growth is closely linked to innovation and post-industrial development, such as Europe, the United States, Canada, and China. In countries where targeted support for the transition to sustainable

economic development is implemented at the national level (especially in European countries), a system of economic stimulation of the development of "green energy" is used at the state and local levels. Such measures include the following, presented in Table 4 (Selin, 2022).

Table 4. Measures of economic stimulation of the development of "green energy"

Measures of economic stimulation of the development of "greenenergy"	Eventdescription
A special "greentarriff"	Introducing a special "green tariff" for producers of renewable electricity, which is higher than the normal electricity tariff. This would help increase the profitability of the production and sale of "clean" energy supplied to the national electricity grid.
Import tax incentives	Reduction of customs tariffs and tax benefits for equipment for the production of electricity from renewablesources.
Reduced landtaxes	Reduced landtaxes on state, municipal, and private lands where "greenenergy" facilities are located. This tax is typically reduced by at least 75% from the standardrate. This applies to land where energycrops such as solarpanels, windturbines, or "energywillows" are grown.
Income tax exemptions	Preferentialtax treatment for corporations and businesses that deriveincome from the sale of electricity from renewableenergysources.
Exemption or refund of VAT	Exemption or automatic refund of VAT on equipment for the production of "green" energy and the export of renewableenergy (in countries where this is provided for by law).
Introduction of a quota system for the production and consumption of "green" energy.	Failure of economic agents to reach the setquotas may lead to fines or revocation of licenses.
Provision of government subsidies to "greenenergy" producers	Provision of government subsidies to "greenenergy" producers, including incentives such as "doublesubsidies," depreciationallowances, and government guarantees for project financing for renewableenergy development.

Source: compiled by the authors based on analysis Selin (2022)

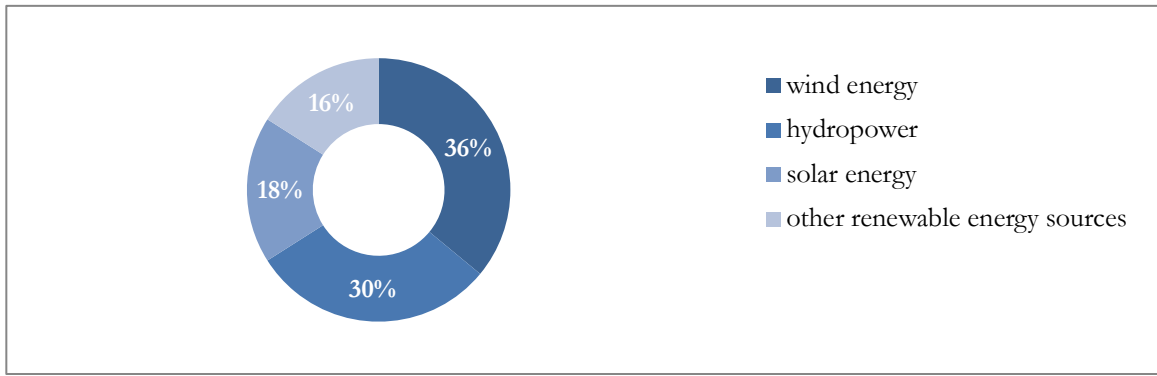


Figure 2. The percentage of use of resources by type

Source: compiled by the authors based on analysis Legal Sources on Renewable Energy (2020)

The implementation of support schemes in the EU, which has significantly accelerated the growth of the “green energy” sector, is particularly different: as of 2022, renewable energy will continue to be one of the fastest-growing energy sources in the EU, contributing more than 80% of electricity capacity growth. This increase in renewable energy production has been driven by the decreasing cost of renewable energy technologies and the completion of long-term installation projects (Huchta & Raines, 2023). However, increasing

financial burdens on national budgets and end consumers have forced EU countries to rethink their renewable energy support policies. After 2020, subsidies and tax incentives have been reduced in some countries, leading to a decline in investment in the renewable energy sector. Renewable energy investment reached \$110 billion in 2020 and will have decreased by 18% by 2022. If this trend continues, it could hurt the achievement of the goal of increasing the share of renewable energy in the energy balance by 2030 (European Parliament and Council, 2021).

Between 2018 and 2022, wind and solar energy steadily increased in renewable energy production in EU countries, replacing hydropower. In 2020, wind energy accounted for 36%, hydropower for 30%, solar energy for 18%, and other renewables for about 16%. The total share of other renewables will be about 16%. This period also saw a significant overall increase in renewable energy production compared to the previous decade due to aggressive new installations and lower

technology costs (Renewable Energy Legal Resources, 2020).

Alternative energies based on the use of solar energy, wind energy, hydroelectric energy, and other forms of energy not only contribute to reducing the environmental impact but also reduce dependence on fossil fuels. Among its advantages, it is worth highlighting the following points, shown in Table 5.

Table 5. Advantages of greenenergy

Advantages of "greenenergy"	Description
Reduction of greenhouse gas emissions	Unlike conventional thermal power plants, solar, wind, and hydroelectric power plants produce few harmful emissions, thus significantly reducing their impact on the climate and helping to combat global warming.
Self-sustaining energy	The use of greenenergy, which is widespread in many countries, can help reduce dependence on fossil fuel imports and increase energy security.
Economic development and job creation	Investments in solar and wind power plants will contribute to the creation of new jobs in the areas of production, installation, maintenance, and research and development. Distributed renewable energy sources can also support local economic development, especially in rural areas.
Price stability	Thanks to technological advances, energy production from renewable

	energy sources is becoming cheaper. Solar and wind power are becoming more competitive because the natural resources that supply them are not subject to market fluctuations or geopolitical influences.
Environmental protection and health conservation	Green energy emits few pollutants into the air and water, thus contributing to the reduction of respiratory diseases, improving environmental conditions and, in turn, people's quality of life.
Inexhaustibility of resources	Unlike fossil fuels, which have limited reserves, solar, wind, and hydroelectric power generation use virtually inexhaustible resources and can provide a long-term energy supply.

Source: compiled by the authors based on analysis Platonova (2021)

However, along with numerous advantages, the use of "green" energy is accompanied by certain challenges and disadvantages that affect its effective implementation. However, along with numerous advantages, the use of "green" energy is accompanied by certain problems and disadvantages that affect its effective implementation, as shown in Table 6.

Table 6. Disadvantages of "green energy"

Description	
High initial costs	Although the operating costs of renewable energy are relatively low, the significant upfront investment in solar panels and wind turbines can be a major barrier for many companies and individual users.
Unpredictability of production	The efficiency of electricity production depends on weather conditions, such as the amount of sunlight, wind strength or water level. This can cause power outages.
Geographical restrictions	The efficiency of using solar energy and wind turbines depends on geographical conditions. For example, solar panels work more efficiently in regions with high insolation, and wind turbines work more efficiently in areas with consistent winds, limiting their widespread use in other areas.
Problems of energy storage	In order to ensure a stable supply of electricity, it is necessary to store excess energy produced, especially during periods of peak production. However, energy storage technologies such as batteries are not yet sufficiently developed and require high costs.
Requirements for the territory	Solar panels and wind farms require large areas to install, which can be a problem in densely populated areas or in areas with limited space.

Source: compiled by the authors based on analysis Platonova (2021)

Green energy has significant advantages that help reduce environmental risks, increase energy independence, and stimulate economic growth. However, there are also certain challenges associated with high capital costs, geographical limitations and the need to improve energy storage technologies. Despite these drawbacks, the development of renewable energy sources is an important step towards a sustainable future, which provides a balance between economic interests and environmental protection.

DISCUSSION

In this study, we analyzed the effectiveness

of various mechanisms for supporting renewable energy and their role in minimizing the consequences of global warming. When considering the results of this study, it is important to conduct a comparative analysis with other known studies and clearly show how our results correlate with the more widely known data and what new conclusions can be drawn.

The study showed that the effectiveness of tariff regimes and regulatory instruments to support RES can differ significantly depending on economic conditions and political strategies. This is confirmed by a study by the International Energy Agency (IEA), which states that stable and predictable tariff regimes are important for stimulating investments in renewable energy (IEA, 2021). The study results support this

conclusion, noting that countries with well-developed RES support systems, such as Germany and Denmark, have made significant progress and exceeded expectations in reducing greenhouse gas emissions.

The development of "green" energy is closely related to international economic security, as it contributes to reducing dependence on the import of fossil resources and strengthening the economic stability of states. For example, Germany, thanks to its "Energiewende" program, significantly reduced the import of Russian gas, which positively affected its energy security and the stability of the EU economy in general. Similarly, India, by developing solar energy, has reduced its dependence on the volatile oil market, which minimizes the risks associated with fluctuations in oil prices.

In addition, the transition to renewable energy sources has led to the redirection of investment flows and the creation of new markets. China, a leader in the production of solar panels and wind turbines, is actively influencing global renewable energy markets, driving economic growth through exports. The US is also investing heavily in renewable energy through large-scale government programs that help create new jobs and strengthen its energy independence.

Mechanisms of "green tariffs" (feed-in tariffs) have different levels of efficiency in many countries. Their success depends on political stability, economy, administrative structure, and regulatory mechanisms. Good examples include Germany, which passed the Renewable Energy Sources Act (EEG), providing a fixed price for electricity produced from renewable sources, and Denmark, which introduced the FIT for wind power, a scheme offering long-term contracts and fixed payments to wind power producers. Inefficient tariffs can be seen in Spain, which, after the first world crisis, introduced a "sun tax," reducing interest in RES investments. In the Czech Republic, the FIT program did not last long due to high tariffs and insufficient verification of new projects.

However, the result is less clear about the auction scheme. This coincides with the conclusions of Agnolucci and DeRubeis (2022), who emphasize that the effectiveness of auction mechanisms can vary depending on the specific circumstances of the country. The study showed that in some cases auctions lead to significant discounts on the cost of "green" energy, while in

others they do not provide sufficient incentives for investment.

The results obtained also support the conclusions of the UN Environment & Bloomberg New Energy Finance (2018) study, which shows that environmental legislation and tax incentives have a positive impact. For example, countries with strict environmental standards and tax incentives for "green" energy have a greater reduction in carbon dioxide emissions, which is also confirmed by our study. However, despite predictions of a reduction in the use of fossil fuels, oil consumption continues to grow. This contradicts the predictions of the Intergovernmental Panel on Climate Change (IPCC, 2018), which state that the use of green energy must increase rapidly in order to meet global warming targets.

Renewable energy production continues to grow, but a study published in the journal *Nature Energy* and reported by ScienceDaily shows that growth rates in 60 countries are insufficient to meet the goals of limiting global warming to 1.5 °C or even 2 °C. The Intergovernmental Panel on Climate Change (IPCC) previously outlined scenarios in which temperatures should not exceed these thresholds by 2050. Most of these scenarios assume a rapid increase in the use of renewable electricity. However, research findings suggest that only a few countries have been able to achieve such growth rates (IPCC, 2018).

This is the first study that accurately measures the maximum growth rates of wind energy in individual countries. An analysis of the 60 largest countries showed that the actual growth rates of onshore wind energy are significantly lower than those predicted by the IPCC scenarios. Only a few small countries, such as Portugal, Ireland, and Chile, have achieved a fast enough transition to renewable energy. Among the large countries, only Germany was able to support the rapid growth of wind energy. Thus, in order to meet the goals of curbing global warming, the whole world must build wind farms at the same rate as Germany did. Since this is almost impossible, researchers are calling for the development of new technologies to help avoid global warming.

Examples of successful implementation of new technologies in the field of "green" energy demonstrate their significant contribution to reducing greenhouse gas emissions. One of the most striking examples is the Horizon 2020 project in the EU, which contributed to the

introduction of innovative energy storage technologies and the development of wind and solar energy. As a result, only in 2020, the share of renewable energy in the EU reached more than 38%, which helped to significantly reduce carbon emissions in the energy sector. Another example is the USA with its investments in Carbon Capture and Storage (CCS) technologies. Through the implementation of projects such as CCS at power plants in Texas, carbon dioxide emissions at individual plants have been reduced by up to 90%. These technologies contribute to the achievement of emission reduction goals and bring the transition to a climate-neutral economy closer.

Studies show that oil consumption is increasing despite the projected reduction in fossil fuels. This phenomenon can be explained by the fact that high natural gas prices and unstable supplies have made countries increasingly dependent on oil as a temporary solution. For example, according to an analysis of the economic situation in Europe by Agnolucci and DeRubeis (Agnolucci & DeRubeis, 2022), high gas prices in Europe increased oil consumption. Political decisions also play an essential role, so traditional energy sources may be preferred in each country – for example, in some countries such as Hungary. Instead of reducing its dependence on Russian energy resources and supporting the EU's climate change goals, Hungary has increased its dependence on Russia and continues to develop coal mining. Such an approach is at odds with pan-European efforts to transition to "green" energy, essential for combating global warming.

Also, the RES infrastructure must be sufficiently developed to transition to new technologies quickly. This is in line with the IPCC's (2018) conclusion that significant investments in new technologies and infrastructure are needed to meet global warming targets. This will require a review of long-term projections and adaptation of policies to encourage a rapid transition to renewable energy. New technologies must be reliably integrated into existing infrastructure to facilitate the transition to renewable energy.

This study significantly contributes to the scientific community by providing new insights into the effectiveness of various mechanisms to support renewable energy and their impact on reducing greenhouse gas emissions. For example, it has become clear that not all regulatory instruments and tariff systems work

However, investments in Hungary's energy sector, such as financing energy storage projects, can stimulate renewable energy development. It is worth noting that the inadequate infrastructure limits the transition speed. For example, in some countries, the existing energy infrastructure must support rapidly deploying new renewable energy technologies. An example is India, where renewable energy sources are usually located in remote regions, making ensuring energy transmission to consumers challenging. In addition, the lack of energy storage technology makes the system unstable, as solar power is not available at night, and wind power can operate erratically. Because of this, the integration of RES is often complicated at the deployment stage. In the United States, one of the main problems is that the country's energy infrastructure is not equipped to transmit energy over long distances from these regions to large cities where demand is concentrated.

This disparity suggests that faster and more significant investment in renewable energy infrastructure is needed to effectively reduce fossil fuel consumption. It also suggests that existing policy instruments must be sufficiently adapted to current economic and political conditions. Despite the projected decline in fossil fuel use, oil consumption is increasing due to political decisions in some countries that have led to continued fossil fuel use. In Hungary, for example, coal mining continues despite European commitments to reduce emissions (Agnolucci, 2022).

the same way in different countries, highlighting the need to consider local economic and political conditions when formulating policies.

Research findings on the effectiveness of auction systems in stimulating renewable energy development have been conflicting due to several key factors affecting their implementation and effectiveness in different countries. These factors include regulatory features, investment climate, energy market structure, and socio-economic conditions. In Germany, this system, which is used for solar and wind energy producers, faces the problem of insufficient interest from financiers due to complex authority requirements and high provisioning costs. Many enterprises still need to receive financing due to the lengthy approval procedure, which reduces the adequacy of the auction.

In addition, after winning the auctions, some companies abandoned the projects when faced with bureaucratic obstacles and unfavorable market conditions. In Brazil, the auction system for wind energy has been successful due to strong government support and access to financing. However, disruptions have occurred in some cases due to a lack of infrastructure to connect new wind farms to the grid. The winning projects could not be implemented due to the lack of transmission lines, which indicates the need for better infrastructure development coordination with the auction results. This system was created in Spain after the abolition of the established green tax system, which caused danger to the renewable viability segment. The auction system led to a drop in costs, but speculators considered the system dangerous due to changes in legislation and the instability of the country's long-term obligations. This negatively affected investor confidence and led to restrictions on new investments in the industry. In South Africa, the auction system has successfully attracted international investors and promoted infrastructure development. However, results have been mixed due to contract delays and unstable government funding. At certain moments, political changes and financial problems of the state energy company delayed the implementation of the project.

The interdisciplinary approach used in this study, including economic analysis, policy evaluation, and technology studies, contributed to a better understanding of green energy's role in combating global warming. For example, a comparative analysis of different mechanisms to support renewable energy can better assess their effectiveness in different economic and political contexts.

Political and economic factors include the following: state support and subsidies – for example, in countries such as Germany and Denmark, guaranteed prices for RES producers are actively being implemented, but India still does not have a stable and unified system of subsidies, which acts as an obstacle and slows down development; regulatory and administrative barriers – in Ukraine, with simple procedures for obtaining permits for the construction of RES, as in Sweden or the Netherlands, the development of renewable energy is faster, but in Spain, the so-called "sun tax" was introduced, which made it challenging

to develop solar energy until its cancellation; energy strategies and national priorities – the "green deal" of the EU, the strategy aimed at sustainable support for achieving carbon neutrality, but there are countries that are significantly dependent on fossil fuels such as Russia or Saudi Arabia; investment – in countries with a high level of economic stability, such as Norway or Switzerland, investors are ready to invest in the development of new technologies, but in countries with high political and economic risks, such as Pakistan or Zimbabwe, investments in RES are often unprofitable due to instability in markets.

The research results showed that the effectiveness of auction systems in supporting the development of renewable energy sources is inconsistent. This is consistent with the work of Agnolucci and DeRoubais (2022), who also note that the efficiency of auctions varies depending on the specific energy source. This study supports the opinion of Kaufmann et al. (2020), who argue that support through green tariffs, for example, in Germany, can significantly increase the share of renewable energy sources in the country's energy balance. However, the analysis showed that fixed fees may not be fully effective in countries with complex administrative barriers, such as the Czech Republic. According to a study by Van der Veen et al. (2021), auctions for wind farms in Denmark reduced energy costs by 30%, supported by the results.

The obtained results regarding the impact of tax incentives on renewable energy development coincide with the conclusions of Kaufmann et al. (2020), who show that providing tax incentives to renewable energy investors, as in the US, has contributed to significant growth in the solar panel market. However, the study also found that instability in public policy, such as cuts in benefits, can have a negative impact on the industry's development.

Similar to Stevens and Van de Graaf (2019), this study's results show that limited investments in renewable energy infrastructure lead to economic losses and reduce the sector's competitiveness. In the case of Hungary, I confirmed that this is possible. This contrasts with the success stories of countries such as Germany, where large investments in infrastructure have fueled the rapid development of green energy.

LIMITATIONS

Limitations in the study and implementation of green energy development strategies aimed at minimizing the effects of global warming are related to a number of political and economic challenges that affect the pace of transition to renewable energy sources. One important factor is the reduction of government support, which may slow the development of the infrastructure and technologies needed for “green” energy production. This poses a risk to the achievement of climate change goals, particularly the reduction of greenhouse gas emissions.

Unstable political decisions at the global and regional levels also hinder a rapid transition to renewable energy. An additional challenge is the high capital cost of building infrastructure and integrating new technologies into the existing energy system. These financial constraints make it difficult to attract the investments needed to accelerate the transition to renewables, which is essential to minimizing the effects of global warming.

Integrating new technologies into existing energy systems also creates technical challenges that slow the adoption of green technologies and delay achieving climate change goals. Despite these challenges, overcoming constraints and developing renewable energy remains necessary for combating global warming and securing a sustainable future.

CONCLUSIONS

In recent years, the development of the green energy sector has been critical worldwide, and it plays a crucial role in minimizing the effects of global warming. Introducing effective regulatory and legal mechanisms and establishing legislative targets to increase the share of green energy sources are critical in reducing greenhouse gas emissions, the main driver of climate change. The war in Ukraine provided the impetus to rethink energy policy and accelerate the transition to “green” technologies. Russia's use of energy resources as a tool of political pressure has forced EU countries to accelerate reducing their dependence on fossil energy resources and

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switch to more stable and environmentally friendly energy sources. The answer to these challenges is the REPowerEU plan, which aims to achieve energy self-sufficiency by 2030 and, at the same time, contribute to the fight against global warming.

One of the key initiatives is a platform for purchasing liquefied gas and hydrogen, which is not only a prerequisite for reducing dependence on fossil fuels but also for the further expansion of green technologies. However, the process of complete independence from fossil resources creates new geopolitical risks regarding possible dependence on other countries.

Nevertheless, green energy offers a long-term, stable solution to reduce emissions and minimize the effects of global warming. Accelerating the development of renewable energies such as solar, wind, and hydrogen energy, supported by national financial incentives and international initiatives, is not only economically beneficial but also an important ecological step toward climate protection.

Suggestions for future research

Future research on the legal aspects of promoting green energy development to minimize the effects of global warming could focus on assessing the effectiveness of existing legal instruments and policies aimed at supporting the energy transition. One important direction is the study of possible improvements in legal regulations that could increase investment attractiveness in “green” technologies and reduce barriers to implementation.

In particular, it would be essential to analyze the impact of international climate change agreements and national policies on national laws and develop recommendations for improving legal mechanisms to support innovation in the renewable energy sector. Research on these aspects will create a stable legal environment for developing green energy, an important instrument to combat climate change and secure a sustainable future for the planet.

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