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Development of Renewable Energy Sources: Impact on Sustainability and the Environment

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Abstract

The increasing global demand for energy represents one of the critical challenges faced by humanity today. Energy production is essential for social development and fulfilling human needs. However, energy production and consumption often result in significant environmental degradation and adverse effects on human health. Most energy companies use coal, oil and natural gas, which causes significant emissions of harmful substances into the atmosphere, pollution of water sources and other negative consequences. This article aims to explore the potential and environmental impacts of renewable energy sources. We conducted an in-depth study of thematic research and scientific literature on the development of renewable energy over the past five years. This research focused on issues of global renewable energy and ecology. The study found that energy production, while essential for social development, often leads to significant environmental degradation and adverse health effects. Traditional energy sources like coal, oil, and natural gas contribute to harmful emissions and water pollution. Technological advancements have facilitated more environmentally sustainable energy sources, such as wind, solar, hydroelectric power, and biofuels. The article concentrates on exploring the potential of renewable energy in the context of its impact on the environment. The findings highlight the importance of phased adoption strategies for renewable projects, tailored to financial capabilities, as demonstrated in Ukraine. This approach contrasts with large-scale investments and offers a model for countries with similar GDP values. Further research is recommended to compare the environmental effects of different renewable energy sources and develop financial support schemes for minor projects. Strengthening the link between financial incentives and investments in renewable energy is crucial for creating optimal conditions for sustainable development.

Keywords

Alternative energy; Sustainable development; Energy legislation; Energy relations; Environmental management

Introduction

Under Russian aggression and the constant increase in energy prices, the developing energy-intensive national economy suffers significant losses, leading to decreased production and inhibition of socio-economic development. Therefore, there is a problem of reorienting needs and proposals related to developing the country's energy sector. Despite the significant contribution of scientists to the development of theoretical and practical aspects of introducing renewable energy sources in Ukraine, several problems remain unresolved, particularly regarding the advantages and prospects of using alternative energy sources in Ukraine.

Renewable energy is energy obtained from natural sources replenished faster than consumed. Such sources are sunlight and wind; they are inexhaustible. Renewable energy sources are all around us. Meanwhile, fossil fuels — coal, oil, and gas — are non-renewable resources that took hundreds of millions of years to form. When fossil fuels are burned to produce energy, they release harmful greenhouse gases such as carbon dioxide contributing significantly to environmental degradation and climate change (Kostakis, 2024). According to the Climate Protection Strategy for 2050 developed by the European Commission, greenhouse gas emissions in EU countries can be reduced to zero within the next 30 years. This goal is planned to be achieved by abandoning fossil energy resources, which emit significant amounts of carbon dioxide during combustion (Marsh, 2023). Given the stable international support for transformational processes in Ukraine, it seems expedient to utilize the maximum potential of transitioning businesses to renewable energy sources to reduce emissions and enhance resilience to climate change during the post-war recovery period. Subsidized financing prospects within the framework of the Eurointegration development strategy open up significant practical opportunities in terms of utilizing renewable energy sources in business (Radmehr *et al.*, 2022).

Analyzing the experience of European countries and the policies of the European Union as a whole, it can be concluded that there is an effectively coordinated approach aimed at developing "green" energy. Significant attention is paid to minimizing air emissions by abandoning traditional energy sources, improving energy efficiency, conserving natural resources, and increasing the share of alternative energy sources in the energy production structure (Twidell, 2021). For instance, as early as 2007, the Polish Government adopted two laws on the production of bio-components and liquid fuels, along with mechanisms for monitoring and controlling the quality of such products. The rapid development of wind energy technologies in Romania was facilitated by an official financial incentive system for "green energy" producers, which aimed to stimulate investment growth in Romania's energy sector. Sweden initiated ambitious goals for its green certificate system (Li *et al.*, 2022).

Contemporary studies highlight aspects of the concept of sustainable development using innovative renewable energy technologies (Ang *et al.*, 2022; Berezovetska *et al.*, 2024; Breyer *et al.*, 2022; Deshmukh *et al.*, 2023; Maradin, 2021; Petruk, Kotsiubynska and Matsiuk, 2014). They analyze the functionality of alternative energy sources in modern business environments, examine the foundations of forming business models in the alternative energy market, and explore sustainable solutions for green financing and investment in renewable energy projects. At the same time, some researchers have

generalized the issues of the convergence of sustainable entrepreneurship, innovation, and business models during the period of global socio-economic transformation towards sustainable development, minimizing destructive environmental impacts, and preventing climate change (Gurieiev *et al.*, 2020). However, issues related to the functional characteristics of fully or partially replacing traditional energy sources with renewable ones, the analytics of relevant tools, and the potential to improve the structural-functional process model through innovative approaches to motivation and stimulation largely remain beyond the focus of contemporary academic research or have been insufficiently studied. Additionally, there are several policy gaps and barriers to developing renewable energy in Ukraine, such as regulatory frameworks, infrastructure issues, and cooperation between the public and private sectors, which underscore the need for an expanded study of this research topic.

It is necessary to develop new, alternative sources of energy, such as solar, water, wind and biogas, to compensate for the shortcomings of the existing energy system, reduce carbon dioxide emissions, improve the ecological situation and solve the problem of environmental degradation. Among the potential benefits of renewable energy are job creation, the reduction of energy poverty, and the promotion of rural development. This issue gains particular importance in the context of the energy crisis. Innovative technologies in renewable energy (e.g., advanced battery storage systems) can address problems related to stability and disruptions in electricity supply (Dmytriiev *et al.*, 2022).

In light of the above knowledge, the article tries to clarify the present challenges toward the transition toward renewable energy, namely the ways of achieving sustainable economic growth as an equitable development of green infrastructures, as well as high initial costs. Therefore, it is also unclear what kind of institutional support and financial stimuli are needed in the long term so that the results can be achieved in terms of sustainable development. However, while the transition to renewable energy is critical for environmental protection, the economy also requires a stable energy supply, which alternative energy sources cannot consistently guarantee. Therefore, the issue of reducing energy dependence through the formation of an adequate energy-saving program and the development of alternative energy in Ukraine should be classified as a strategically important issue that requires an urgent solution.

Methodology

We reviewed emergent literature and statistical data to critically investigate modern trends in assimilating alternative energy technologies with national energy systems. To ensure the standards of transparency, the following steps were undertaken:

Data Source Identification: The data was collected from sources such as official government databases (State Agency on Energy Efficiency and Energy Saving of Ukraine, 2018), scientific journals, and other official publications. Sources were chosen according to their themes of renewable energy sources with additional consideration of the source publication date as a criterion for its practical relevance.

Data Selection Criteria: The selection was based on the following criteria. We searched for the latest literature from 2014 to the present. The search queries included the

following keywords: Alternative energy; Sustainable development; Energy legislation; Energy relations; and Environmental management. Accordingly, our study focused on literature primarily dedicated to European countries and Ukraine, with diverse sources of renewable energy considered, including solar, wind, bioenergy, and others. Specific focus was made on data that characterise the effect of renewable energy sources on the environment. Data were obtained by querying databases and using Pubmed for a systematic review of the literature. Consistent type of search and method of selection procedures were used, such as keywords, themes and date of publication. Data collection was continued for two months to get more relevant information.

Data Quality and Reliability Checks: To increase the reliability of data collected, whereby independence may lead to some inconsistency, efforts were made to cross-check from some other sources so that inconsistencies may be checked. Due to the social and environmental consequences of renewable energy consumption, special focus was placed on ethical factors where potential effects on flora and fauna, and people were evaluated.

Results & Discussion

Current trends in the development of alternative energy in Ukraine

In recent years, Ukraine has observed increasing trends in using renewable (alternative) energy sources (State Agency on Energy Efficiency and Energy Saving of Ukraine, 2018). This corresponds to global trends, especially in the countries of the European Union. This shift can be attributed to global factors, such as the consequences of the development of the world economy (technical progress, which leads to the search for alternative sources of energy, the need for diversification of energy sources and optimization of the fuel-energy balance, as well as with the aggravation of environmental problems). Additionally, local and temporary reasons such as the rise in energy prices and periodic interruptions in the supply of energy due to irregular transit conditions, have further pushed the demand for alternative energy sources. The use of alternative energy sources is also aimed at increasing energy and environmental security, which is an integral component of sustainable development that directly contributes to improving the quality of life of the population. In 2017, the Government of Ukraine adopted a new Energy Strategy of Ukraine until 2035, titled "safety, energy efficiency, competitiveness". This document outlines the strategic guidelines for the development of the fuel and energy complex of Ukraine up to the period 2035 (Government of Ukraine, 2017). In particular, special attention is paid to developing renewable energy sources. The part of energy obtained from alternative sources is about 3% today. According to the Ukrainian energy strategy, by 2035, the part of alternative energy in the country's total energy balance will increase to 20%. The primary and most effective directions of renewable energy in Ukraine are wind energy, solar energy, bioenergy, hydropower, and geothermal energy (Table 1).

According to the new Energy Strategy of Ukraine, until 2035, electricity production from renewable energy sources will increase yearly. The transition to more ecologically clean sources of energy, which include the sun, wind, water and biogas, will help reduce the rate of climate change. After all, the main advantage of using

renewable energy sources is environmental friendliness and the complete absence of harmful emissions into the atmosphere (Dobryanska, Lagodiienko and Torishnya, 2020; Government of Ukraine, 2014).

Table 1: Indicators of the development of the use of renewable energy sources according to the energy strategy of Ukraine (all units in million tons)

Energy source	*Year*		
	2010	*2020*	*2035*
Bioenergetics	2.7	6.3	9.2
Solar energy	0.032	0.284	1.1
Small hydropower	0.52	0.85	1.13
Geothermal energy	0.08	0.19	0.7
Wind energy	0.21	0.53	0.7
In total	3.542	8.154	12.83

Specialists of the Institute of Renewable Energy of the National Academy of Sciences of Ukraine forecast the introduction of renewable energy sources (RES) in Ukraine with a perspective until 2050 (Kudria, 2018). Table 2 shows the data obtained according to the primary development scenario regarding the installed capacity and volumes of gross electricity production from renewable sources. The electricity consumption forecast for the specified period is also given.

Table 2: Forecast of the Institute of Renewable Energy of the National Academy of Sciences of Ukraine regarding the implementation of RES in Ukraine until 2050

Types of RES	*2020*		*2030*		*2040*		*2050*	
	GW	*billions kWh*	*GW*	*billions kWh*	*GW*	*billions kWh*	*GW*	*billions kWh*
Small Hydroelectric Power Plants	0.15	0.34	0.25	0.56	0.33	0.9	0.34	0.95
Wind Power Plants	1.5	4.2	10.0	30.0	18.0	54.9	23.0	73.0
Photoelectric Plants	2.0	2.4	4.5	5.5	8.0	10.0	14.0	20.0
Geothermal Energy	0.02	0.12	0.5	3.0	1.0	6.0	1.2	7.2
Biomass	1.0	4.2	1.6	7.0	2.4	10.6	2.7	12.5
In total	4.6	11.3	16.9	46.1	29.7	82.4	41.2	113.7
Part of RES, %		6.2		23.6		36.8		44.9
Large hydroelectric power plants	5.8	10	6	12	6	12	6	12
Part of RES with hydroelectric power plants, %		11.7		29.8		42.1		49.7

Source: Institute of Renewable Energy of the National Academy of Sciences of Ukraine (2024)

Ukraine has significant renewable energy potential that can be used to improve the trade balance, create jobs and stimulate economic activity at a time when the country must overcome significant economic challenges (Bondarenko *et al.*, 2019; Lebedeva, Dobrianska and Gromova, 2018; Savchenko, Yurkevych and Liubuska, 2023a). Renewable energy development will also be an essential contribution to post-war

reconstruction. Such an energy supply will also better ensure energy security (Sirotyuk, 2015).

Reasons for low environmental awareness and existing restrictions on the development of renewable energy sources

One of the major challenges facing the energy industry today is the problem of sustainable energy supply since generating electricity by stations based on renewable energy sources is variable. To maintain a stable and sustainable energy supply, it is necessary to address several problems related to the integrated use of renewable energy sources, the creation of innovative dispatching models (smart and virtual networks), the reliability of energy production forecasting, and the accumulation of electric and thermal energy. The use of alternative energy sources has economic and environmental benefits. Ecological aspects of the use of renewable sources are highlighted in the works of (Donovan, 2015; Kasich and Litvynenko, 2017; Melnykova and Degtyar, 2019).

Critical analysis suggests that renewable energy sources can replace traditional fossil fuels, reduce dependence on imported fuel, create additional opportunities for specific branches of industry and agriculture, and reduce emissions of greenhouse gases and other harmful substances (Donovan, 2015). However, certain limitations complicate the development of the field of alternative energy. The most significant among them are high initial investments in infrastructure and technologies and insufficient opportunity to assess the positive consequences of using alternative energy sources in monetary terms (Prokip, Dudiuk and Kolisnyk, 2015).

Besides the positive, alternative energy sources have negative environmental consequences. The main environmental drawbacks associated with renewable energy sources are linked to issues such as land use, noise, landscape change, and the use of new materials, some of which can have adverse environmental impacts — such as the extraction of silicon for solar panels. The nature of the interaction of these installations with the environment is fundamentally different from the harmful effects traditionally associated with fossil fuels (Marsh, 2023). Therefore, an analysis of possible consequences should be carried out during the development and design stages. This will make it possible to avoid the mistakes made with traditional power plants where technological systems were developed first, and environmental concerns were addressed only during operation. When evaluating the environmental advantages and disadvantages of renewable energy sources, it is necessary to consider the capacity of their installations, which depends on the degree of impact on the environment. Low-power installations are practically safe from an environmental point of view; the positive effect of their operation is much higher than possible environmental damage.

Wind power as a promising alternative energy source

The operation of wind energy is determined by the following most critical environmental factors, such as blocking land territories and noise effects, which increase with increasing power and number of wind turbines; high metal capacity of wind turbines, related to the requirements of the previous cycle of metal extraction and processing; vibration effect on biota; leading to the death of many birds under the blades of vibration

motors (Twidell, 2021). Wind power plants create high-frequency noise, so they need large plots of land for their placement, and they also disturb nearby settlements. Additionally, the generators of large wind turbines rotate at a speed of about 30 revolutions per second, close to the synchronisation frequency of television signals. Therefore, giant wind turbines can interfere with the reception of transmissions at a distance of up to 1.6 kilometres (Dam, Işık and Ongan, 2023). Wind turbines can change the microclimate in their location, reducing air humidity and increasing temperature. Furthermore, wind turbines can impact groundwater and water flows, negatively impacting local ecosystems.

The maximum power that can be obtained from 1 km^2 of area varies widely depending on the area of use, the type of station and the technological features of the design (the average value is ~ 10 MW/km2). The noise effect near the wind turbines can reach 50 dB to 80 dB, while the threshold endurance of the human ear, based on pain sensations, is 180 dB (Sadorsky, 2021). A separate environmental problem arises from the noise effect of installations of significant power (over 250 kW) when the airflow velocities at the ends of the blades of large-diameter windmills are supersonic (Butt, Khan and Xia, 2024). At the same time, an infrasound effect appears, negatively affecting humans and other biological subjects. An important role is played by the metal consumption indicator per unit of capacity, it determines the volumes of the raw material preparation cycle for production. Depending on the power level, this indicator for wind turbines varies approximately in the range of 50 kg/kW and 70 kg/kW, and a significant number of high-strength materials is required. At present, there is a tendency to replace elements of metal structures (primary blades of windmills) with fibreglass ones (Yousaf *et al.*, 2024). An ecological analysis of the consequences of chemical production related to creating those structural materials is necessary. The impacts of wind energy on the environment are summarized in table 3.

Table 3: Impact of wind energy

Type of influence	*Positive influence*	*Negative influence*
Renewable energy source	+	-
No greenhouse gas emissions	+	-
Minimal use of natural resources	+	-
The possibility of placement in remote locations	+	-
Sound pollution	-	+
Impact on the landscape	-	+
Injury to birds	-	+

Source: Sadorsky (2021)

Solar power plants and small hydropower

The use of solar energy requires large areas of land for the construction of solar power plants, and the photocells used for the manufacture of solar batteries contain poisonous substances, such as lead, cadmium, gallium, and arsenic (Dmytriiev *et al.*, 2022). Low-temperature solar heat and water supply systems are currently the most common in industrialized and developing countries. From an ecological viewpoint (Shevtsov, 2019; Vozniuk, 2015), the operation of low-temperature systems is characterized by

environmental impacts from the extraction and processing of raw materials. However, they also reduce negative environmental effects by lowering emissions from traditional boiler houses and decreasing thermal pollution. Medium- and high-temperature solar installations are still in the intensive development stage. Several stations have been created worldwide using distributed parabolic concentrate systems (with a total capacity of 400 MW). The experience of their operation has shown that the main environmental factor for solar power plants (SPPs), according to the thermodynamic cycle of energy conversion, is the blocking of significant land areas by the equipment. Thus, the average potential of this cycle is estimated at 30...40 MW per 1 km^2.

The disadvantage of small hydropower is the flooding of territories and the drying up of small rivers, and if the dam is planned in the wrong place, it can disrupt ecosystem change and lead to biodiversity loss, particularly affecting fish species (Melnykova and Degtyar, 2019). In particular, today, the Terebly River has been almost destroyed due to the construction of the Terebly-Rytska HPP and reservoir. Beyond the hydroelectric dam, the river does not exist for more than 5 km. Due to constant changes in water levels (turning on turbines in the direction of the Terebly River), having such an area and being a continuation of a natural water body, the reservoir is one of the least productive fish habitats in Transcarpathia. Attempts at one time to carry out mass stocking and acclimatisation of individual species turned out to be fruitless. According to ecologists, to avoid a natural disaster in Transcarpathia, small hydropower plants should operate exclusively in the mode of natural flow. All this indicates that when deciding to construct hydroelectric power stations on mountain rivers, it is necessary to take a very responsible position. It is easier to destroy the natural balance, and restoring it is very difficult takes a long time, and may not be possible (Sotnyk *et al.*, 2023). Reducing the negative impacts of using mini-hydroelectric power plants with improved hydro turbines operating at low pressures has less environmental impact. Such installations have a minimal impact on the environment, as they do not require the construction of dams, reservoirs, and coastal structures. The effects of hydropower on the environment are summarised in table 4.

Table 4: The impact of hydropower on the environment

Problem	*Negative influence*
Loss of natural ecosystems	Big
Flooding of large areas	Potentially large
Impact on local fauna and flora	Considerable
Destruction of river ecosystems	Considerable
Obstruction of fish migration	Considerable
Influence on the regimes of rivers and water resources	Considerable
Impact on the population	Potentially large

Energy from waste and biomass: benefits and risks

Biomass processing, based on gasification, pyrolysis and production of liquid fuel, has gained significant development (Potemkina and Kosinskyi, 2020). As a result of the fermentation process during biomass processing into ethanol, by-products are formed, particularly washing water and distillation residues. The latter is a severe source of environmental pollution. Their mass is several times (up to 10) more significant than the mass of the produced product, i.e. ethyl alcohol.

Technologies that make it possible to obtain mineral substances to clean these wastes, used in the chemical industry and mineral fertilizers, are of interest. Various areas of organic waste utilization are characterized, first of all, by a sharp ecological orientation. To a large extent, it is focused on waste processing (Sotnyk *et al.*, 2023). The elimination of the latter and the associated improvement of the ecological and sanitary-epidemiological conditions of the populated environment play an even more significant role than the energy effect based on using this type of raw resource. This is especially important for regions with humid, warm climates and large cities. It is here that the technology of waste elimination plays an extraordinary role, which makes it possible to use their energy potential at the same time. Scientists have also established that it is inefficient to make biodiesel from rapeseed oil because it takes approximately 1,500 litres of oil to fuel one car for a year, which is the size of a football field with a rapeseed yield of up to 3,000 kg/ha (Sotnyk *et al.*, 2023).

In addition, growing plants for biomass can lead to deforestation, loss of biodiversity and other environmental problems. Some plants require large amounts of water and fertilizers, which can lead to water pollution and a decrease in soil quality. Carbon dioxide and other harmful emissions are released during biomass processing into energy. Although these emissions may be lower than using traditional fuels, they still have some impact on the environment. The effects of the use of bioenergy are summarized in table 5.

Table 5: Impact of bioenergy

Type of influence	*Positive influence*	*Negative influence*
Sustainable source of energy	+	-
Reduction of harmful emissions	+	-
Increasing energy independence	+	-
Use of waste	+	-
Impact on land and forest resources	-	+
Impact on biodiversity	-	+
Use of water resources	-	+

Geothermal energy and its environmental impact

The ecological impact of geothermal power plants and geothermal technological installations on the environment is reduced to the action of mineralized geothermal waters and steam, to the lowering of the earth's surface (sometimes significant in size) located above the geothermal layer that is being developed and to the increased (compared to TPPs of the same capacity) thermal effect of GeoTPS on the environment (Savchenko *et al.*, 2023b). Thus, geothermal energy development is associated with significant adverse environmental consequences. The first is the excessively high cost of the equipment that collects and converts geothermal heat, that is, the high cost of obtaining energy. The second is a significant negative impact on the environment – degradation of forests and ecosystems around deposits, significant subsidence of the land after extraction of water and steam from the depths, the release of gases together with steam, severe pollution of soil, air and water in the places of extraction of hydrothermal vents, and this requires quite severe control. In addition, hydrothermal deposits are often located in hard-to-reach places (Gurieiev *et al.*, 2020). Geothermal water has increased corrosive properties, and therefore, the gas-water mixture intended to produce electricity

must be separated in advance on centrifugal separators into dry steam and water. The remaining hot water and condensed steam must also be either pumped back into the ground or used as a means of heating. However, the problem of mineralization of geothermal waters remains: the large amount of salt in them pollutes reservoirs and pipes. Nitrides, chlorides, sulfides of some metals, and dangerous chemical elements (boron, arsenic) are in the composition of waters brought to the surface; hydrogen sulfide (harmless – in small quantities, toxic – with increasing concentration). In the absence of reverse injection into the formation, there is a danger of soil salinity in the area of use and a drop in formation pressure (Atstaja *et al.*, 2022). The change in pressure in the reservoir during the long-term operation of the wells affects the groundwater level in the area. It can negatively affect the operation of artesian wells and water supply.

Decarbonisation of energy processes

Wide deployment of renewables is crucial to decrease electricity production's emission intensity and energy efficiency. As electricity production is seen as potentially emission-free thanks to renewables being the primary source, electrification of many processes has started to take off (e.g., electric vehicles and heat pumps, or various industrial processes originally dependent on energy from fossil fuels), supported by increasing energy efficiency. Therefore, it is expected that electricity will cover an increasing part of the energy needs of our society in a decarbonized economy.

The use of renewable energy sources is relevant today for Ukraine because traditional energy reserves (oil, gas, coal) are non-renewable; that is, sooner or later, they will be exhausted. In addition, the advantages of renewable energy sources are their environmental friendliness (they reduce greenhouse gas emissions and do not disturb the climate balance), their regenerative nature (they are inexhaustible), and it is also a modern new trend that is popular in all developed countries of the world. Ukraine has significant potential for using alternative energy sources, particularly solar and wind energy because its geographical position and climate favour it. However, it is also necessary to consider the adverse effects of renewable energy sources.

Concepts of the issue in the scientific research of individual researchers

Li *et al.* (2022) and Twidell (2021) demonstrate the dependence of financial development indicators of socio-economic systems on the level of integration of renewable energy. The findings demonstrate that the goals of sustainable energy development are achievable through managerial incentives and compelling tax motivation. Such strategic measures contribute to increased demand for renewable energy sources and enhanced investment potential in the energy sector. Empirical studies also convincingly show that intensive financial development is driven by rising demand for environmentally friendly energy sources. The effect of renewable energy on sustainability demonstrates mixed outcomes. For example, Dam, Işık and Ongan (2023) argued that renewable energy alongside institutional quality can stabilize the environment. In contrast, Sethi, Behera and Sethi (2023) find that the growth in the economy and utilization of energy have maximum limits, but achieving optimum utilization of resources along with the conservation of the environment is much tougher and not as cost-efficient as now to build green infrastructure. According to Dam *et al.*,

the results are consistent with their views, that better-developed institutions can significantly facilitate the progress of renewable energy technologies and their permanency. For instance, Noor *et al.* (2024) confirm that compared to the other world regions, South Asia's difficulties in its transition to the exploitation of renewable energy sources are somewhat different because of economic disparities and reliance on the least renewable power supply. This regional disadvantage is quite opposite to the studies conducted on developed countries like the G7 member countries where Radmehr *et al.* (2022) prove the effectiveness of renewable energy initiating globalization along with human capital investment. These challenges enrich the idea that for less economically developed regions, financially and politically oriented specific interventions are to be needed. The current study's findings also show that financial incentives are, however, effective, they should be supported by financial incentives that must accord to the region's economic and environmental circumstances.

Dam, Işık and Ongan (2023) examine the effects of renewable energy and institutional quality on environmental stability and propose a new perspective on the inverted load capacity factor: An insight into energy and sustainable development. Noor *et al.*, (2024) focus on the South Asian region and the impact of renewable and non-renewable energy on sustainable development. Behera *et al.* (2024) show the connection between energy consumption and economic growth in India and illustrate how the more extensive utilization of both kinds of energy can help the economy.

Sustainability according to Sethi *et al.* (2023) adopted economic growth and energy consumption and emphasised that a balanced resource approach is critical for sustaining the environment. Kirikkaleli and Adebayo (2022) are concerned with Brazil to assess the impact of a green financial system and innovation in enhancing the quality of the environment, and the capability of institutional and financial measures in reducing environmental impacts. Specifically, in Dhillon and Kaur (2023), there is a focus on the relation between sustainable development, energy usage, and economic growth considering such aspects of data analysis as both the aggregate and disaggregate levels.

Idroes *et al.* (2024) discuss how Indonesian renewable and non-renewable energy influenced CO_2 emissions and ecological footprint, thus rejecting a simplistic approach to decrease dangerous emissions. Static and dynamic CO_2 emission indicators: Voumik *et al.* (2023) analyse generation from different sources of electricity in G7 countries. Raihan and Tuspekova (2022) establish the correlation between economic growth, the use of renewable energy, and urbanization with emissions in Turkey, which presents many problems related to economic development and its impact on the environment.

Recently, Radmehr *et al.* (2022) discussed the further use of renewable energy and the level of the ecological footprint in G7 economies, which is facilitated by globalization and human capital. Kostakis (2024) examines the relationship between renewable energy, financial openness and environmental pollution in ASEAN countries by arguing that financial support of environmental programs is useful. Financial development and renewable energy have been analyzed by Yousaf *et al.* (2024) for Asian countries on environmental quality to conclude that financial incentives for environmental security indeed work. Lüdeke-Freund (2020) discuss the effect of different energy sources on

natural gas rents with a specific focus on imported energy and its effect on the natural resources available, which favours de dependency on imported energy.

The necessity of renewable energy development in Ukraine offers the same problems, and potentiality and requires institutional backing and genuine financial reward contour. Consistent with prior studies, this paper's observations corroborate that general agreement emphasises policy structures that reduce high initial investment threats. However, different from some other papers that argue for direct large-scale green investments (e.g., Butt, Khan and Xia, 2024), our analysis highlights a gradual shift in policy supported by small-scale RE projects as a feasible approach. This approach reduces the cost implication drastically and allows incremental implementation as influenced by changes in technologies.

Our study aligns with the previous findings, that renewable energy has environmental benefits, it is also evident that implementation significantly differs by region and economics. There exists a major research gap regarding country-specific renewable energy strategies and small-scale renewable energy projects because large projects raise the problem of development fix and increase the initial risks associated with renewable energy projects.

Conclusion

Renewable energy sources have emerged as strategic interventions toward the achievement of sustainable development, emanating from the reduction of the reliance on fossil fuels, and controlling the negative impacts. Thus, it is possible to conclude that the subject of this research exhibits the need for the proper integration of IT development ideas with the relevant institutional support for environmental responsibility. Therefore, the study establishes that the adoption of renewable energy improves the quality of the environment while supporting political consensus is paramount to enhance the changes. The findings of the study reveal the concept of a phased adoption strategy of undertaking renewable projects that correspond to the financial capabilities of Ukraine. This approach contrasts with large-scale investment projects which some researchers have suggested, oriented to lesser economic load during the first transition steps. Although few studies are carried out at the regional level and actual statistical data on the environmental effects of discrete renewable energy sources in Ukraine are rather scarce, we conclude that the fluent status of the economic situation creates problems for the steady investment in green technologies. The practical importance of this work is in illustrating the potential of a step-by-step strategy for the development of renewable energy sources that may be utilized in other countries with comparable Gross Domestic Product (GDP) value. Therefore, the outcome of the study is useful in forming strategies for energy security and environmental management at the national level. Further research is required in comparative analysis of the effects of different kinds of renewable energy sources on the environment, and the elaboration of financial support schemes for minor renewable energy projects. Furthermore, it is suggested that the existing link between the offered and paid financial incentives and investment in renewable energy sources strengthens the creation of the best conditions for sustainable development.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*
Conceived and designed the research or analysis	Yes	Yes	Yes	Yes	Yes
Collected the data	Yes	No	Yes	No	No
Contributed to data analysis & interpretation	Yes	Yes	Yes	Yes	Yes
Wrote the article/paper	Yes	Yes	Yes	Yes	Yes
Critical revision of the article/paper	No	Yes	No	Yes	No
Editing of the article/paper	Yes	Yes	Yes	Yes	Yes
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