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NS global economics
ECONOMICS
Innovative and Economics Research Journal
Volume 11, No. 2, 2023
www.economicsrs.com

FORMATION OF THE MODEL OF SUSTAINABLE ECONOMIC DEVELOPMENT OF RENEWABLE ENERGY

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Received 14.07.2023. | Sent to review 24.07.2023. | Accepted 04.11.2023.

Original article

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JEL Classification: C50, O11, Q29, Q42

Doi: 10.2478/eoik-2023-0050

UDK: 338.1:[620.9:502.171

ABSTRACT

The article considers the use of sustainable energy as a potentially effective alternative energy source capable of replacing traditional natural fuels. The aim of the research is to develop a complex model of sustainable economic development able to promote introducing and expanding sustainable power engineering as potential alternative energy source, providing sustainable economic development, energy efficiency and reducing damages to the environment. The hypothesis lies in introduction of a model for sustainable economic development due to expansion of renewable energy which will result in economic growth, rise in energy efficacy and reducing hazards to the environment. A comparative analysis of costs and revenues of various types for using energy sources was carried out to estimate the economic efficiency and feasibility of renewable energy. The data analysis toolkit uses MS Power BI software, in which the data model was created. The conducted regression analysis provided valuable nu-merical and practical results on formation of the model of sustainable economic development of renewable power engineering. The research is based on the analysis of the impact "share of energy" on the level of electric energy import and CO_2 emissions. It is recommended to intensify efforts to develop renewable energy as a key direction for sustainable economic development to ensure energy security, reduce negative environmental impact and achieve global sustainable development goals.

Keywords: *renewable energy sources, model, sustainable development, investment, technology, ecology, energy efficiency, energy market*

1. INTRODUCTION

The use of renewable energy sources can become an important component of sustainable economic development. The formation of a model of sustainable economic development involves ensuring the development of the economy without damage to the environment and preserving natural resources for future generations.

The sufficient research in the different aspects of stable economic development refers to Gro Harlem Brundtland notes in his research growth with environmental protection and resource conservation. It is about finding innovative ways to meet our present needs without compromising the ability of future generations to meet their own needs (Brundtland, 1987).

One of the key factors contributing to sustainable economic development is restraining the dependence on unstable energy sources such as oil, gas, and coal, which in turn require additional resources for production, maintenance, processing, etc.

Dr. Jessica Smith suggests, that dependence on instable energy sources puts country's economic stability and security at risks. The way towards steady economic development consists in switching to a more balanced and steady energy system based on renewable energy sources and energy efficient technologies (Smith & Tidwell, 2016).

The use of renewable sources does not require a constant intermediary of processing and conversion, which reduces, and in many cases does not require at all, dependence on these sources and provides a stable source of energy, which can positively affect the sustainability of the economy. They say that "renewable sources be first built to make the system work in automatic mode in the future". Moreover, the usage of renewable energy sources can reduce the emission of harmful substances into the atmosphere, which contributes to preserving the environment and public health, ensures economic stability for many years, since environmental pollution can seriously deteriorate the environment.

However, some factors hinder the implementation of alternative renewable energy. To them refer: high installation costs – renewable energy sources such as solar, wind, geothermal, and hydropower, usually require significant investment; dependence on changeable weather conditions. This can result in insufficient stability of the electricity supply, especially in the case of reduced energy production due to technical problems or worsening weather conditions.

At present, modern digital technologies provide control of production and network loads, which can enable a smooth transition to alternative energy.

Digital technologies enable integration of numerous renewable sources into the power engineering system. Due to automatization and control these technologies help balance production and consumption of energy, which makes the switch to alternative energy sources more effective and stable. Certain directions in digitalization of power engineering require "blockchain" technology which implies decentralized energetic transactions, accounting of renewable energy source, its volume, current price and billing (Avenston, 2019).

Modern industry produces electronic devices "Grid tie inverter" for installation of alternative energy stations for the whole districts or households, automatically tuned to the general power grids. This approach is used to deal with infrastructure issues related to renewable energy. Accordingly, the construction of infrastructure for storing and transporting energy from renewable sources is carried out step by step with large power grids.

The development of a "smart" network system helps to separate energy production from its consumption. This will permit more flexible energy management and ensure more precise coordination between production and energy consumption, which will eventually ensure both the efficient use of renewable energy sources and a more sustainable and reliable energy supply. Also, political and social problems also hinder the development of renewable sources. For example, renewable energy is often associated with regulation and legislation. The absence of relevant legislation may become an obstacle to the introduction of renewable energy in various sectors of the economy. The introduction of renewable energy creates social conflicts, for instance, related to the use of land for equipment and infrastructure projecting, ownership conflicts or fear of income loss in agricultural sectors.

The development and implementation of new technologies and the production of highly efficient systems for electricity production from hydrogen, wave, wind, and geothermal energy provide a balance between these sources under climatic changes.

Thus, the aim of this research lies in developing a model of steady economic development of renewable power engineering. We pursue to define effective strategies and policies to promote stable and sustainable economy based on the use of renewable energy sources.

Our contribution lies in the analysis of the factors that determine the effectiveness of the renewable power engineering development and its interconnection with conventional fossil fuels. We aim to consider current trends, technologies and innovations in the sphere of renewable power engineering, taking into account social, environmental and economic factors of influencing the stability of the development model.

Respectively engagement Investments from private economic agents and the government significantly promotes the development of renewable energy, has a positive effect on the environment which in its turn increases the availability of renewable energy sources, improves new technologies and infrastructure to reduce the costs of energy production.

According to F. La Camera, CEO of IRENA, investment into renewable energy is stable, cost-effective, and attractive. It provides consistent and predictable efficiency and, at the same time, provide benefits to the global economy (IRENA, 2020).

The transition to renewable energy also poses some economic and social challenges that must be addressed to ensure sustainable development (Lyeonov et al., 2021):

1) cost: renewable energy often requires significant investment costs and infrastructure projecting. This can reduce company profits and increase the cost of energy for consumers;

2) instability: renewable energy sources such as wind and solar depend on weather conditions. This can lead to fluctuations in the production and supply of energy, which makes it difficult to ensure a stable energy supply and can affect the economy;

3) infrastructure: the development and construction of the necessary infrastructure for renewable energy require significant costs and time. This can be done under effective coordination between different industries and regions to ensure efficient resources usage;

4) development of markets: renewable energy is a new industry, so there is a need to develop advertising and market organization.

Since February 2022 because of warfare in Ukraine, the issue of establishing steady economic development of renewable power engineering have become of secondary importance. Ukraine's economy is currently internationally subsided. But the issues of developing this energy branch have not lost their importance, because they deal with the country's strategic development in post-war period. Ukraine studies foreign experience of developing renewable power engineering. Considering the situation with blackouts during 2022-2023 due to shelling of Ukrainian energy infrastructure points in winter and damage to energy systems and lines, Ukraine managed to rely on renewable energy sources which reduced the negative impact of destruction. This put renewable power engineering at an advantage.

The National Action Plan for the Development of Renewable Energy in Ukraine for the Period until 2030 considers indicative goals of electricity and heat production and the development of transport. In particular, the Law of Ukraine "On Renewable Energy" sets a national goal to increase the share of renewable energy sources in the total amount of electricity produced to 25% and the production of renewable energy at 25 GW by 2035 (Ministry of Energy of Ukraine, 2021).

Unfortunately, currently (2023) the development of the steady model of renewable power engineering of Ukraine has been suspended. Nevertheless, it calls for further profound research of the corresponding foreign experience.

The world's experience in the introduction of alternative energy is relevant and investment effective. For example, Germany is known for its ambitious "Energy Turnaround Plan", which implies a transition to 80% renewable energy by 2050. It includes the construction of wind and solar power plants, as well as the development of hydroelectric power plants and biofuels. Denmark leads in the use of wind energy. More than half of all wind turbines in Europe are in Denmark. In addition, Denmark also has a significant number of solar power plants and biomass power plants. Iceland uses geothermal energy for heating and electricity. More than 80% of the energy produced in Iceland comes from geothermal sources. China is the largest producer of solar panels and wind turbines in the world. Moreover, China also has a significant number of hydroelectric and biomass power plants. The United States has many wind and solar power plants, as well as hydroelectric and biofuel power plants. Some states, such as California and Texas, are actively working on the development of renewable energy.

Respectively, considering the positive experience of renewable energy in the world, experts consider and build a sustainable model of economic development based on renewable technologies. For example, biochar is a technology based on plant material to produce fuel and can replace coal, oil, and gas. Hybrid systems are a combination of different sources of renewable energy, such as solar panels and wind turbines to provide a constant source of energy. Energy storage systems are technologies that allow us to store energy for later use. Such systems can replace renewable solar and wind energy sources in case of their failure. Geothermal energy is the use of heat generated by the inner layers of the Earth. Hydrogen can serve as machine fuel.

The world experience in renewable energy shows certain problems in its production related to instability of its generation and accumulation of generated energy. These problems are deeply studied (Pavlova & Pavlov, 2020; Buratynskyi, 2019; Albertus et al., 2020) and the ways of partial solution to these problems are proposed. But the issue of stability/instability of generating this energy lies above of our research, though requires profound scientific research of developing technological systems.

From a technical point of view, the stability of the power system is a key factor for the safe and uninterrupted operation of the system. The stability of the energy system is defined as the ability to restore the working balance after injury or destruction (Mazur et al., 2023; Kaletnik et al., 2022). One of the most important parameters during the simultaneous operation of energy systems is the inertia of the system. The smaller the inertia of the system, the more sensitive the system is to frequency deviations (Impram & Nese, 2020).

Renewable energy sources (RES) power plants do not contribute to system inertia, as they are connected to the grid by power electronics, and they are electrically isolated from the grid.

Power grids are one of the most complex dynamic networks ever designed, and ensuring their synchronization is critical, as their absence can lead to any disturbances leading to persistent oscillations and loss of stability.

Synchronization in the power grid can be interpreted as a stable state, when the rates of evolution of the electric angle in all generators throughout the network are the same. Stability is crucial for the reliable and continuous operation of the energy system. Levels of wind and solar penetration, topologies of their connection, types of wind turbines define voltage stability, stability of transient processes, small signals and frequency stability of power systems containing renewable energy sources (Jiang et al., 2019).

Thus, the growth of renewable energy in the world economy has provoked the need for an interdisciplinary approach to the formation of a sustainable model of its economic development, which will consider legal, economic, and organizational factors. The use of modern economic and mathematical methods and logic will consider both quantitative and qualitative factors of influence on socioeconomic processes.

The study is devoted to the implementation of this approach to building an effective model for the renewable energy development, which will facilitate the solution of the problems of its development and contribute to the creation of a sustainable and long-term economic model.

The aim of this research is to develop a complex model of stable economic development on the basis of introducing and expanding renewable energy, providing stable economic growth, energetic efficiency and reduction of environmental hazards.

2. THEORETICAL BACKGROUND

One of the key approaches to greening is the concept of sustainable development, which involves meeting the current needs of mankind without compromising the ability of future generations to meet their needs. This concept involves the balanced use of natural resources to ensure economic development and environmental protection. At the basis of renewable energy concept there is the use of renewable energy sources such as solar, wind, hydropower, etc. The main idea is to reduce dependence on fossil fuels, reduce emissions and reduce environmental impact. The technological paradigm of renewable energy is a global trend. The International Renewable Energy Agency (IRENA) produces comprehensive, reliable datasets on renewable energy capacity and its usage worldwide. 2022 Renewable Energy Statistics provides data on electricity generation capacity for 2012-2022, actual electricity generation for 2012-2020, and renewable energy balances for more than 150 countries and districts for 2019-2020 (IRENA, 2020).

It is important to mention that economic growth based on distortions of ecologic services is not stable. This is also evident from the oil crisis of 1973 which taught us the importance of overcoming dependence on fossil fuels which led to environmental and economic profits (Sajadi et al., 2022).

The scientific research "Understanding multidimensional ties between renewable energy, pollution, economic growth and urbanization in modern economies: qualitative estimations in certain countries with various income levels" incorporating statistical methods studied the interrelations between renewable energy and economic growth, CO_2 emissions and urbanization in the period 1990–2014. It was statistically proven that "high income countries showed commonality between the use of renewable sources and CO_2 emissions, renewable and nuclear power energy, energy consumption and urban population". This is explained by the interest of these countries in environmental protection. Besides, the by conducting Granger causality testing the authors defined the causality relation between the economic growth and power intensity in the low-income countries, while there are many bidirectional relations between the variables in high-income countries, especially between power intensity and CO_2 (Jiang et al., 2019).

The Sustainable Development Goals, also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to reduce poverty, preserve the planet and ensure that by 2030 all people live in peace and prosperity. However, as the population continues to grow, so will the demand for cheap energy, and an economy dependent on fossil fuels is dramatically changing our climate.

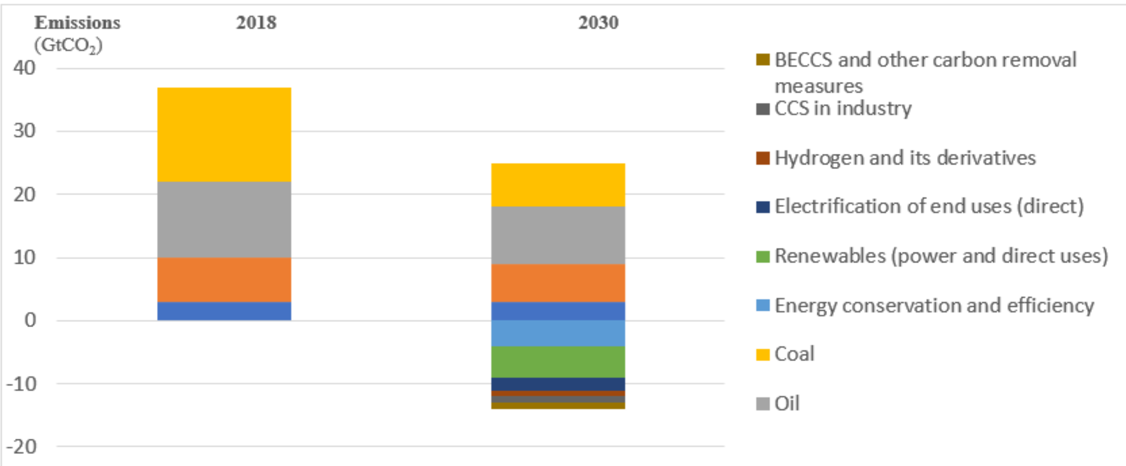
Investing in alternative energy, increasing productivity and providing energy for all are vital goals for future green growth by 2030. Expanding infrastructure and modernizing technology, respectively, will contribute to the growth of clean and more efficient energy in all countries and help the environment (Armeanu & Joldes, 2021).

Therefore, clearing and preserving the environment are important determinants of sustainable development, as they are directly related to energy consumption. This explains the shift of attention towards environmentally friendly energy sources during the last few decades, caused partially by the development of technology.

According to the International Renewable Energy Agency (IRENA), in 2021, renewable energy provided about 29% of global production capacity (Renewable Energy Statistics, 2022).

Increasing the pace of switch to renewable energy sources with a simultaneous aggressive strategy to improve energy efficiency is the most realistic way to reduce emissions by half by 2030, as recommended by IPCC (Fig. 1). In the electricity sector, renewables can be deployed faster and at a lower cost than alternatives (Global Energy System Transformation Forecast, 2022). But to achieve the goal outlined by the IPCC, the annual increase in renewable energy capacity should be three times higher than the current rate. Such an increase is possible if there are proper conditions. Technology-specific goals and policy tools are especially needed to support less mastered technologies such as ocean energy.

Figure 1. The prospects for global energy transitions 1-5C



Source: (World Energy Transitions Outlook, 2022)

To increase sustainability of the system (Koziuk et al., 2020; Shevchuk et al., 2023; Kozlovskyi et al., 2017) and ensure the flexibility of a diversified and integrated energy system capable of operating with a large variable renewable energy volume, it is necessary to update, modernize and expand the infrastructure. The idea is that integrating more variable solar and wind energy would require only fossil natural gas, quickly supplanted by improved economics of alternative sources of energy. But in addition to numerous technological solutions, markets will need to adapt, both in liberalized and regulated systems. The modern structure was formed in the era of fossil fuels to reduce the operating costs of large, centralized power plants with various fuel and alternative costs (Trofymenko et al., 2022).

In research Jacobson et al. (2022) stick to the opinion that the US can meet its energy demands by 2050 with 100% wind, water, and solar. His models use no fossil fuels, carbon capture, direct air capture, bioenergy, blue hydrogen, or nuclear power. Jacobson's 100% renewables plan uses hydropower as a clean, flexible resource to backstop the days when wind and solar don't produce enough to supply the country.

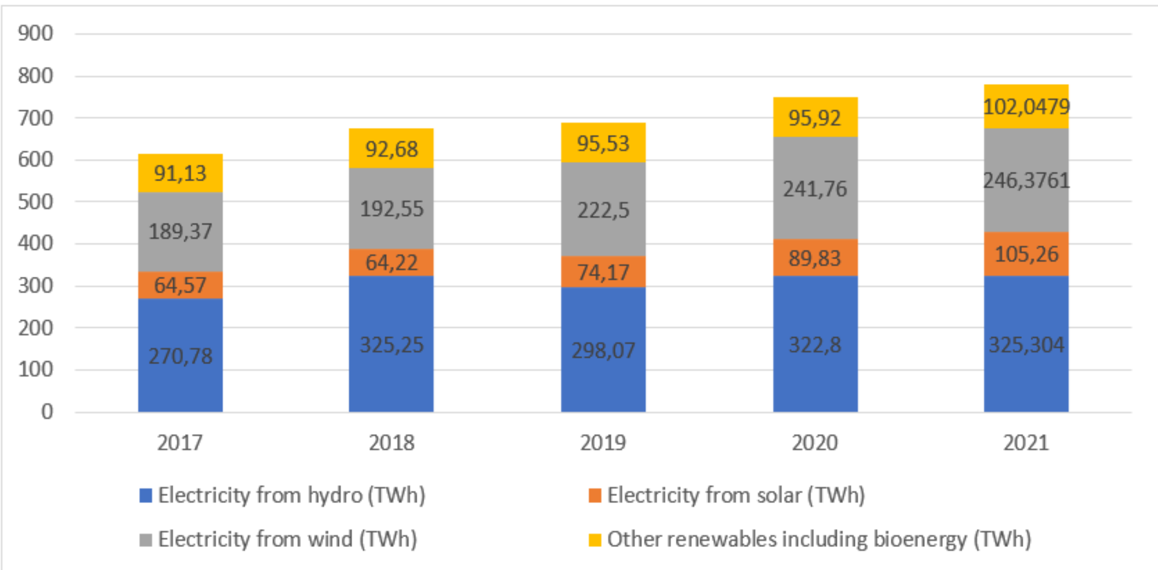
An American economist and sociologist who studies sustainable energy systems and the interaction between the economy and energy Rifkin (2013) has written books "The Third Industrial Revolution" and Rifkin (2015) "The Zero Marginal Cost Society", which argue for a transition to a sustainable and decentralized energy system. According to Rifkin, industrial revolutions are driven by the convergence of changes in the type and availability of energy and in how people connect and share information.

The Kammen & Sunter (2016) in research in the field of renewable energy and sustainable development, argues that renewable energy can provide a future for energy security and reduce greenhouse gas emissions. The transition to renewable energy can act as a catalyst for economic development and the creation of new workplaces. Renewable energy should be perceived as global issue that requires cooperation and joint action of countries and the public.

An American physicist and environmentalist Lovins (2022) who has been promoting energy efficiency, renewable energy sources, energy production close to its consumption sites also advocated a "megawatt revolution" arguing that utility customers don't want kilowatt-hours of electricity; they want energy services. According to the International Energy Agency (IEA), in 2019 global energy production per unit of GDP was 2.5 kilowatt-hours per dollar, which in 2010 was three times higher. In 2020 the use of renewable energy provided a reduction in CO_2 emissions by 2 billion tons compared to this energy generation via coal usage (International Energy Agency, 2022).

According to official data from OurWorld (Fig. 2), we can see that hydropower is by far the largest modern renewable source. But we also see that wind and solar energy are growing rapidly.

Figure 2. Renewable energy generation



Source: (Our World in Data, 2021)

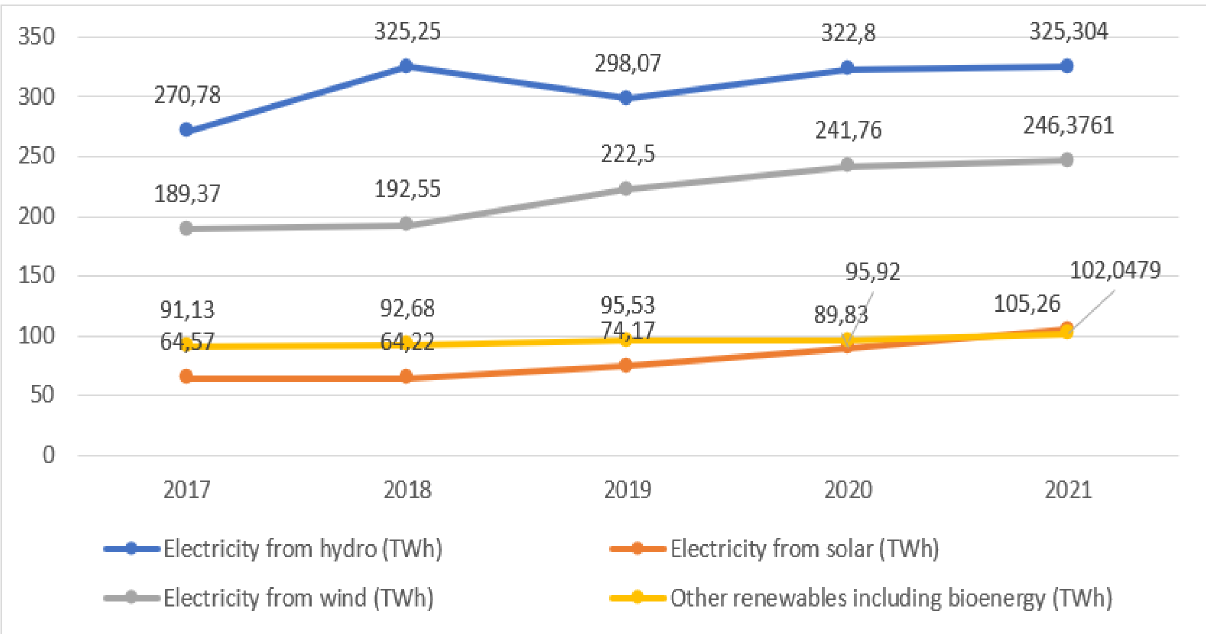
Fig. 3 shows constant growth of renewable wind, solar and biotechnology sources. One of the advantages of solar energy is its availability and versatility. Solar panels can be installed in any area that receives enough sunlight, which allows their use in almost all regions of the world (Statista, 2023; World Bank, 2023). In addition, the relatively simple design of solar panels reduces the cost of production and ensures their durability.

Wind turbines possess more power than solar panels, so wind energy is used to produce high-capacity electricity. However, wind turbines depend on wind, while solar panels can generate electricity throughout the day (Chygryn et al., 2021; Soulaf et al., 2022). Besides, some countries have greater potential for generating energy from the sun, while others have wind or hydropower.

Therefore, when designing a model of energy development based on the theory of sustainable development, we combine the concept of building economic and social development with environmental protection. According to this theory, sustainable economic growth should be based on three components: economic development, social progress, and environmental conservation.

To form a model of sustainable economic development (Kaya, 2019; Lavrov et al., 2022) of renewable energy, the theory of sustainable development (Kozlovskyi et al., 2018) should ensure a balance between the provision of energy needs of mankind and the preservation of the natural environment. Renewable energy is a key element of this model because it enables sustainable energy provision and reduces environmental impact.

Figure 3. Modern renewable energy generation by source



Source: (International Energy Agency, 2022)

The study aims to develop strategies and policies aimed at supporting the sustainable development of renewable energy following the requirements of the modern economy and ecology. The study aims to develop models that will ensure the use of renewable energy sources with the greatest possible economic and environmental benefits, reduce dependence on imported energy resources, and contribute to increasing the level of competitiveness of the country in the production and use of renewable energy. On its basis it is proposed to develop recommendations on the promotion of renewable energy use and development of new energy technologies.

3. METHODOLOGY

3.1. ALGORITHM OF MODEL CONSTRUCTING FOR SUSTAINABLE ECONOMIC DEVELOPMENT OF RENEWABLE ENERGY

The algorithm shows extended arguments for the research, but it is not necessary, while building a model can incorporate only the available data on regions or countries.

1. Identifying the main factors: collecting data on technological innovations in energy production (such as conversion coefficients, capacity and costs), costs of installation and exploiting renewable sources, ecological standards, the share of alternative energy sources and restrictions that influence the development of renewable power engineering.
2. Gathering data on sustainable energy and economy: to obtain and update the date on the quality and types of available sustainable energy points, renewable energy production, its cost and consumption, employment in this industry, dependence on imported resources, economic indices (GNP, indices on energy efficiency, investments etc.).
3. Integrated model development: to build a model that considers relation between the development if renewable energy and economic growth. To consider the influence of renewable power engineering on reducing dependence on import, pollution reduction, increasing competitiveness and creation of new vacancies.
4. Use of regression model for forecasting the development of renewable power engineering and its probable economic outcomes. The regression model enables to establish statistical relations between the input factors such as technological innovations, production costs, ecological standards, use of alternative sources of energy and others and output data such as energy production, employment, economic indices and others.
5. The analysis of the obtained results and continuous improvement: analyze the obtained modeling results and keep improving it on the basis of new data and emerging tendencies. This iterating process allows to improve the accuracy of the model.
6. Defining the optimal development strategy: estimate the obtained results for defining the optimal strategy of development of renewable power engineering considering different factors such as ecologic stability, economic expediency and social appropriateness. Put forward proposals including definition of the optimal share and quantity of alternative energy sources to sustain stable development.

The measure units can vary depending on the indices in each country. For instance, energy production can be measured in megawatt, its price/value in UAH or USD, the number of power stations/points - in units, employment – in the number of employees etc.

While using regression model it is important to have enough quantitative and qualitative data on factors of influencing g the development of renewable energy.

3.2. CONCEPTUAL BASIS FOR A MODEL CONSTRUCTION

The conceptual research of the sustainable development of the stable energetic system implies finding interrelation between the factors affecting the sustainable economic development of renewable energy. The regression model defines how one or more independent factors affect the dependent variable, which in this case is the share of renewable energy consumption of each country out of the total consumption.

The model considers different types of dependent and independent variables, for example, the level of state support of renewable energy development, the level of competition in the energy market, the use of the latest technologies in the production of renewable energy, available developed infrastructure for storing and transporting renewable energy to determine the sustainability factor.

Accordingly, the regression model can help in assessing the effect of each factor separately and in combination with other variables on the dependent variable (Carr & Thomson, 2022). This determines the degree of influence of each variable on the dependent variable, which allows us to draw conclusions which variables have the greatest impact on the sustainable development of renewable energy and what measures can be taken to its increase (formula 1):

$$St = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \varepsilon, \quad (1)$$

where St – sustainable economic development of renewable energy, i.e. a fraction of the electricity that comes from renewable technologies; β_0 – intercept or initial level St, when all other input variables (X_1, X_2, X_3, X_4, X_5, X_6, X_7) are zero, i.e. β_0 shows the expected value of Y when other influencing variables are absent (this can usually be interpreted as a baseline or starting point from which any changes to other variables can affect Y); X_1 – production of Geo Biomass Other into renewable energy; X_2 – production of Solar Generation into renewable energy; X_3 – production of Wind Generation into renewable energy; X_4 – production of Hydro Generation into renewable energy; X_5 – the level of investment in alternative energy in countries containing financing is aimed at the development and implementation of various types of renewable energy sources that can replace traditional fossil fuels; X_6 – innovative potential of the country, i.e. an available developed infrastructure for storage and transportation of renewable energy (energy networks, means of transportation, storage sites, and other infrastructure facilities necessary for the efficient use of renewable energy sources); X_7 – annual CO_2 emissions (per capita) – indicator measures the amount of carbon dioxide emissions (CO_2) per person in the country for one year (it is expressed in metric tons (thousand kilograms) per person per year); β_0, β_1, β_2, β_3, β_4, β_5 β_6, β_7 – regression coefficients that reflect the influence of each of the independent variables on St; ε – model error that takes into account all other factors that can affect Y, but are not taken into account in the model.

Correspondingly $\varepsilon = Y - \hat{Y}$, where Y is the observed quantity, and $\hat{Y}$ is the predicted quantity for a given value of X (formula 2):

$$\beta_0 = \bar{Y} - \beta_1 X_1 - \beta_2 X_2 - \beta_3 X_3 - \beta_4 X_4, - \beta_5 \bar{X}_5, - \beta_6 \bar{X}_6, - \beta_7 \bar{X}_7, \quad (2)$$

where $\bar{Y}$ – the average value of the variable Y.

To calculate the regression model, we use the least squares method, which consists in finding the coefficients β_0, β_1, β_2, β_3, β_4, β_5 β_6, β_7, which minimize the sum of the squares of the differences between the actual values St and the predicted values St, calculated by the regression model.

3.3. CHARACTERISTICS OF MODEL ELEMENTS

The initial index St is a dependent variable in the regression model, influenced by the values of independent factors X_1, X_2, X_3, X_4, X_5, X_6, X_7 and reflects the level of development of renewable energy.

X_1 – production of Geo-Biomass-Other is considered as a combination of three different types of renewable energy: geothermal energy (Geo), biomass (Biomass), and other sources (Other). Unit of measure – terawatt-hour (TWh). Geothermal energy uses the heat of the earth's crust to produce electricity or for direct heating. Geothermal power plants convert earth heat into electricity, and geothermal heating systems use earth heat to heat buildings. Biomass is an organic material obtained from plants and animals that can be used for energy production. This includes plant waste, wood pulp, agricultural waste, and even sewage. Biomass can be turned into biofuels that can be converted to produce electricity or heat or used as gas for various industrial processes. Other sources – other types of renewable energy that do not fall to the main categories, such as solar, wind, hydropower, geothermal, or biomass (technologies of tidal and outflow energy, wave energy, or even energy from electrostatic charges).

X_2, X_3, X_4 – solar generation, wind generation, and hydro generation respectively belong to the three main types of renewable energy. Unit of measure – terawatt-hour (TWh).

X_5 – level of investment and government support for the development of renewable energy. It characterizes the number of approaches to calculating the level of state support and includes an assessment of the number of state initiatives in the field of renewable energy, such as the creation of state support programs, benefits, and subsidies for renewable energy. It determines the degree of implementation of such initiatives (formula 3), as well as the level of financing of these initiatives in comparison with other energy sectors:

$$Ri = Sf / Sz \qquad (3)$$

where Sf – the amount of funding for the initiative's implementation (a total amount of funds that allocated for a particular initiative); Sz – the total amount of funds allocated for financing (a total amount of funds that were allocated to finance all initiatives). The unit of measure is millions of dollars.

X_6 – the country's innovation potential is a composite index that takes into account several key indicators related to renewable energy sources (formula 4):

$$IPC\_AE = w_1*R\&D\_AE + w_2*HC\_AE + w_3*I\_AE + w_4*C\_AE + w_5*B\_AE + w_6*P\_AE \qquad (4)$$

where R&D_AE – expenditures on research and development in the field of alternative energy (as a percentage of GDP); HC_AE - the number of highly educated personnel working in the field of alternative energy (as a percentage of the total population); I_AE – the number of patents for inventions in the field of alternative energy per country's inhabitant; C_AE – communication between research institutions and industrial enterprises in the field of alternative energy; B_AE – the level of state support and stimulation of alternative energy development (for example, subsidies, tax incentives, loans, etc.); P_AE – the share of alternative energy at the national level (for example, the percentage of renewable energy from total energy consumption). Also, the coefficient considers the level of competition in the country's market; w_1, w_2, w_3, w_4, w_5, w_6 – weighting coefficients that reflect the importance of each indicator for the overall innovative potential of alternative energy. Weighting factors are used in alternative energy and innovation. The unit of measure is an index (1-100).

X_7 – annual CO_2 emissions (per capita) is an energy, climate change, sustainable development, and innovation-related indicator in the field of alternative energy. This indicator helps to assess the responsibility of each country for greenhouse gas emissions that cause global warming. It can also serve as an indicator of the effectiveness of energy policy and the degree of implementation of alternative and energy-efficient technologies. Unit of measurement – tons of carbon dioxide per person per year.

4. RESULTS

4.1. THE STUDY FORMATION OF THE CONCEPTUAL BASIS OF THE MODEL USING MS POWER BI

To automate the acquisition and processing of research data, we will use MS Power BI tools to create a sustainable renewable energy model.

A similar approach provides an opportunity to analyze and visualize data using MS Power BI tools to develop a model for the sustainable economic development of renewable energy. Grouping data and building an information model opens the conceptual basis of the model as well as tools and methods used to form it. With the capabilities provided by MS Power BI, it is possible to process large amounts of data quickly and efficiently and analyze them from different perspectives. Using MS Power BI allows valuable insights and model processes of effective use of renewable energy and propose ways of its further increase. Visual reports also help to quickly understand complex data and, accordingly, make productive conclusions.

The data set shown in Table 1 contains a set of data on the indicators of alternative energy production sources as of 2021, the share of use, the level of attractiveness to investment, and so on. Therefore, the information data model (Fig. 4) groups the data from sources (Khadka & Chandra, 2021) based on the ties between the key fields of the tables.

The study of the economic development of renewable energy production of alternative energy, the purpose of which is to analyze the production of alternative energy, in particular wind, solar, hydropower, and others. The study reflects the investigation of the dynamics of production, establishing the ratio between different types of alternative energy, and assessing the level of investment and competitiveness in the market.

Table 1. Renewable energy statistics and environmental indicators of countries

Country	Geo-Bio-mass-Other (tWh)	Solar genera-tion (tWh)	Wind genera-tion (tWh)	Hydro genera-tion (tWh)	In-vest-ment level ($ millions)	Country's innovational potential, index	Annual CO_2 emis-sions (per capita)	Share of re-newable energy sources, %
	x1	x2	x3	x4	x5	x6	x7	y
Austria	4.3925185	2.1249056	6.751889	42.851505	2.60	21.00	7.24	36.45
Belgium	4.916279	5.608193	11.8788595	0.37435636	2.70	25.00	8.24	13.14
Bulgaria	1.694698	1.4895724	1.4332225	4.5625234	0.60	40.00	6.18	17.15
Denmark	8.734226	1.2779185	16.031755	0.0163087	4.40	7.00	5.05	34.78
France	11.1924715	14.605709	36.96734	57.966537	20.60	12.00	4.74	19.34
Greece	0.17746587	5.1679754	10.470926	5.8237925	1.90	37.00	5.39	21.92
Hungary	2.217125	3.793289	0.651231	0.208048	0.90	33.00	4.99	14.11
Iceland	5.787858	0	0.006083361	13.824003	0.10	26.00	9.11	85.78
Ireland	0.9686464	0.06360574	9.712766	0.7478114	3.80	15.00	7.53	12.54
Italy	25.756252	25.066978	20.618114	43.05632	10.10	30.00	5.55	19.03
Lithuania	0.5536734	0.12369155	1.3614266	0.3850306	0.20	36.00	4.98	28.23
Luxem-bourg	0.38976282	0.22130644	0.33903947	0.105368376	0.18	24.00	13.07	11.73
Poland	7.616	3.949	16.203	2.339	3.30	29.00	8.58	15.62
Portugal	3.742	2.208	13.225	11.853	1.30	31.00	3.96	33.98
Romania	0.70867634	1.701	6.576	16.900232	0.80	49.00	4.10	23.59
Slovakia	2.0455492	0.672096	0.003989071	4.2292657	0.17	42.00	6.48	17.41
Slovenia	0.29847902	0.302205	0.005535	4.706957	0.01	27.00	5.92	25.00
Spain	6.615242	26.806072	62.353806	29.566423	6.70	32.00	4.92	20.72
Sweden	13.329401	1.449	27.306503	71.458435	2.10	2.00	3.42	62.57
Ukraine	0.77824664	6.326277	3.9034183	10.418119	1.10	37.00	4.64	14.04

Source: compiled by the authors based on World Bank "International Renewable Energy Agency" (IRENA)

To automate the study, we will create an information data modeling using MS Power BI. The data model for the development of renewable energy comprises charts with the country's data on the economy and energy, renewable energy sources and key indicators, and others (Fig. 4).

According to the data model, the data chart relations were created on the basis of the key fields in Power Pivot to provide further reporting and accountability as well as visualization from these combined charts.

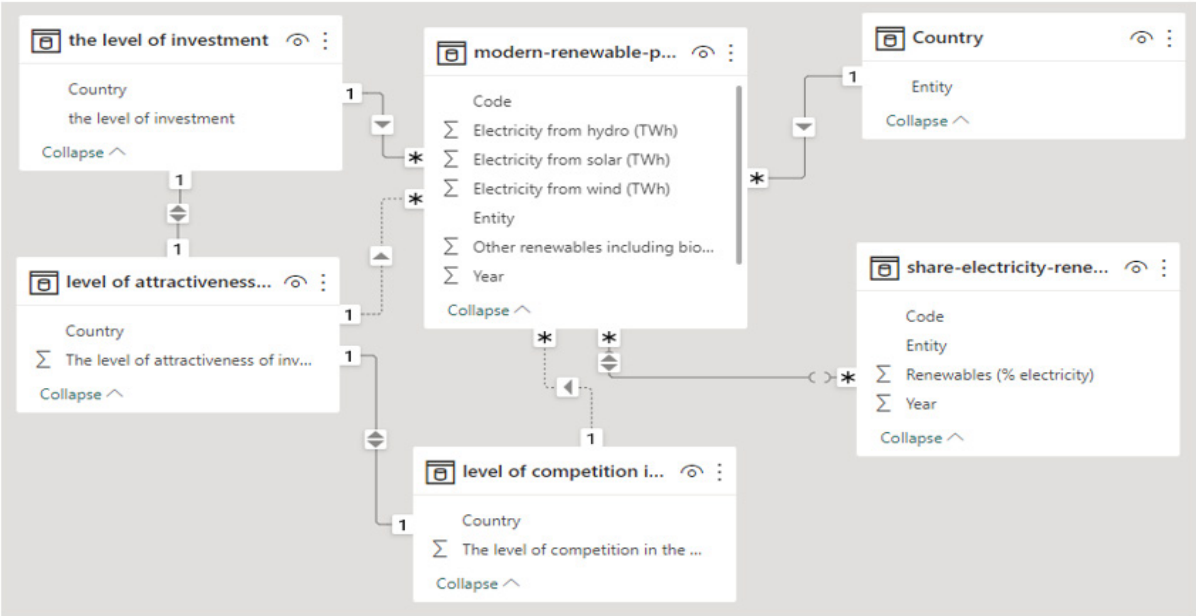
The data model contains the following tables:

1) modern-renewable-prod - production of alternative energy by types of energy (electricity from wind, electricity from hydro, electricity from solar, other renewables including bio-energy) by the country for the period 1965-2022;
2) share-electricity-renewables - hours of alternative energy in the world related to the total energy consumption of the country;
3) share-vehicle-electric - the number of electric vehicles in countries that are among the largest consumers of electricity;
4) level of investment in alternative energy - the level of investment in alternative energy in

different countries;

5) level of competition in the alternative energy market by country;
6) level of attractiveness of investors - the level of attractiveness of investors in alternative energy by country;
7) country – a list of countries selected to analyze the renewable energy market.

Figure 4. Renewable Energy Development Data Model (MS Power BI)



Source: authors' development

To calculate the regression coefficients, we construct "Regression Coefficients" measurement of calculations based on the formula of regression coefficients using the LINEST function using the Python programming language, the main parts of program code 5 are given see Appendix 1.

Apply a regression model to predict St values, namely the regression coefficients found to calculate predicted St values based on independent variables in your dataset or for new data.

According to the regression coefficients, we apply a regression model to predict St values based on independent variables in your dataset or for new data. To do this, use the measure in Power BI using the DAX formula 5:

$$Predicted\_St =$$

$$VAR\ Intercept = <data>[Intercept]$$

$$VAR\ X1\_Coeff = <data>[coef\_solar]$$

$$VAR\ Ri\_Coeff = <data>[coef\_wind]$$

$$// \text{-------- } reduction \text{ -----------------}$$

$$RETURN$$

$$Intercept + coef\_hydro * [Electricity\ from\ hydro\ (TWh)] + coef\_wind * [Electricity\_from\_wind\_TWh] \ .... \tag{5}$$

The result of code execution is a measure in our DataSet with predicted St values, which can be used to visualize, compare with actual values, or analyze the effect of independent variables on St.

4.2. FACTOR SYSTEMATIZATION OF THE PROPOSED MODEL

The systematization of model factors justifies and implements the relationships between different variables in the study. Since the process of selecting and including relevant variables in our model is multi-factorial based on different data types, it can further provide a clearer and more consistent representation of the results.

Systematization of factors of sustainable economic development of renewable energy:

- identification of possible impact factors that may affect the sustainability of the economic development of renewable energy;
- classification of factors – division into groups according to their characteristics, such as economic, technical, environmental, social, etc.;
- selection of factors considering the statistical study of each group for inclusion in the model based on the theoretical background, data availability, and previous studies;
- verification of multicollinearity – verification of the existence of multicollinearity between selected factors to identify and remove problems associated with high correlation between independent variables;
- model construction – incorporate selected factors into the regression model and perform the analysis;
- systematization of factors to improve the quality of the model and optimal selection of appropriate variables for building a model based on renewable energy.

4.3. SYSTEMATIZATION OF DATA ARGUMENTS AND MODELING RESULTS

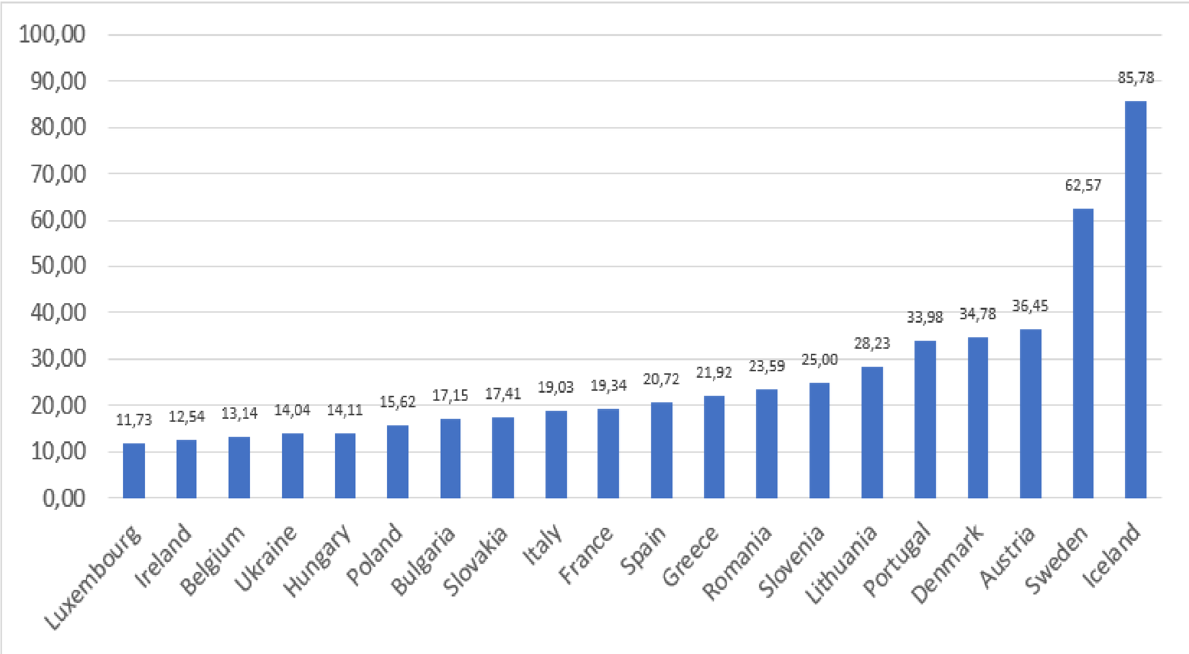
Modeling of sustainable economic development of renewable energy is carried out according to the following stages: 1) Collection and preparation of data on the economic development of renewable energy; 2) Checking data quality and balance for the model; 3) Construction of a formal model; 4) Parameterization and evaluation of the model, i.e., determination of model parameters using statistical methods that allow drawing conclusions about the statistical significance and influence of variables; 5) Analysis of results, that is, conclusions from the obtained parameters, their interpretation and comparison with hypotheses.

Accordingly, the analysis of renewable energy types in the world practice and the implementation of the model in stability of economic development should be reflected relatively positively.

The data consolidation (Table 1) contains electricity production by type of production, information on the share of energy use, the investment level, state support, the country's innovation potential, etc.

Fig. 5 shows an increase in the development of alternative energy sources, namely the share of renewable sources such as wind, hydropower, solar energy as well as other types of renewable energy, including bioenergy. This indicates that the world community is focusing on reducing dependence on traditional energy sources such as oil and gas and moving to more environmentally friendly and sustainable energy sources. It should be noted that many countries have different levels of alternative energy development, but in general, the trend towards increasing their role in the energy system of the world is obvious.

Figure 5. The share of electricity generation from total consumption by the country, %



Source: (International Energy Agency, 2022)

According to the International Energy Agency (IEA), in 2021, alternative energy sources provided about 29% of global electricity production. Solar power provided about 4% of production, wind power – 7%, hydropower – 16%, and other sources of renewable energy, such as biomass, geothermal energy, and wave energy, provided 2% of electricity production. In Fig. 5 indicators depend on the country and region of the world. For example, in developed countries such as the European Union and Japan, the share of renewable energy in electricity production is higher than in countries that have a lower level of development. It should also be kept in mind that the development of infrastructure of alternative energy sources may require significant investments and time, so the speed of their development may be different in different countries.

According to the data in Table 1 and the computer program in Appendix 1, we determine the quality of the data and their balance for correct processing in the model. In case of imbalance, data will not be entered into the table.

We will conduct a study based on regression analysis incorporating a linear multifactor model.

The multicollinearity that arose in the independent variables in this regression model (Table 2 factor X_5) indicates a natural relationship between them, namely the level of investment in alternative energy. Therefore, the regions in which multicollinearity is observed should be considered separately during individual calculation. Large values of correlation coefficients between some variables may indicate their endogeneity.

Table 2 and Table 3 show the geothermal and hydropower indicators which have a moderately strong positive direct correlation (0.651). If one variable grows, the other does as well. Accordingly, these factors are associated with the natural seasons, which enables us to consider the timing of energy from other alternative sources.

Factors x_2 and x_3 solar and wind energy are usually correlated with each other depending on weather conditions.

The factors of geothermal, bioenergy technologies x_1, and innovation potential x_6 have a moderate negative correlation (-0.407), which indicates an inverse correlation between them. If one variable increases, the other decreases, which is about the development of other sources of alternative energy. The factors of wind energy x_3 and, accordingly, annual CO_2 emissions (per capita) x_7 have a moderate negative correlation (-0.328), which indicates a decrease in CO_2 emissions with the development of wind energy.

Table 2. Correlation analysis of impact factors

	x1	*x2*	*x3*	*x4*	*x5*	*x6*	*x7*
x1	1						
x2	0.533124	1					
x3	0.489907	0.374308	1				
x4	0.49109	0.447906	0.470933	1			
x5	0.602292	0.658741	0.651315	0.580007	1		
x6	-0.40744	0.027107	-0.32678	-0.45306	-0.38964	1	
x7	-0.1866	-0.23827	-0.32785	-0.37152	-0.20744	-0.06329	1

Source: authors' development

Table 3. Linear regression statistics

Regression Statistics	
Multiple R	0.890136
R Square	0.776288
Adjusted R Square	0.170789
Standard Error	10.71539
Observations	20

Source: authors' development

In Table 4 the F-statistic value indicates a statistically significant contribution of independent variables to the regression model. The Significance F (α-level) is 0.043807, which is less than the 0.05 lower limit. This suggests that there are statistical grounds to reject the null hypothesis of no relationship between independent variables and dependent ones. It makes the model statistically significant.

Based on these findings, it can be argued that the model of sustainable economic development of renewable energy has statistically significant interconnections between the factors under study.

Table 4. Variance analysis (ANOVA) for linear regression

	df	SS	MS	F	Significance F
Regression	7	3049.237	435.6052	15.59051	0.043807
Residual	12	3352.849	279.4041		
Total	19	6402.086			

Source: authors' development

Thus, the results of the study substantiate the importance of forming a model of sustainable economic development of renewable energy. The development of renewable energy sources contributes to reducing CO_2 emissions, as well as improving economic stability and sustainable development of the country.

In this regard, it is recommended to focus on policies and initiatives that contribute to the development of renewable energy, such as government incentive programs, scientific and technical cooperation, and training programs for training specialists in the field of renewable energy sources.

Encouraging investment in renewable energy, supporting, and expanding research and development of new technologies, and improving energy efficiency can be key to achieving sustainable economic development and reducing dependence on traditional forms of energy (Table 5).

Table 5. The regression result of stable economic development

Observation	Share of energy	Predicted Y	Annual CO_2 emissions (per capita)	Predicted CO_2	ε
Austria	36.45	40.52711	7.24	5,9758	1,26
Belgium	13.14	20.59024	8.24	7,2462	0,99
Bulgaria	17.15	22.88782	6.18	6,0322	0,15
Denmark	34.78	29.52983	5.05	4,9111	0,14
France	19.34	14.39399	4.74	4,5218	0,22
Greece	21.92	17.16038	5.39	5,2016	0,19
Hungary	14.11	17.80192	4.99	4,3743	0,62
Iceland	85.78	98.81764	9.11	6,7636	2,35
Ireland	12.54	21.30986	7.53	6,7917	0,74
Italy	19.03	24.25472	5.55	5,0813	0,47
Lithuania	28.23	22.32876	4.98	4,4941	0,49
Luxembourg	11.73	24.64375	13.07	7,9237	5,15
Poland	15.62	27.17532	8.58	5,8193	2,76
Portugal	33.98	30.0599	3.96	2,9995	0,96
Romania	23.59	26.7108	4.10	4,0372	0,06
Slovakia	17.41	24.57254	6.48	5,8053	0,67
Slovenia	25.00	24.25736	5.92	6,4858	-0,57
Spain	20.72	13.87847	4.92	4,5564	0,36
Sweden	62.57	72.08306	3.42	3,2969	0,12
Ukraine	14.04	17.13954	4.64	4,6147	0,03

Source: authors' development

To analyze the heteroskedasticity of the regression data, we will apply the Breusch-Pagan test using the Python pandas and statsmodels libraries, which provides information about the presence of heteroscedasticity of the model according to the data in Table 5 and Table 1.

Test result:

p-value: 0.11753293583732878

Lagrange multiplier p-value: 2.315675876765868

F-statistic p-value: 0.12900446008797137

Conclusion – there is no statistically significant heteroskedasticity.

Interpretation of results – according to the results of the Breusch-Pagan test, we have the following p-values: 0.11753293583732878 for the test statistic, 2.315675876765868 for the Lagrange p-value, and 0.12900446008797137 for the F-statistic p-value. All these values are greater than the 0.05 significance level.

Therefore, taking into account the chosen level of significance, we can conclude that there is no statistically significant heteroskedasticity in the regression model. This means that the variance of the regression residuals (residuals of the model) is uniform and stable.

To conduct an autocorrelation test, we will use the Python pandas and matplotlib.pyplot libraries, according to the data in Table 5 and Table 1.

Test result:

Autocorrelation for 'A share of energy': -0.3344502816168777

Autocorrelation for 'Predicted Y': -0.33732386405279796

Interpretation of results – the autocorrelation values we obtained for Table 5 "Share of energy" and "Predicted Y" values are -0.334 and -0.337, respectively. These values range from -1 to 1, indicating the presence of weak negative autocorrelation in the data.

As mentioned above, this is due to seasonal natural influence and investment in renewable sources (wind, solar, hydro), namely, the volume of alternative electricity production increases (or decreases) in one period, then the opposite shift is observed in the next period.

Since we are working with regression data on the development of alternative energy, one of the factors of its progress is the reduction of CO_2. We will conduct a test for the normality of the residuals, such as the Anderson-Darling test:

Test Statistic: 0.2975405678835789

Critical Values: [0.557 0.632 0.759 0.885 1.053]

Significance Level: [15. 10. 5. 2.5 1.]

The residuals are almost normally distributed at the 5% significance level.

From the results of the Anderson-Darling test, it can be seen that the residuals (the difference between the actual and predicted values) are almost normally distributed at the 5% significance level. This suggests that the regression model reflects the relationship between the variable «Annual CO_2 emissions (per capita)» and the variable «Predicted CO_2».

Countries around the world are increasingly focusing on reducing carbon emissions and energy dependence by switching to alternative energy sources. This leads to increased demand for technologies and equipment related to renewable energy, as well as increased investment in this sector.

It is also important to note that the development of alternative energy contributes to the creation of new workplaces and promotes economic growth in general. Therefore, investing in this sector is considered an important step in dealing with climate change and creating sustainable development.

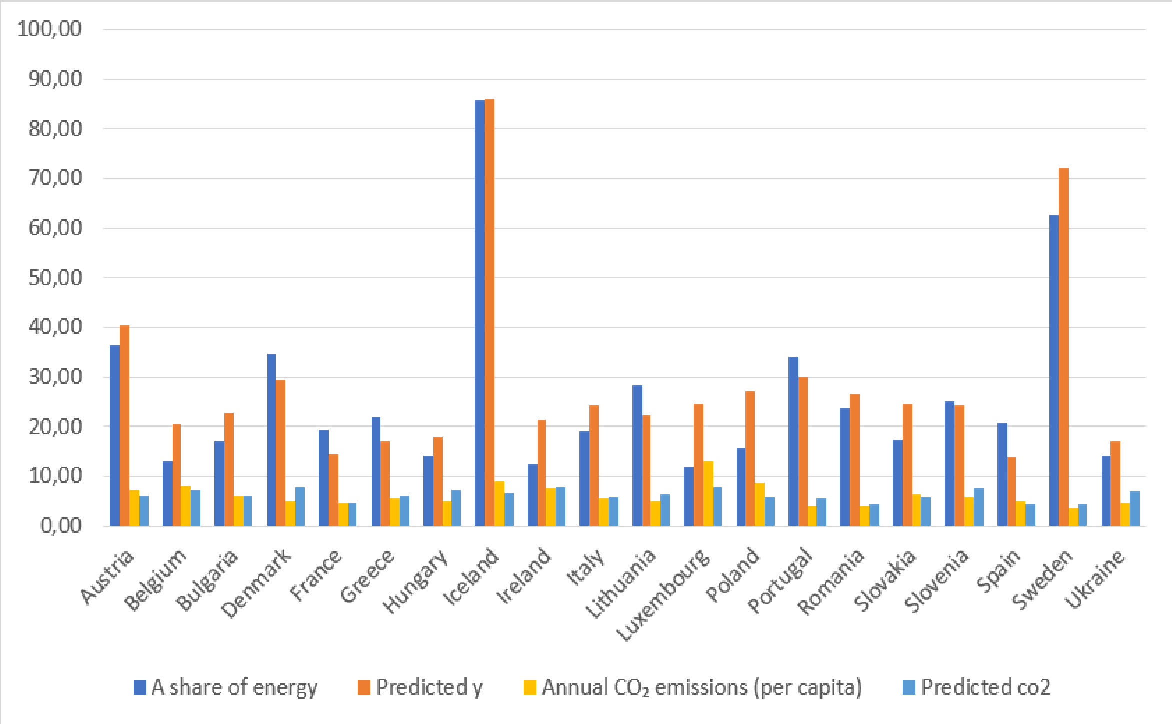
Therefore, in the first stage of the study, the sustainable development of alternative energy sources, such as solar, wind, hydro, and others, is obvious, which reduces the dependence on complex and expensive coal, oil, and gas sources (Fig. 6).

Moreover, the development of alternative energy sources is a key factor in preventing climate change, as it reduces emissions of greenhouse gases and other pollutants into the atmosphere.

The use of alternative energy sources can also reduce the cost of electricity production and ensure sustainable economic development.

It is expected that the development of alternative energy sources will continue to grow in the future (Fig. 7). By 2040, according to forecasts of the International Energy Agency, more than 40% of electricity production in the world will be provided by renewable energy sources, such as wind energy, solar energy, and others.

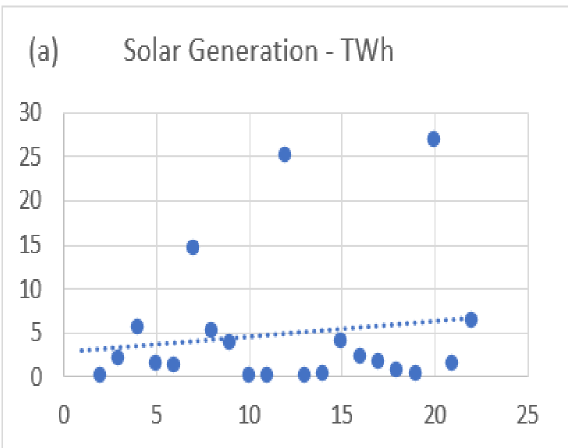
Figure 6. Growth of the share of alternative energy and reduction of CO_2 emissions

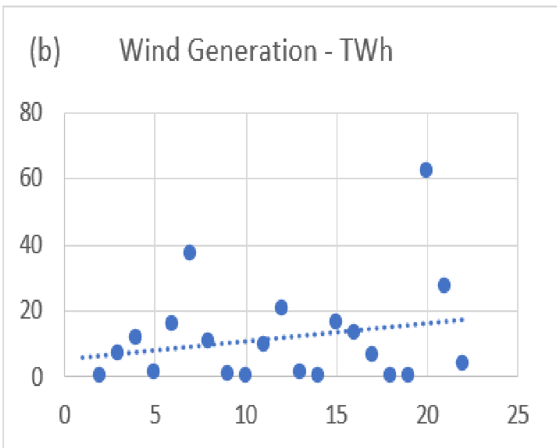


Source: (International Energy Agency, 2022)

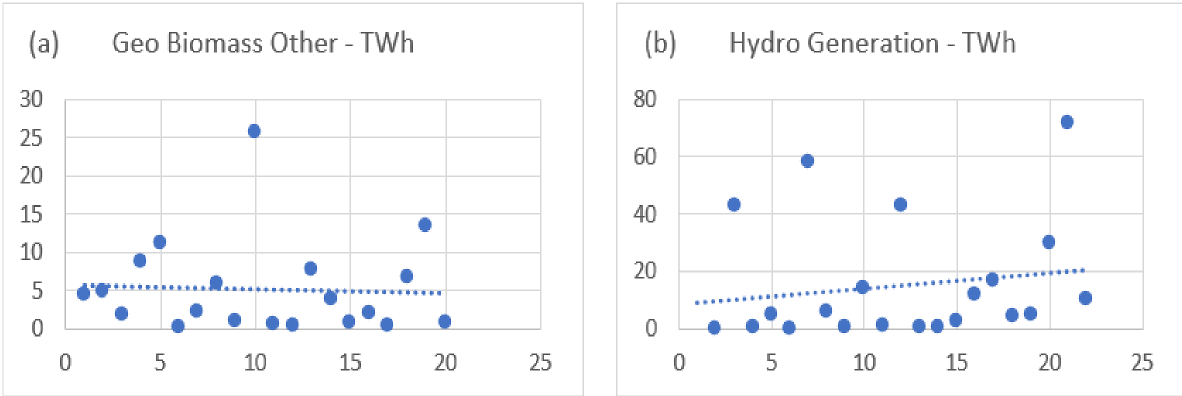
Figure 7. The expectation of the development of alternative sources by types: (A) (a, b) increase in solar and wind energy; (B) (a, b) stable geo-biomass-other and hydro generation growth

(A)





(B)



Source: (International Energy Agency, 2022)

Based on results, possible creations of management measures include:

1) development of investment strategies in the development of renewable energy sources aimed at increasing the share of renewable energy in the overall energy balance of the country;
2) stimulating the country's innovative potential by supporting research and development in the field of renewable energy;
3) implementation of energy efficiency and energy saving measures to reduce CO_2 emissions per capita;
4) development and modernization of infrastructure for the generation and distribution of energy from renewable sources (geothermal, biomass, solar, wind, and hydropower);
5) attracting private investments and international financing for the renewable energy development;
6) work out and implementation of legislative acts and regulatory mechanisms to support renewable energy and sustainable economic development;
7) promote international cooperation and knowledge sharing in the sphere of renewable energy to extend best practices and innovative technologies.

The model of the establishment of sustainable economic development of renewable energy is considered as an important component of the management decision-making system concerning improvements of the situation in alternative energy development, including appropriate measures at the state level.

5. DISCUSSION

This study suggests a model of sustainable economic development of renewable energy, which has certain advantages over existing approaches. The basic concept is to use fuzzy logic systems to analyze the internal and external factors influencing the development of the industry.

Internal factors cover various aspects of renewable energy, such as equipment condition, the efficiency of energy conversion processes, the availability of skilled personnel, and environmental indicators (Koziuk et al., 2020). External factors include legislative regulation, investment flows, scientific and technical achievements, and global trends in the development of alternative energy sources.

The proposed model is based on the principles of efficiency, optimal management, adaptability to changes in the internal and external environment, legality, responsibility, and complexity. This allows us to develop strategies, programs, and projects that will contribute to the sustainable development of renewable energy while ensuring rational decision making on investment, modernization, and expansion of production.

Analyzing the experience of leading countries in the development of renewable energy, such as Germany, Italy, France, Austria, and others, we can conclude that the active application of such a model of sustainable economic development of renewable energy can contribute to improving energy security, reducing dependence on imported energy carriers and reducing the negative impact on the environment.

Incorporating this model involves development of various sources of renewable energy, such as solar, wind, hydropower, biomass, and geothermal energy. This implies the development of appropriate infrastructure, creating a favorable investment climate, training skilled personnel, and conducting research.

Particular attention within the framework of the formation of a model of sustainable economic development (Yousuf et al., 2022) of renewable energy should be paid to supporting innovations that will increase the efficiency of energy production, storage, and distribution processes, as well as developing new technologies that will ensure the sustainable development of the industry.

Similar research of international companies reflects stable economic development while resorting to renewable energy sources that results in reducing environmental pollution. The research conducted by the International Energy Agency (IEA) shows that by 2050 the use of renewable sources can reduce the world CO2 emissions by 70% as compared to the scenario with fossil fuel energy consumption. It can also increase the GNP and create economic advantages such as reduction of import dependence in energy (Ukrhydroenergo, 2021).

The research conducted by the International Renewable Energy Agency (IRENA) proves that the development of alternative energy sources such as solar and wind energy can boost economy by creating new work places and attracting investments (IRENA, 2020).

Successful implementation of the sustainable economic development model of renewable energy requires interaction between government agencies, businesses, scientific institutions, and the public. This implies the development and implementation of a comprehensive state policy in the field of renewable energy, aimed at stimulating investment, infrastructure development, supporting innovation and training, and ensuring social and environmental responsibility.

The implementation of the sustainable economic development model of renewable energy will open new opportunities for creating workplaces, promoting the export of technologies and services, strengthening energy independence, and improving the quality of life of the population.

Another important aspect is the development of international cooperation in the domain of renewable energy, joint projects with leading countries, and the experience exchange on innovative technologies. This will contribute to the integration of the national energy system into the world market and ensure the competitiveness of domestic companies.

As a result, the formation of a model of sustainable economic development of renewable energy is an important task that requires an integrated approach, active participation of all stakeholders, and constant monitoring of implementation results. This will ensure sustainable, safe, and environmentally friendly energy supply, promote economic growth, and ensure a high quality of life for future generations.

6. CONCLUSIONS

The result of this study is the formation of a model of sustainable economic development of renewable energy, which requires the active assistance of states, the private sector, and international organizations. Based on the data analysis, it was found out that countries with a higher level of investment, innovative potential, and a percentage of renewable energy sources in the energy balance have lower levels of CO_2 emissions.

Countries with higher levels of investment and innovation potential have a greater share of renewable energy in total energy consumption. Increasing the share of renewable energy contributes to reducing CO_2 emissions per capita, thus indicates the positive impact on the environment.

The development of geothermal, solar, wind, and hydropower depends on the geographical, climatic, and other characteristics of each country, which requires an individual approach to the formation of strategies for the development of renewable energy.

Considering these conclusions, it is proposed to intensify efforts to develop renewable energy as a key area for sustainable economic development, to ensure energy security, reduce negative environmental impact and achieve global sustainable development goals.

Priority areas for achieving sustainable development of renewable energy are:

- expanding the research and development base to support innovation in renewable energy;
- stimulation of the private sector for the development of renewable energy;
- improving the regulatory and legislative framework to ensure the reliable, efficient, and safe functioning of the renewable energy market;
- infrastructure development for the distribution and storage of energy from renewable sources. This involves modernization and development of power grids, creation of energy storage systems, as well as the development of transport infrastructure using renewable energy sources;
- raising public awareness of the importance of renewable energy and its benefits for sustainable development, namely raising awareness of the environmental, economic, and social benefits of renewable energy, as well as encouraging consumers to choose "green" products and services.

In conclusion, this study has presented a model for sustainable economic development of renewable energy, highlighting the need for active involvement from states, the private sector, and international organizations. The analysis of data revealed that countries with higher levels of investment, innovative potential, and a greater percentage of renewable energy in their energy balance tend to have lower levels of CO_2 emissions. Additionally, countries with higher investment and innovation potential have a higher share of renewable energy in total energy consumption, indicating a positive impact on the environment.

It is clear from the findings that the development of geothermal, solar, wind, and hydropower depends on the unique geographical, climatic, and other characteristics of each country. Therefore, it is crucial to adopt an individual approach when forming strategies for the development of renewable energy.

Based on these conclusions, it is recommended to intensify efforts towards the development of renewable energy as a key driver for sustainable economic growth, energy security, and reduction of negative environmental impacts. To achieve these goals, several priority areas have been identified.

Firstly, expanding the research and development base to support innovation in renewable energy is crucial. This includes investing in scientific research, fostering collaborations between academia and industry, and providing financial incentives for technological advancements in the renewable energy sector.

Secondly, stimulating the private sector to actively participate in the development of renewable energy is essential. This can be achieved through financial incentives, tax breaks, and the creation of favorable business environments that encourage investment in renewable energy projects.

Thirdly, improving the regulatory and legislative framework is vital for ensuring the reliable, efficient, and safe functioning of the renewable energy market. This involves implementing clear and transparent regulations, streamlining administrative procedures, and establishing standards for the integration of renewable energy into the existing energy infrastructure.

Furthermore, infrastructure development for the distribution and storage of energy from renewable sources is crucial. This requires the modernization and expansion of power grids, the development of energy storage systems, and the integration of renewable energy sources into transportation infrastructure.

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APPENDIX 1

Program calculation code of "regression coefficients" on the basis of the coefficient regression formula incorporating function LINEST in program language Python for MS Power Bi.

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from sklearn.linear_model import LinearRegression

# Create a dataframe wirh data
data = pd.DataFrame({'Solar_Energy': dataset['Electricity from solar (TWh)'],
'Hydro_Energy': dataset['Electricity from hydro (TWh)'],
'Wind_Energy': dataset['Electricity_from_wind_TWh'],
'Bio_Energy': dataset['Other renewables including bioenergy (TWh)'],
'investment': dataset['(investment )'],
'Innovative potential': dataset['(Innovative potential )'],
'AnnualCO': dataset['(Annual CO2)'],
'Y': dataset['Share of renewable energy sources']})

# Initialize and train linear regression
regression_model = LinearRegression()
regression_model.fit(data[['Solar_Energy', 'Hydro_Energy', 'Wind_Energy', 'Bio_Ener-
gy']], data['Y'])

# Prediction of  Y based on X
data['Y_pred'] = regression_model.predict(data[['Solar_Energy', 'Hydro_Energy', 'Wind_
Energy', 'Bio_Energy']])

# Displaying data and regression lines for Solar_Energy
plt.subplot(2, 2, 1)
plt.scatter(data['Solar_Energy'], data['Y'], label='Actual')
plt.scatter(data['Solar_Energy'], data['Y_pred'], color='red', label='Predicted')
plt.xlabel('Solar Energy')
plt.ylabel('Y')
plt.legend()
# ------ code reduction for other components -----

# Lines regression adding to the graphs
x_solar = np.linspace(data['Solar_Energy'].min(), data['Solar_Energy'].max())

# Saving coefficients for regression lines
coef_solar = np.polyfit(data['Solar_Energy'], data['Y'], 1)

# Regression lines calculation
y_solar = np.polyval(coef_solar, x_solar)

# Displaying of the lines regression in the graphs
plt.subplot(2, 2, 1)
plt.scatter(data['Solar_Energy'], data['Y'], label='Actual')
plt.plot(x_solar, y_solar, color='red', label='Regression Line')
plt.xlabel('Solar Energy')
plt.ylabel('Y')
plt.legend()
plt.tight_layout()
plt.show()
```