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Environmental and economic impacts of energy transformation: concepts innovation and business models

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CONTENT

INTRODUCTION

In recent decades, there have been dramatic changes in the energy sector, which significantly impact other areas of activity. It is widely believed that traditional energy sources are the leading cause of air pollution, although they play the most prominent role in electricity generation. Such dependence on fossil energy sources is a significant challenge on the path to sustainable development. The introduction of sustainable business models and innovative concepts in the energy sector is a tool for transitioning from traditional to "green" energy to reduce the negative impact on the environment. Therefore, it is essential to assess the effects of energy transformations and identify the environmental and economic effects of the deployment of such solutions. Sustainable business models can solve environmental problems associated with harmful emissions from the energy sector. These models are more environmentally friendly and are part of "green" growth. They ensure the creation and maintenance of the values of organizations and provide competitive advantages in the industry. Although moving to sustainable business models is quite complex, they contain alternative solutions to avoid a global collapse due to energy shortages and climate change.

In this regard, the priorities are to improve regulatory policy in the energy sector, the formation of environmentally friendly competitive advantages of energy companies, the description of opportunities to deploy smart energy networks, development of sustainable business models for energy sector transformation, optimization of energy financing.

Therefore, in the first section of the monograph, the authors analyzed the innovative, organizational, and economic principles of state regulation of energy supply. The second section of the monograph described the basics of green competitiveness of energy sector enterprises the determinants of the competitive environment of energy companies.

The third section of the monograph provided a description of security and integration processes in the EU and partner countries' priority areas for the deployment of energy networks.

The fourth section of the monograph presented the principles of the concept of smart grid deployment, trends in sustainable transformation, and a description of sustainable business models for the transformation of the energy sector.

The fifth chapter concludes the monograph. The section describes the concept of optimizing sources of financing for smart energy networks.

The monograph was performed within the framework of the research themes "*The Optimization Model of Smart and Secure Energy Grids Building: an Innovative Technologies of Enterprises and Regions Ecologisation*" (state registration number 0119U100766), "Causal modelling of stakeholder collaboration in green production: reconciling socio-ecological and economic contradictions" (state registration number 0119U101860), which are financed by the State budget of Ukraine and was prepared by authors:

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1. THEORETICAL AND METHODOLOGICAL FUNDAMENTALS OF IMPROVING REGULATORY POLICY IN THE ENERGY SUPPLY SYSTEM

1.1. The formation of transparent and innovative principles of state regulation of energy supply

Integrating the national economy into the European Economic Area requires the formation of transparent and innovative principles of state regulation of the energy sector to create competitive and non-discriminatory advantages in the European energy market.

According to the Energy Strategy of Ukraine until 2035 "Security, energy efficiency, competitiveness", approved by the Order of the Cabinet of Ministers of Ukraine dated 18.08.2017 №605-r, Ukraine plans to maintain the position of one of the largest producers of hydrocarbons in continental Europe and reliable transit of energy resources. It should ensure a stable supply of energy resources to its consumers and consumers in other markets. It is emphasized that energy resources will be extracted and transported based on high environmental and social responsibility, in compliance with the obligations to reduce greenhouse gas emissions.

Diversification of sources and ways of energy supply is relevant for the national economy. One of the ways to implement this provision is to increase domestic oil production, which will increase the state's economic, energy, and environmental security. It is important to optimize the energy balance and create a basis for a stable energy future in the country.

The urgency of development and modernization of the energy sector is substantiated in the Energy Strategy of Ukraine until 2035 (Fig. 1.1).

Energy independence must be ensured through the intensive increase of the resource base and production of primary energy resources, increasing renewable energy, modernization of domestic capacities for their processing, transportation, creation of stocks and reserves, diversification of sources and supply routes, technical and technological re-equipment of key enterprises (Strekal, 2015).

The main theses of modern public policy that should provide the modernization of the energy sector are presented in Table 1.1

One should note that the proposed components can, to some extent, be applied to all sectors of the energy sector since the systems of organizational and economic relations of the respective sectors are interconnected and complementary.

At the same time, the main requirements and motivating factors in promoting the processes of attracting investment in the energy sector should be:

- Rule of Law;
- adaptation to European energy legislation;
- deoffshorization of the economy;
- introduction of stimulating regulatory legislation;
- economically justified tariffs;
- conducting communication and marketing policies to encourage entry into the market of strategic and financial investors;
- deoffshorization of the economy.

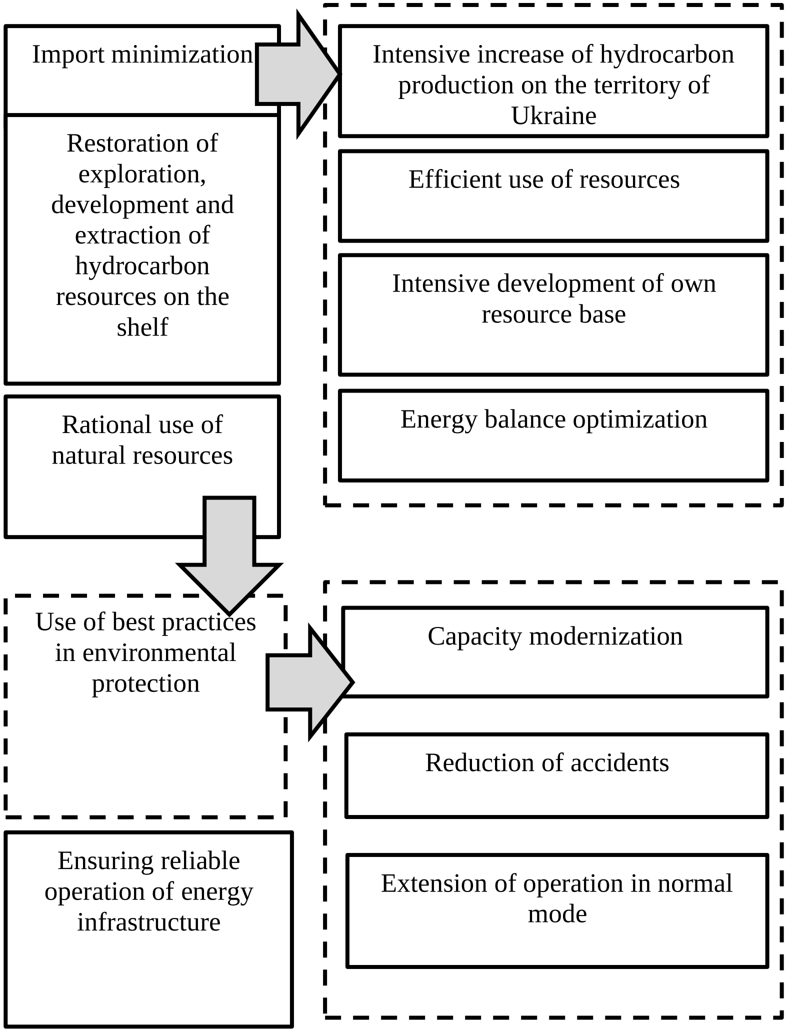

Figure 1.1. Prerequisites for energy independence

Source: compiled by the authors

Table 1.1. Directions of the energy sector modernization in the national economy

No	**Directions**	**Content**
1	Implementation of modern energy strategies	Formation of forecasts and scenarios, improvement of statistical and accounting system through full and timely exchange of information on energy balance, energy flows, infrastructure development
2	Creating transparent energy markets	Formation of organizational and economic bases on EU rules and standards, cooperation within the framework of the agreement on the establishment of the energy community (Cohe, 2017)
3	Modernization of energy and transport infrastructure	Diversification of suppliers, ways and methods of transportation on the principles of ecological and economic efficiency
4	Strengthening long-term stability in the industry	Improving the security of trade, transit, exploration, extraction, purification, production, storage, distribution, marketing of energy sector products (Yúneza, 2017)
5	Creating a favorable investment climate	Providing institutional, legal, fiscal and other stimulating conditions by promoting mutually beneficial investment in energy production and supply (Cheng, 2017)

Table 1.1. Continued

No	**Directions**	**Content**
6	Cooperation with international financial institutions	Interaction with the European Investment Bank, EBRD to finance projects in the energy sector (Addison, 2018)
7	Ensuring environmental safety in the industry	Promotion of the implementation mechanism to reduce greenhouse gas emissions, use of modern environmentally friendly technologies (Chygryn, 2018; Chygryn, 2016)
8	Scientific and technical cooperation and exchange of information	Development and improvement of technology in the field of extraction, transportation and final consumption of energy resources using climate-neutral and environmentally friendly technology

Source: compiled by authors

One should note traditional views that the availability of natural resources in countries is crucial to building efficient national economies since rent from the use of natural resources is one of the determining components to form the revenue side of national budgets (Figure 1.2).

Extraction of natural resources, development of extractive and processing industries should ensure stable economic development, GDP growth per capita, improving the quality of life, creating a productive institutional environment that will contribute to the rational distribution of rents to improve the welfare of national economies (Umar, 2017; Vasylyeva, 2014).

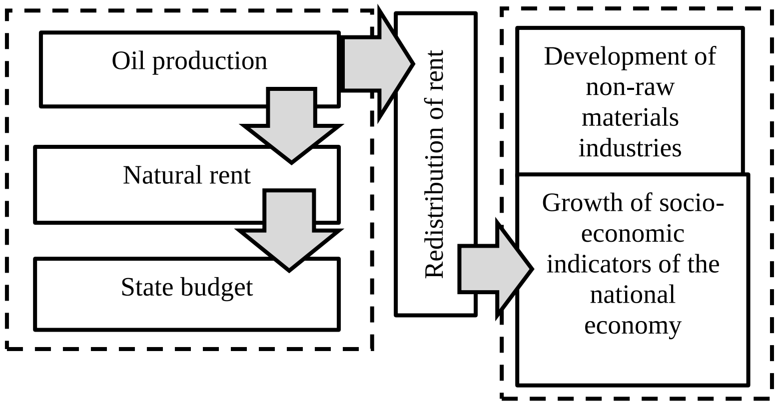

Figure 1.2. Natural rent in the national economy

Source: compiled by the authors

However, the analysis of publications (Lyeonov, 2018; Pimonenko, 2018a; 2018e) and the assessment of socio-economic indicators of energy companies show inverse links between the development of national economies and the availability of natural resources in countries and their production.

Thus, the authors Addison T., Johnson S., Kerubin P. and Robinson J. (Addison, 2018) point out that the overestimation of rental rates almost always causes disparities in the macroeconomic policy, which in turn affects the deformation of the macroeconomic regulatory instruments regulation in favor of the narrow groups' (sectors) interests. At the same time, modern economic influential instruments become direct levers of income redistribution.

In the early 1990s, Richard Auty first defined the category of "resource curse" or "surplus paradox" (Auty, 2001) in his writings. Relevant concepts were introduced into scientific circulation in accordance with observations of the growth rates of oil-exporting countries, which showed a decline in the dynamics of GDP per capita for two decades after the oil crisis of the 1970s.

Later in (Sachs, 2001; Pimonenko, 2013; Umar, 2017) there was a discussion that the surplus of natural resources often becomes a problem rather than a benefit for rentier states. Thus, in 1965–1998, the growth of the average GDP per capita in OPEC countries was 1.3%, while in developing countries - 2.2% (Ngene, 2016).

Nigerian scholars note that during 1965-2000, rent payments per capita increased from $ 33 up to $ 245, while GDP per capita remained unchanged at $ 325. At the same time, the share of the poor in the country increased from 36% to 70% during the same period (Sala-i-Martin, 2004).

It is emphasized that the proper effects (low quality of life, poverty, high level of corruption, etc.) are not the result of the availability of natural resources in countries. In their view, the problem is the rigid dominance of mining and processing industries in the export structure of national economies and the slow pace of socio-economic reforms.

Some authors (Sala-i-Martin, 2004; Vasylieva, 2018; Pimonenko, 2018b) note that in general, the resource problem relates to the underdevelopment of institutions, the dominance of informal rules and procedures in managerial decisions, declining quality of life of the most population, the state's usurpation in the interests of ruling circles and degradation of institutions after the discovery of surplus oil or gas reserves (examples of Russia, Latin America, Africa). Besides, the authors empirically confirm the hypothesis of an inverse relationship between the level of democracy, efficiency of government, and raw material exports (Figure 1.3).

At the same time, the authors generalize the hypothesis that within the two polar political regimes (democracy and autocracy) appropriate institutions can be formed, within which macroeconomic policy and socio-economic development of national economies will complement each other.

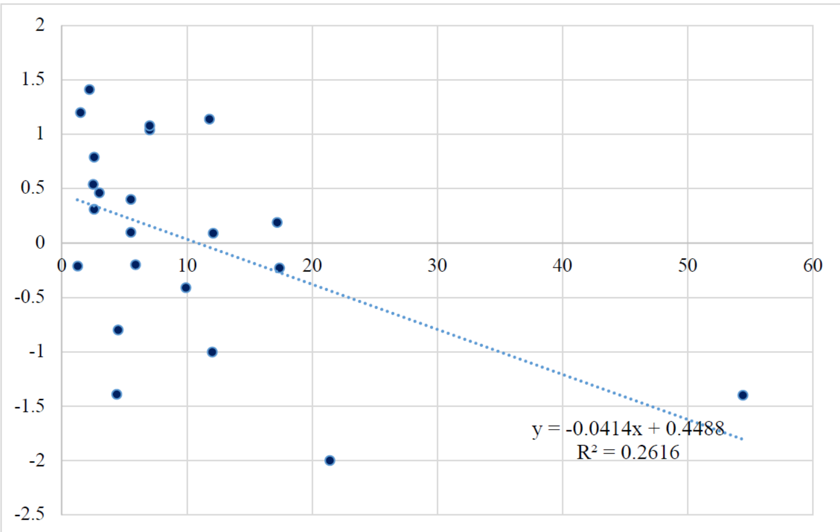

Figure 1.3. The relationship between resource wealth and political stability

Source: compiled using (Nurudeen, 2015)

Moreover, the situation is also considered when the instability of the national economy and political tensions will exclude the welfare growth and hinder socio-economic development (Figure 1.4).

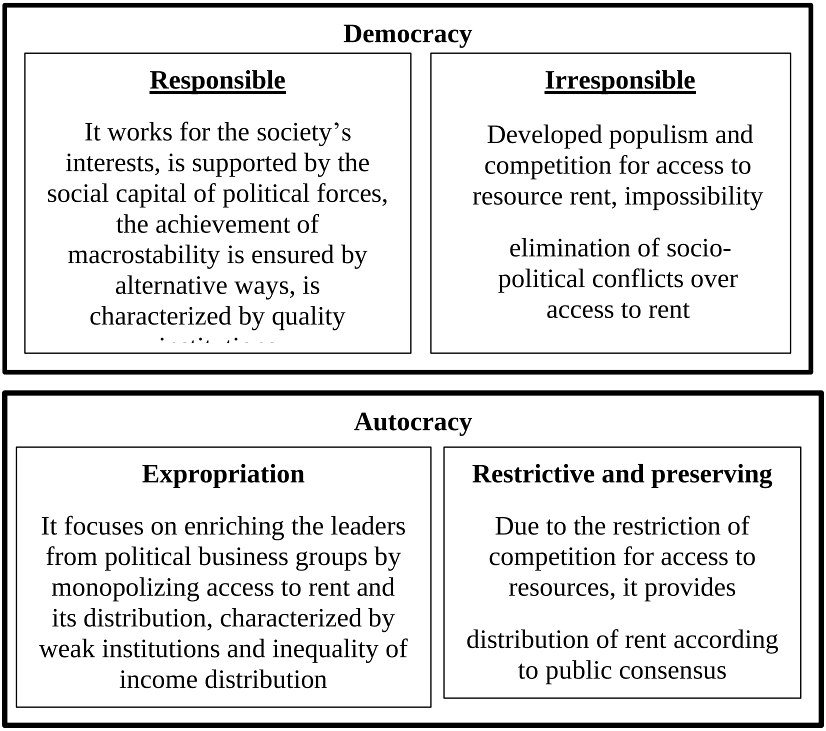

Figure 1.4. Resource rent and the state system

Source: compiled by the authors (Nurudeen, 2015)

However, the works of Habert and Menaldo (Hubbert, 1956) define the opposite concept of "resource well-being". In the 1970s in Venezuela and in the 2000s in Mexico there was a correlation between rising oil prices and democracy, while key political and civil rights and freedoms were preserved (Doyle , 1994; Nurudeen, 2015). At the same time, Botswana, Chile and Norway are often seen as exclusions from the general rule of the "resource curse", given that they are examples of stable and economically successful democracies, while other resource-dependent economies show opposite trends.

At the same time, T. Friedman formulated the so-called “First Law of Petropolitics”, according to which the price of oil and political freedom "move" in opposite directions (Freeman, 2010).

Some scholars (Bannon, 2003; Mlaabdal, 2017) explain the disparities in the development of national economies by the fact that resource-dependent economies are more likely to have internal civil conflicts than in countries devoid of this problem. On the one hand, the resources can be a motive for resolving internal conflict or external aggression, and on the other hand, the excess profits from their sale are often used to finance military-political unrest in the interests of the ruling elites.

As noted in (Chervyakov, 2014; Lyeonov, 2018), the oil and gas business representatives are interested in the weak political institutions, underdeveloped civil society, which indirectly contributes to the increase of their wealth (often to the detriment of environmental and social progress). Recently, in Nigeria, the development of the oil business has supplanted agro-industrial production and, at the same time, harms the environment in the Niger Delta and deprives many people of their jobs without appropriate government action.

One should note that the "resource curse" ("Dutch disease") is characterized primarily by non-diversified and resource-dependent national economies, significantly affected by sales of resources on the world market (Torvik, 2009). Such countries are also characterized by a decrease in the competitiveness of other economic sectors, lack of interest and motivation for the innovative technology development in various sectors of the economy, high corruption component.

1.2 Organizational and economic principles of state regulation of the energy sector

Formation of organizational and economic principles for effective system of accumulation and distribution of natural rent requires the analysis of the main stages in the formation of legislative regulation (Kovalko, 2001; Bilan, 2019).

1. 1991-1996. Formation of general principles of rent legislation: definition of property rights, substantiation of necessity of paid use of subsoil, laying of bases of the rent relations system.

2. 1997-2004. Creation of a regulatory framework for determining the nature, content and institutional principles of ownership of natural resources, the mechanism of paid subsoil use (allocation of rents for oil and gas). Legislative consolidation of non-tax methods for distribution and redistribution of natural resource rent.

3. 2005-2010. Reforming the system of paid subsoil use. Approval of the Budget and Tax Codes of Ukraine.

4. 2011-2013. Improving tax legislation in terms of setting rates for subsoil use, reforming the subsoil use system. Approval of mechanisms for conducting auctions for the sale of special permits for subsoil use and determining the features of lease and concession of certain objects of the fuel and energy complex, which are in state ownership.

5. 2014. Changes in rental rates with simultaneous redistribution of rent payments to the state budget.

6. 2015 – 2018. Formation and approval of legislation on the fair distribution of rents to local budgets.

7. 2018 – 2020. Development and approval of legislation regulating the renewable energy market of Ukraine.

However, with regard to the domestic economy, one should note that the risk of strengthening its commodity orientation corresponds to a break in the trend of world commodity prices, which does not guarantee the possibility of rapid conversion of "resource welfare" into accelerated growth and GDP growth per capita.

It determines the urgent need to form a clear and transparent system of national institutions and strategies designed to regulate the relationship in the field of resource extraction and mechanisms for the use of appropriate rent.

Thus, the existing imperfect state institutions to define, accumulate and distribute the resource rents can in turn give rise to many system problems (Table 1.2).

One should note that during 2013-2017 in Ukraine there were no programs of direct state support for resource extraction. According to the amendments to the Tax Code of Ukraine from January 1, 2018, only for natural gas production, the rental rates for natural gas from new wells were reduced to 12% and 6%. In this case, these rates should be stable for the next 5 years (Pimonenko, 2018d).

Table 1.2. Problems of inefficient rental policy in the oil sector

Problems	**Consequences**
Imbalance between national interests and the interests of the regions	Lack of proportional and relative distribution of funds received from natural rents between state and local budgets
Low level of investment opportunities for socio-economic development of resource-producing territories	Socio-economic imbalance in the development of oil-producing areas
Low level of development of market relations in nature management sphere	Impossibility to implement and use modern practices of developed countries and international standards
Lack of incentives for the resource industry development	Restrictions on financing the modernization of the industry, the use of environmentally friendly technologies, the development of new fields
Inefficiency of the tax system	The lack of a clear and transparent government policy in the fiscal sphere determines the taxation cost of mining industries, the financing of losses resulting in uneven distribution of the tax burden
Nontransparet and inefficient use of rent	Due to the high level of corruption, the accumulation of significant amounts of natural rents does not lead to the growth of other (non-raw materials) sectors of the national economy

Source: compiled by the author

Thus, there is an urgent need to improve the theoretical and methodological approaches to improving the mechanism of state regulation of the resource complex.

The analysis of modern approaches allowed to form the basic principles of the system for state regulation of the resource-producing branch in the national economy (Figure 1.5):

1. Focus on long-term goals.

2. Equal access to the subsoil. It can be ensured by introducing a system of auctions to sell special permits for subsoil use. One should note that in Ukraine, about 84% of special permits were issued during 2013-2017 without competitive procedures, and current market participants received them, as a rule (Kvasniy, 2007).

The regular electronic auctions for the sale of special permits for subsoil use ensure the equality of access to the subsoil. It is necessary to improve methodological approaches to forming lots to avoid conflicts between issuing special permits and signing a production sharing agreement. In particular, it is essential to narrow the criteria for subsoil areas for which relevant agreements can be concluded. Increasing the transparency of auctions, in turn, will be provided by the Prozorro system.

3. Standardization of information about the resource base. Modern market conditions require the use of digitized, up-to-date information in line with international standards on the resource base. One should note that the geoinformation received today is often inaccurate, outdated and unusable. In addition, it must be translated into foreign languages and be available online. The use of relevant information must follow the procedure approved by law.

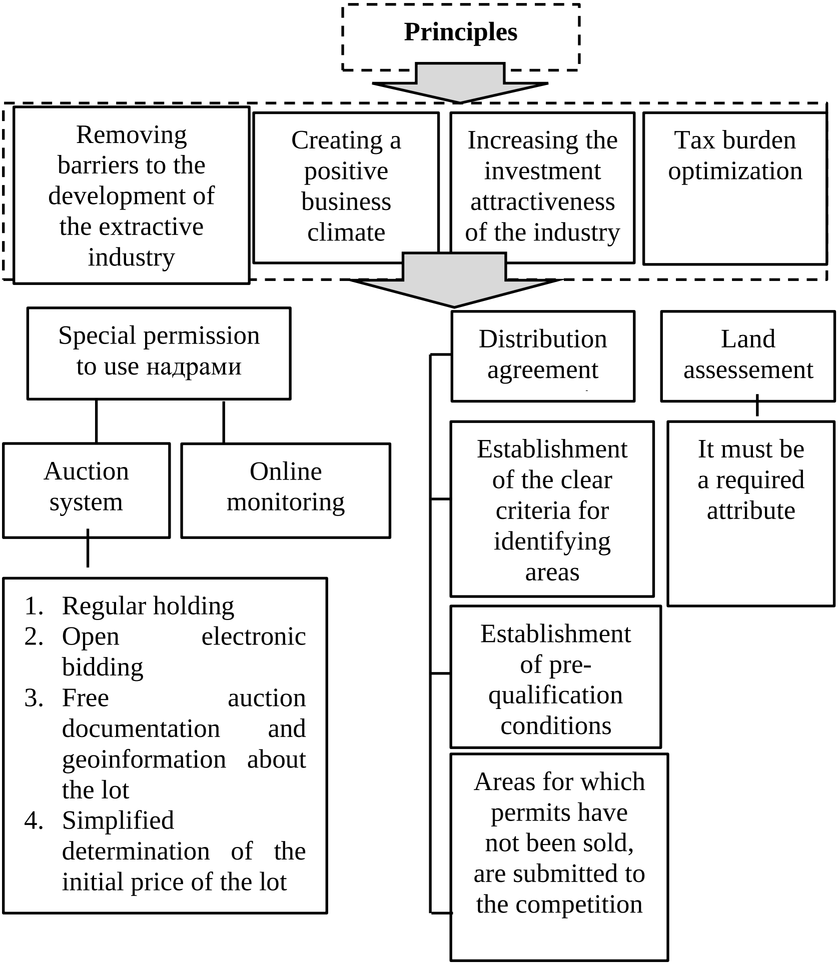

Figure 1.5. Implementation of the principles regarding the state regulation of the resource production complex

Source: compiled by the authors

4. Transparency. The implementation of the principle of resource-extraction industries is significant. Accordingly, it will

help reduce corruption in the oil industry, create a favorable business climate and increase the investment attractiveness of the industry.

5. Inclusiveness is a stakeholders' clear understanding of the resource industry regarding everyone's role in preventing and eliminating socio-environmental and economic contradictions in the industry.

6. Systematicity and complexity provide for maximum coverage and consideration of the determinants' relationships of the oil industry development, taking into account their impact on the management results in the industry.

7. Ecological, socio-economic efficiency. The implementation of this principle is to ensure the development of existing and hidden development potential of the resource industry.

8. The sequence is a clear correspondence between the implementation of planned activities. Public administration of the oil complex based on sustainable development should take place gradually, in stages according to the established development program (road map).

9. Accountability involves the direction of the management system of the resource complex, joint, and several liabilities for compliance with the planned performance indicators, management synchronization.

10. Prevenance is the formation of public policy aimed at preventing the negative externalities (socio-ecological and economic) of the resource industry.

11. The adaptability of the public management system of of the resource complex lies in its flexibility to appropriate changes in the environment, including international, political, environmental and economic factors. At the same time, the possible adaptation of sustainable development target is important.

12. Innovativeness is the planning and implementation of modern innovative technology for resource production, environmental protection in the industry, the modernization of existing production facilities.

We have to note that according to the Institute of Natural Resources Management (Extractive, 2013), Ukraine has an unfavourable rating (Table 1.3) by the use of resource potential, income management and environmental friendliness in resource extraction.

According to the results of the Index, Ukraine received low results, which are possible to improve due to the integrated approach of the government, local governments, mining companies and local communities (Pimonenko, 2014). The implementation of the relevant principle should include the following components (Pimonenko, 2019; Ngene, 2016):

- realization of value, which reflects the management of such aspects as the granting of rights to subsoil development, exploration and production, environmental protection, taxation, the activities of state enterprises;

- income management, which characterizes the formation of the national budget, the distribution of revenues from the use of resources at the regional level and the work of national welfare funds;

- creating favorable conditions: openness of information; political stability; fight against corruption; rule of law; efficiency of state policy; income distribution system, etc.

Table 1.3. Resource management index

	Country	Index
1	Norway	86
2	Canada	75
3	USA	74
4	India	70
5	Argentina	57
6	Kazakhstan	56
7	Ecuador	54
8	Tanzania	53
9	Oman	50
10	Ukraine	49

Source: compiled by the authors based on (Transparency, 2018)

The above data confirm the fact that there is an empirically proven correlation between the Natural Resources Management Index and the so-called Extractive Industries Transparency Initiative, which provides for transparency in the country's natural resources management and disclosure of public revenues from the extractive sector (Extractive, 2013). Thus, one can note that the more open a country is, the higher its indicator in the Natural Resources Management Index.

Effective functioning of the extractive industry is impossible without forming an effective mechanism of state regulation of the industry. Current developments (Kvasniy, 207; Pimonenko, 2018b) will not allow to define its main components and relevant regulatory tools clearly. Besides, it is important to implement market-oriented approaches and tools (competitions, auctions, e-trading, certification, audit, etc.) in the structure of the existing system.

The structural and functional model of the state regulation mechanism should include the following components: objects and subjects of management; management principles; management methods; management tools. The state regulation mechanism of the extractive complex of the national economy is a set of economic, organizational and legal (political) ways of stakeholders' (management entities) purposeful interaction to ensure the effective functioning of the industry.

We can note that the corresponding mechanism is formed by the principle of substantive homogeneity of management tools. It is possible to distinguish mechanisms on the principle of nature and content homogeneity in the presence of leading features. However, one should note that it is often difficult to identify so-called "pure" mechanisms that are only economic or only organizational. For example, product standardization can be considered as a mechanism for coordinating the activities of economic entities in the life cycle of products, i.e., as an organizational mechanism. The requirements of the standards are set using economically optimal solutions. Thus, standardization is also an economic mechanism (as a mechanism for reconciling economic interests). If standardization harmonizes national standards with the standards of other countries, then standardization acquires the features of a political mechanism (Makov, 2009). The state regulation subjects in the field of natural resources extraction are public authorities of different levels of the hierarchy, in particular:

1. Ministry of Ecology and Natural Resources of Ukraine;
2. State Service of Geology and Subsoil of Ukraine;
3. Ministry of Energy and Coal Industry of Ukraine;
4. State Ecological Inspectorate of Ukraine;
5. State Labor Service, other bodies of specialized post-resource and branch management.

The objects of public administration are companies and enterprises of the extractive industry. Thus, the structure of the state regulation mechanism of the extractive industry includes the following components.

1. Economic mechanism, the operation of which is ensured by the following instruments: stock auctions, financial transfers, contractual distribution of products, compulsory insurance, transparent pricing of oil, payment for subsoil use (rent), environmental taxes, purchase and sale of geological information, penalties, green shares, preferential lending for environmental modernization projects (Chygryn, 2018).

2. Organizational component: implementation of the sustainable development strategy for the oil industry, formation of the state cadastre of deposits and manifestations of minerals, certification of fields, creation of a national information online platform, formation of information maps of oil industry objects,

keeping profiles of oil producers, reporting system modernization of the oil industry.

3. Institutional support. The corresponding component provides for differentiation for two levels of government: national and sectoral. At the national level, it is necessary to ensure political freedom and democracy; reduce the level of corruption in the country; rule of law; deoffshorization and de-shadowing of the national economy; transparency and efficiency of political institutions; quality of state regulation. At the sectoral level, there should be a legally established procedure for independent examination of projects and assessment of oil reserves, a transparent system of producers' licensing, a comprehensive mechanism for assessing the impact of the production complex on the environment, the formation of a transparent system of quotas and permits for oil production, programs for ecological modernization of the extractive industry (Pimonenko, 2018c). One should note that the best way to improve the state policy in the extraction industry is to implement comprehensive changes to eliminate administrative and information barriers to the development of the industry and optimize the tax burden.

We emphasize that regardless of the method of obtaining a special permit, the system for state regulation of extraction should provide:

- integrated approach and minimize subsoil user's costs for relationship with local governments, including on land use issues;

- stabilization provisions in agreements with producers, which protect against unforeseen legal and financial risks.

- clarity of the grounds and conditions of inspections, suspension / revocation of special permits, application of different sanctions.

Acceleration of production growth and investment in the industry may be due to improved legislation to ensure that investors do not increase the tax burden while setting a reduced rental rate for production growth compared to the previous period. The producers will also be motivated through the fixed rate of rent, the payment of which becomes mandatory after the end of the period required for the preparatory work for industrial production. If the planned indices are not achieved or if there is no production, the rent size should be defined at the level of planned volumes of oil production.

For subsoil users who have not reached the targets or have not started production, it is reasonable to provide a gradual increase in the rent rate from obtaining a special permit every 2-3 years. In this case, an alternative to rent may be a tax on reserves for the relevant areas of the subsoil. In this case, miners who do not have the opportunity to use the subsoil but have received a special permit will be incentivized to apply to Gosgeonadra for its cancellation. Other subsoil users will have an incentive to intensify production to increase the production profitability (Figure 1.6).

State regulation of the extraction complex is a component of the state regulation system of the national economy. With this in mind, it uses appropriate traditional methods.

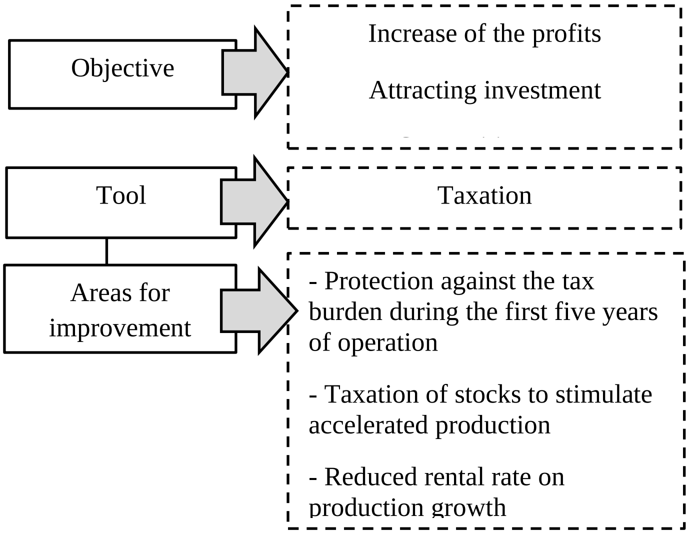

Figure 1.6. Conceptual changes in the taxation of resource extraction

Source: compiled by the authors

Thus, the main methods include normative and legal, organizational, administrative, economic and socio-psychological methods (Chou, 2018). By using appropriate methods, the state can use numerous tools to influence the oil industry. Organizational and legal methods of regulating oil production are represented by laws that are aimed at long-term legal regulation of the industry; resolutions, decrees, orders, programs, and strategies that perform the functions of strategic management, medium- and short-term regulation.

2. FORMATION OF ECOLOGICALLY ORIENTED COMPETITIVE ADVANTAGES OF ENERGY ENTERPRISES

2.1 Green competitiveness of energy sector enterprises: a retrospective analysis of the concept

Current development trends are characterized by the tendency of many countries to promote environmentally friendly development strategies that will ensure sustainable development goals, solve global environmental issues, the formation of green competitiveness of regions and the business sector as a whole. At the same time, a significant number of countries that favor green functioning strategies, trying to solve global and regional environmental problems, achieve considerable success. For example, the United States has put forward a Green New Deal and passed a Climate and Energy Security Act to improve national environmental competitiveness by investing in clean energy (A Green, 2019). The Chinese government has advocated for innovation in hopes of reducing greenhouse gas emissions to improve the country's environmental competitiveness through a low-carbon model (Cheng, 2019).

Focusing on green growth and ensuring the sustainable competitiveness of companies causes many problematic aspects, which include the following features:

- focus on the rational use, protection and reproduction of natural resource potential;

- ensuring the recycling of resources and production waste;

- ensuring targeted green investment at different levels of the economy (for the national economy, for the regions, for individual companies and business structures);

- the need to use different sources of funding for environmentally oriented activities of energy companies, the possibility of combining them in time and space, ensuring the implementation of various objects differentiated to investment;

- the need to consider the properties of natural ecosystems (assimilation potential), which may lose their original properties and corresponding value under the influence of anthropogenic impact of the energy sector;

- the differentiation in the forms of investment for energy enterprises of state, interstate, private, mixed forms of economic activity organization;

- consideration of the specific natural properties regarding self-regulation and restoration of ecosystems with their individual components.

One should note that along with economic and technological development, countries' implementation of the goals and objectives of the sustainable development concept, the presence and scale of anthropogenic pressure on the environment in the global context become more widespread, which determine the countries’ development strategy (Chigrin, 2015).

Thus, it is essential to study the theoretical and methodological principles of the green competitiveness of energy sector enterprises to improve the categorical apparatus further and form a system of its organizational and economic principles provision.

Analysis of scientific publications on green competitiveness concluded that in the long run, environmental competitiveness would be a powerful driver for countries, regions, and energy companies to ensure efficient economic activity, international cooperation, solve resource and environmental problems, sustainable development and promotion of alternative energy.

One should note that the scientific works of J. Schumpeter observed the development of the prerequisites for green competitiveness. He put forward the idea of "creative destruction", where new businesses and new ideas displace the old (Porter, 1991).

According to the classic traditional competitiveness theory of M. Porter, green competitiveness is characterized by the ability to provide competitive advantages in the market in terms of the ecological economy, environmental protection, sustainable development.

Porter's green competitiveness concept is based on three basic components:

- economic targets;

- resource and environmental benefits;

- social development.

Thus, from the economic component view, green competitiveness is defined as large-scale economic competitiveness, which provides high performance of companies. At the same time, resource and environmental benefits will ensure the environment quality, rational use of resources with a high level of environmental management, and the formation of social sustainability with environmental competitiveness should be understood as efficiency, equality, justice and continuous innovation.

Researchers at the International Institute for Governance Development (Lausanne, Italy) believe that the main determinant of green competitiveness is productivity, which defines regional competitiveness as the ability of a country, region or company to create and maintain a quality environment, sustainable development and welfare (Leonidou, 2017).

Scholars also consider green competitiveness in the context of the functioning of urban areas and the sustainable development of modern cities. They note that environmental competitiveness is determined primarily by significant environmental pressures and large-scale regional environmental problems. Thus, an ecologically oriented competitive environment, in this case, should have the ability to support life in the field of regional development and active coordination of environmental quality.

Chinese scientists H. Cheng et al. (Cheng, 2018) believe that environmental competitiveness is characterized by the ability to make efficient use of available natural resources, active environmental protection and is a determining factor in increasing regional environmental competitive advantage

The Organization for Economic Co-operation and Development (OECD) (Dechezleprêtre, 2018) identifies regional aspects of sustainable development as a key player in assessing green competitiveness and, above all, sets resource efficiency. Besides, according to OECD experts, asymmetric environmental policies cause changes in companies' production costs and cause various negative reactions from firms. Companies can respond to pricing, production, or investment decisions, particularly in the fight against environmental pollution. Relevant changes can affect the results in various economic, technological, international and ecological aspects, i.e., there will be third-order effects (Table 2.1).

Table 2.1. Effects of competitiveness depending on the rigidity of environmental regulation

First order effects	**Second order effects**	**Third order effects**			
Price effects: changes in the structure and volume of direct and indirect costs	Production effects of the company: - change in output; - price change; - investment in production; - investments in environmental protection	Technological effects: - product innovation; - process innovations; - resource-saving technologies; - factor productivity	Economic effects: - profitability; - employment; - growth of market share	International effects: - growth of trade flows; - investment climate; - foreign direct investment	Environmental: - reduction of pollution; - preservation of the environment

Source: based on (Dechezleprêtre, 2018).

The World Economic Forum (Schwab, 2017) in 2016 defines green competitiveness as a set of social institutions, relevant policies and other elements that will enable the country to maintain high productivity and ensure sustainable social and environmental development for a long time.

Researchers W. Charles and L. Zegarra (Charles, 2014) also study sustainable competitiveness in terms of regional development, which, in turn, is characterized by regional competitive advantages, ensuring high living standards and building social infrastructure.

Scientist R. Gouvea et al. (Gouvea, 2013) emphasize that the source of sustainable competitive advantage is innovation, determining the competitive advantage in resource use, economic and social development.

Generalization and systematization of scientific achievements on the green competitiveness in terms of national and regional development are presented in Table 2.2.

In addition, many foreign scholars (Chen, 2019) consider green competitiveness from two main points of view:

- as a system concept, which should combine different hierarchical levels of management (national economy, regional development, business sector, companies);
- as a type of economic development that provides certain advantages to economic entities.

Chiang et al. (Chiang, 2011) believe that green competitiveness should cover several specific aspects of the economy functioning based on sustainable development. These are the following processes: purchase of raw materials to produce products and services, production of goods and services, consumption and use, waste management.

Researchers Bowen and Funkhauser (Fankhauser, 2013) emphasize only some of the competitive advantages of environmentally friendly management, and relevant publications consider green competitiveness as a concept that makes goods and services more attractive than other competitors.

Table 2.2. Approaches to determining green competitiveness: national and regional level

Author	Key landmark	Determinants	Definition
M. Porter	Identification of structural components	Economic, resource, environmental, social	Ability to provide competitive advantages in the market in terms of the ecological economy, the organization of environmental protection, the sustainable development promotion.
International Institute for Management Development (Italy)	Productivity of economic activity	Additional value, welfare of the population	The country's, region's or company's ability to create and maintain a quality environment through the constant production of value by business, the production of values to ensure sustainable development and improve the welfare of the population
R. Hu	Functioning of urban areas	Quality of the environment	Ability to support vital activities in the regional development and active coordination of environmental quality

Table 2.2. Continued

Author	Key landmark	Determinants	Definition
H. Cheng	Regional developme nt	Environmental protection, rational use of resources	Ability to effectively use available natural resources, ensure environmental protection in order to increase regional environmental competitive advantages
Organization for Economic Cooperation and Developmen t (OECD)	Sustai-nable develop-ment of regions	Resource efficiency	Ensuring regional aspects of sustainable development and resource efficiency
World Economic Forum	Productivi-ty and sustainabi-lity of economic develop-ment	Social and political institutions	A set of social institutions, policies and other elements that will enable the country to maintain high productivity for a long time and ensure the sustainability of social and environmental development
W. Charles, L. Zegara	Quality of life of the population	Social infrastructure	Guaranteeing regional development, regional competitive advantages, high living standards and building social infrastructure
R. Gouvea	Economic and social develop-ment	Innovations	Ensuring sustainable competitive advantage through innovation that will determine competitive advantage in resource use, economic and social development

Source: compiled by the authors.

Recently, scientific publications on the regional green competitiveness have become relevant, according to which it is possible to ensure sustainable competitiveness at the regional level under the following basic conditions:

- efficient use of natural resources;

- ensuring high quality of the natural environment;

- use of technologies and approaches to energy saving in all spheres of life of the regions.

It is necessary to note that the regions or individual territories that demonstrate high environmental competitiveness should develop on the sustainable development principles, covering economic and social development.

According to the authors (Sprengel, 2011; Stuart, 2003), an essential component of green competitiveness is focusing on people, i.e., the dominance of the social factor of development. The main determinant of regional development here is the improvement of people's health and living conditions. At the same time, regional green competitiveness is a development in terms of environmental protection, with changes in approaches to the use of natural resources through innovation. The authors emphasize that regions must ensure the introduction of resource-saving and environmentally friendly technologies, innovative products, and services compared to other competitors to achieve sustainable economic and social development, as well as healthy living (Tceplit, 2014).

A significant number of authors have devoted their scientific publications to studying the main components of enterprises' green competitiveness.

A group of scientists (Mena, 2019; Us, 2021) notes that systems and approaches to environmental protection should become an integral part of the company's overall strategy, which in the future will ensure the formation of green competitiveness.

Using the principles of environmental economics in modeling the business sector development, scientists (Stern, 2010; Sustainable, 2008) emphasize that companies can increase sustainable competitiveness in environmental constraints through innovation, scaling and improvement of appropriate environmentally friendly functional mechanisms.

S. Fankauscher et al. (Fankhauser, 2013) analyzed the manufacturing sectors in eight countries and identified the factors of their success to determine the basic components of green competitiveness:

- the speed with which the relevant sectors move to green products and services;
- the ability to develop new markets and hold on to them;
- a favorable starting point.

When using economic-mathematical modeling, namely the structural equation model, to evaluate the survey results, scientists (Aboelmaged, 2018) found that it is necessary to encourage companies to implement green supply chains, finance environmental activities, green innovation. It will improve the environment and economic indicators and strengthen green competitive advantages in the world economy. Systematization of scientific achievements on the green competitiveness of enterprises is presented in the Table 2.3.

Table 2.3. Approaches to determining green competitiveness: entrepreneurial level

Author	**Definition**
S. Hart, (1997)	Ability to use systems and approaches to environmental protection as an integral part of the company's overall strategy
B. Shireman, K. Tachi, (2002)	Ability to use innovations, environmentally oriented functional mechanisms to ensure sustainable performance of enterprises
T. Chiu, (2011)	The ability of enterprises to implement green supply chains, green innovations, to finance environmental activities to ensure benefits in the world economy.
S. Fankauscher, (2013)	Green competitive advantages of the enterprise, which are determined by the speed of transition to the production of green products and services, the ability to develop new markets and keep them.

Source: compiled by the author.

The study of key scientific developments on the topic of green competitiveness allowed us to draw the following conclusions:

1. "Green competitiveness" is quite new for the domestic scientific space.

2. The international experience of scientific research in the relevant field includes the scientific achievements of foreign authors since the late 1990s.

3. The vast majority of research focuses on categories of the macroeconomic level, i.e., green competitiveness is considered more in terms of the functioning of the national economy and regional development.

4. The key categories considered in conjunction with the theme of green competitiveness are the concepts of sustainable development, "green" growth, "green" innovation, "green" economy etc.

5. From the individual enterprise's point of view, the definition of green competitiveness is fragmentary; the authors do not systematically and comprehensively identify all its main components and determinants.

Thus, in the conditions of changing a social paradigm towards the sustainable development, it is relevant to construct the theoretical and methodological basis to maintenance green competitiveness of the enterprises from energy sector.

2.2 Determinants for the formation of a competitive environment of energy companies

The analysis of scientific research on the topic of green competitiveness allowed us to determine the main determinants of its development for enterprises in the energy sector:

1. Production and technological potential of energy companies. hus, the effectiveness of positioning energy companies in the market largely depends on their production and technological capabilities, the use of modern environmentally neutral technologies, recycling and energy-saving, energy

infrastructure. One should note that the high environmentally-oriented intellectual potential of companies will provide the benefits of energy companies in the development, creation and marketing of appropriate technologies and approaches.

2. Market determinants that characterize the main competitors. If the company demonstrates a high level of innovation, uses modern methods of management and market positioning, it will be easier to position its services.

3. Market determinants that characterize consumers. The speed and volume for promoting ecological goods on the market will be determined by the environmental culture and consumers' consciousness. In addition, the demand for innovation will easily support new technological solutions, which will lead to saving of scale and learning effect.

4. The structure of economic entities and their participation in communications along the value chain. Thus, powerful economic entities can form and develop new (foreign) markets, to manage the future promotion of the product. At the same time, close interaction in the value chain between suppliers, users, research institutions, as well as integration into international value chains, are important factors in strengthening the green competitiveness of energy companies.

5. Management and marketing of environmental innovations. When promoting eco-innovation in new markets, demand for them will largely depend on the content of ecological policy of energy sector enterprises. At the same time, the relevant regulations should be open to various technical solutions and should consider international quality standards.

The company's green competitiveness largely depends on the key determinants, which are proposed to be classified according to the following criteria

1. Belonging to the environment. We distinguish internal and external determinants by this criterion.

The internal determinants of green competitiveness include:

- organizational and legal form of ownership of the energy sector;

- enterprise management and management system (environmental management);

- production and technological potential of energy companies;

- introduction of ecological innovations;

- resource, energy and material consumption of production;

- the anthropogenic impact of the energy company on the environment;

- intellectual potential, determining the staff of the enterprise, the level of its professionalism and environmental awareness.

External factors of green competitiveness include:

- competitive environment of the company;

- state support system of ecological innovations and resource saving;

- the diffusion level of innovations and environmental innovations in society;

- level of financial infrastructure development;

- ecological culture of society and consumers;

- environmental pollution, availability (depletion) of natural resources.

2. In terms of temporal measurement:

- strategic, which will determine the company's long-term environmental policy, aimed at ensuring climate-neutral growth;

- tactical, within which a system of economic, organizational and motivational tools to form or increase green competitiveness of energy companies is formed;

- operational, which reflect a clear phased implementation of planned activities in the short term.

3. According to the object principle: technological, production, management, related to labor resources, organizational.

4. According to the impact mechanism:

- factors of direct action: consumers, suppliers, competitive environment, market infrastructure;

- factors of indirect action: socio-economic, political, ecological and cultural environment, international cooperation and interaction, integration into the international economic space.

5. According to the content, the following types of determinants of green competitiveness are distinguished:

- economic;

- social;

- technological;

- political;

- legal;

- ecological;

- ethnic and cultural.

6. According to the content of the impact:

- hard action factors, which include all the above factors, the effect of which on the provision and formation of green competitiveness is clear;

- soft action factors, which are not always perceptible and quantifiable, but essential and sometimes crucial in establishing environmentally neutral development of energy companies and forming the consumers' environmental awareness. These may include information about environmental goods and services, knowledge, skills and managerial talent of company management, motivation systems, the level of environmental culture of society.

Identifying the main determinants to form and increase the green competitiveness of energy sector enterprises is an important management task since it creates the key areas to implement appropriate economic or marketing policy.

Studies of theoretical and methodological principles of economic systems on sustainable development have shown that the functioning and development of green competitiveness of energy companies are often considered in terms of sustainable development, green economy, and green growth.

Therefore, it is important to define the essence and differentiate the relevant categories to specify their contents and key role in ensuring sustainable development of energy sector enterprises.

There is a traditional approach developed by the International Organization for Economic Cooperation and Development, which defines the green economy as a set of environmental goods and services, all activities that measure, prevent, limit, minimize or adjust the anthropogenic impact on the environment (OECD, 1998, 2009).

At the same time, today scientists estimate the scale of the green economy as ranging from several hundred billion to trillions of US dollars per year in the global dimension (BIS, 2011).

However, a significant number of scientists understand green growth as a relatively radical way of managing. They do not see green management as a tool that coexists with other traditional methods of regulation. They argue that the organizational, managerial and economic changes needed to tackle global issues, for example, climate change should not be marginal, as most traditional models suggest, but transformational, system-wide and integrated (Stern, 2011). Accordingly, the development of a green economy will affect all sectors, product cycles, and production processes of the national economy. Thus, green growth is interpreted as a transformation of the economy rather than expanding the environmental goods and services sector. It will be accompanied by structural changes in the economy (low-emission technologies, resource conservation, recycling) and the expansion of certain sectors (e.g., alternative energy, solar panel production, smart grids) through others (e.g., mining).

As for green business, it is traditionally defined as business practices that are assessed as environmentally friendly.

The activities may include:

- use of organic, natural materials and products in economic activities;

- use of technologies and practices that reduce the anthropogenic pressure on the environment;

- introduction of resource and energy saving technologies, alternative energy;

- environmentally responsible supply and design;

- introduction of environmental management and audit systems;

- green investing.

Today, the competitive businesses must make commitments to the state and society to improve their environmental performance. It is necessary to emphasize the relevant benefits of green business development for enterprises and for society as a whole (Figure 2.1).

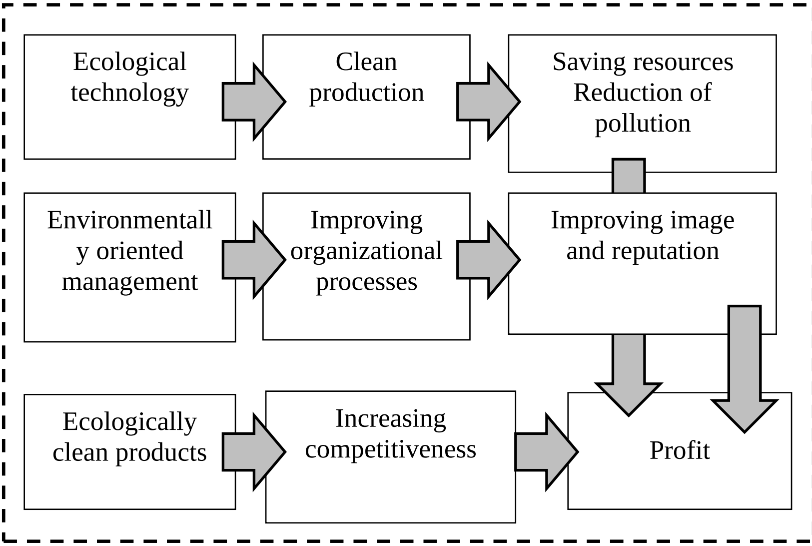

Figure 2.1. The benefits of green business development
Source: compiled by the authors based on (Chygryn, 2019)

The "green entrepreneurship" category is closely related to green business and corporate social responsibility. However, many scholars emphasize that green entrepreneurship is the driving force of green growth, the promotion of innovative green technologies, the formation and strengthening of green competitiveness of the national economy and enterprises.

Experts on economic cooperation and development (OECD, 2009) note that green entrepreneurs have a traditional business approach. However, ethical and environmental imperatives that are part of their business development models are the main drivers of green entrepreneurship. In addition, their business activities generally have a positive impact on the environment; it is a modern form of business activity. Thus, green growth, green economy, green business, environmental entrepreneurship are certainly related. Relevant processes in the business sector and at the national economy level are interconnected.

Thus, green competitiveness of energy companies is the ability to form and effectively use green competitive advantages (greening of business processes, green marketing, and management tools, a regulatory framework that regulates environmental activities, the inclusion of stakeholders, green energy infrastructure) and their convergence effects that ensure sustainable development of enterprises, expanding the competitive position of the enterprise in the market, increasing investment attractiveness and capitalization, the formation of an environmental brand.

2.3. Principles of ensuring innovative development of energy enterprises

While studying the theoretical and methodological principles of formation and increase of innovative competitive development of energy enterprises and competitive strategies in their development, focused on the implementation of sustainable development principles, allowed to conclude that their formation and growth is possible in the presence of the proper determinants.

Sustainable development of the business sector and individual companies can be achieved when companies meet the consumers' needs and desires without endangering the environment. Companies based on environmentally oriented management implement environmental management systems and environmental management models, choosing strategies to ensure green competitive advantages (Ponomarenko et al., 2018).

The key strategies for ensuring green competitiveness and providing green competitive advantages in a market environment are green marketing strategies (Figure 2.2).

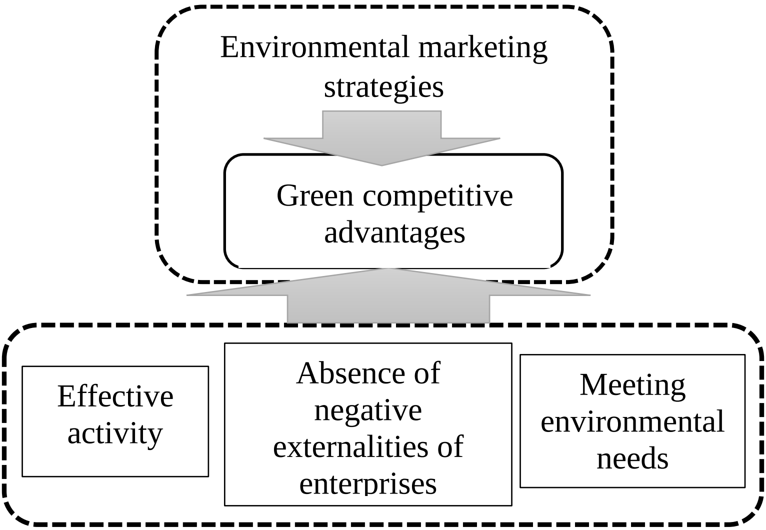

Figure 2.2. Ensuring green competitive advantages of the enterprise

Source: compiled by the authors.

However, scientists (Lisowski et al., 2020) emphasize that the overall level of green competitiveness can be achieved by ensuring the efficient work of enterprises, meeting the consumers' needs and desires and the absence of negative externalities (economic damage from pollution and depletion of natural resources). With this in mind, it is necessary to study the key targets (target groups) and determinants that will find the substantive basis of appropriate marketing strategies to ensure the green competitiveness of enterprises.

Representatives of green business traditionally choose environmentally oriented business strategies, implemented, for example, via environmental management and audit. At the same time, compliance with environmental laws and regulations is ensured. It is strategically planned to achieve sustainable competitive advantages. Focusing on sustainable green competitive advantages, modern enterprises use the so-called "double-bottom line" or "triple-bottom-line models" (Fankhauser et al., 2013). The first group of business behavior models characterizes the socially responsible behavior of economic entities, considering social, economic and environmental factors, which will provide appropriate advantages of enterprises in the competitive environment and contribute to green competitive advantages. The second group of models ("triple-bottom-line models") considers environmental and social performance indicators.

These types of models emphasize and determine the importance of sustainability in gaining competitive advantage or so-called green positions on the market.

A group of scientists (Firoiu et al., 2019) argues that while building green market positions or environmental competitive advantages, companies, in particular, should focus and build on the interaction between emotional preferences of consumers and their specific features focused on environmental factors. In this case, for example, the formation of a green image and brand is possible through the use of appropriate green marketing strategies.

Scientific approaches (Eisenmenger et al., 2020), which consider consumer motivation, as a key determinant of green competitiveness, identify a number of criteria that are dominant in consumer decision-making on purchases:

- possibility of recycling;
- availability of environmentally friendly packaging;
- efficiency in production;
- environmental friendliness of production and consumption of products or services;
- safety of consumption;
- ease of use and disposal;
- ecological image of the company.

Relevant consumer demands include clear criteria for companies to form an appropriate system of green marketing strategies, such as green branding, the formation of green alliances, greening of innovation and overall business. Some scholars, for example, study the differentiation in the levels of green focus of enterprises, i.e., how comprehensive the company provides greening of all economic processes (Dechezleprêtre et al., 2018; Chygryn et al., 2020).

Clearly focused green marketing strategies and appropriate tactical marketing tools will provide green competitive advantages generated by consumers' perception of a better offer.

The purpose of green marketing in terms of providing competitive environmental advantages is to determine the added value of goods and services for consumers due to the relevant ecological features of the economic activity of enterprises.

Moreover, each company will gain green competitive advantages by forming unique ideas and associations of potential consumers and customers.

Current trends in the competitive environment are characterized by fierce competition in different markets. The use of marketing strategies by companies trying to be competitive goes far beyond traditional 4P (product, price, promotion and placement). Today there are mixed marketing theories suggesting to use 8P, 12P systems. At the same time, new modified marketing strategies are being used - 4C, 4A, 4E, SIVA and 2P + 2C + 3S.

Effective green marketing strategies will allow businesses to become better or unique in different markets and their segments. Appropriate preferences can be achieved by consumers receiving sustainable benefits through differentiation or low cost of goods and services (Chygryn, 2016), in the form of customer satisfaction and loyalty.

A separate component of competitiveness is the optimization or improvement of financial performance, the enterprise's competitive advantage. Although current trends are characterized by a growing number of prospects in each industry and increasing interest from both businesses and consumers in environmental decision-making, not all companies that try to position themselves as green, gain green competitive advantages.

The performed analysis allowed to systematize the relevant research and assess the nature and content of the relationship of marketing components of the enterprise's green competitive advantages (Table 2.4).

Thus, the systematization of scientific directions in the research of green marketing effect on formation of the enterprises' competitive advantages, will allow to form conceptual bases of green marketing strategies to form and increase green competitiveness of the enterprises.

The processes of providing environmentally oriented competitive advantages are determined, to a large extent, by a set of appropriate determinants. We propose to combine the relevant determinants into two groups, which will be determined by objective (external) and subjective (internal) components.

Table 2.4. Systematization of research on the green competitiveness determinants

Approach	**Essence**
1. Marketing	Consideration of the enterprise's competitive orientation and its competitive advantages in green marketing strategies
2. Technological	A direct correlation between the production of environmental goods, technological processes and competitive advantages of enterprises is revealed
3. Innovative	The effect of green innovations on the creation of additional value of goods is studied

Table 2.4. Continued

Approach	Essence
4. Communicative	The effect of green marketing strategies on competitive advantages is proved
5. Stakeholder	Consideration of the stakeholder behavior impact on the companies' competitiveness
6. Quality and content	The impact made by the qualitative and meaningful features of goods on strengthening of green competitive advantages is investigated
7. Level	Study of differences in the activities of macro-, micro- and medium-sized enterprises in terms of competitive advantage
8. Financial	The optimization of financial indicators with competitive advantages is proved
9. Ethical	The formation of corporate environmental ethics is a prerequisite for ensuring competitive advantage

Source: Chygryn et al. (2020).

We propose to classify this system according to the following criteria, which will be the same for the two groups of determinants, but the content for each subgroup will be determined separately.

Thus, the criteria for classifying the green competitiveness determinants include the following.

1. Management determinants. From the point of view of internal construction, they include the system of environmental management and audit, existing strategies and relevant tactics of environmental policy, environmental control and monitoring, environmentally oriented business planning.

External management factors include the existing system for state regulation of environmental protection and resource conservation, the system of environmental standardization and certification of products and activities of enterprises, state environmental control.

2. Financial determinants. The internal environment of the enterprise is characterized by the financial stability, the scale of financing of green production and environmentally oriented activities, the market value of the enterprise, the structure and value of securities of the enterprise. The external component is determined by the general financial and economic situation in the country, the level of public funding for environmental costs, the essence and scope of support for green business.

3. Infrastructure determinants. From the point of view of the enterprise, these determinants are characterized by the availability and development of the enterprise's environmental infrastructure, which is responsible for energy and resource efficiency, periodic and one-time procedures of internal environmental auditing, departments, responsible for green marketing and logistics.

4. Stakeholder determinants. Internal factors are characterized by the owners (shareholders) of companies, enterprise management, heads of departments, staff

In the scientific literature, there is a separate concept of "nanoeconomy", related to the activities of company managers, whose decisions can dramatically change the enterprise behavior strategy in a market environment. The key changes that can ensure the functioning of the nanoeconomy of companies can be systematized as follows:

- increasing the environmental responsibility of companies, encouraging environmentally oriented business initiative;

- transition of enterprises from a passive position in solving environmental problems, determined only by the environmental legislation requirements, to a proactive position, largely defined by conscious environmentally oriented own goals and objectives;

- expanding the boundaries of initiative environmental activities of companies, shifting priorities to the causes and sources of negative impact on the environment;

- understanding and implementation of existing relationships between the results of environmental activities with opportunities to attract investment, development of production, saving resources, reducing production costs, improving the environmental friendliness of products and their competitiveness;

- activation of internal unused economic reserves and opportunities to ensure green competitiveness;

- open declaration and proclamation by companies of ecological goals, programs and achieved ecological and economic results, including negative consequences of activity;

- active cooperation with all stakeholders, including investors, shareholders, business partners, consumers, the public and competitors.

The external component is formed by stakeholders in the person of the state, shareholders of enterprises, affiliates, consumers of green goods and services, contractors and competitors of the enterprise

5. Behavioral determinants. At the enterprise level, they are determined by the green image of the company, the analysis of the role of behavioral factors and cognitive processes in decision-making by consumers of green products, motivation of environmental activities and resource conservation and green competitive advantage in the market. The external side of the impact made by the behavioral determinants of green competitiveness is represented by the social perception of environmental innovations and green goods by consumers, features of consumer behavior psychology, motivation of green consumption, framing processes and anomalies of consumer behavior.

6. Technological determinants. The internal component of the enterprise will be determined by the available production potential of the enterprise, the possibility of implementing green innovations, resource intensity of production, the anthropogenic pressure on the environment, staff qualifications. The external environment for these determinants is characterized by the level of STP development and its perception in society, the development and availability of green technologies.

7. Innovative determinants. It is essential to define the relevant determinant since all environmentally friendly products are innovative in content and technology used in their production. Some factors determine opportunities for developing and producing innovations at the enterprise. Thus, the basic ones include the size of the enterprise (small, medium, large). In terms of flexibility of response and speed of green innovation implementation, small and medium enterprises have

significant advantages, both in terms of organizational and managerial processes, as well as technical and financial capabilities.

8. Cultural and ethical determinants. The success of the green competitiveness will be determined by environmentally oriented management, corporate environmental ethics and culture. The company's integrity level in the market the compliance of the declared environmental benefits of green goods to the actual quality of goods are also significant. The external component will describe the environmental norms in society, voluntary and mandatory green regulations, the level of greenwashing of competing companies. The general level of ecological culture and moral and psychological climate in society are important.

It is important to identify the main barriers that hinder innovative competitive development (Figure 2.3).

1. Lack and incomplete information. Lack of clear awareness and understanding of producers and consumers of environmental goods and services, their benefits and environmental features, information about existing differences.

2. Shadow destructive impact of consumers on producers. For example, a company may face a problem: companies are often under pressure. They may be on the side of consumers and public organizations to optimize their activities or improve the performance of goods (services) to environmentally improve their products. A striking example is the replacement of a paper bag and a jute bag with a synthetic bag to save trees resulted in a much more significant destructive impact on the environment.

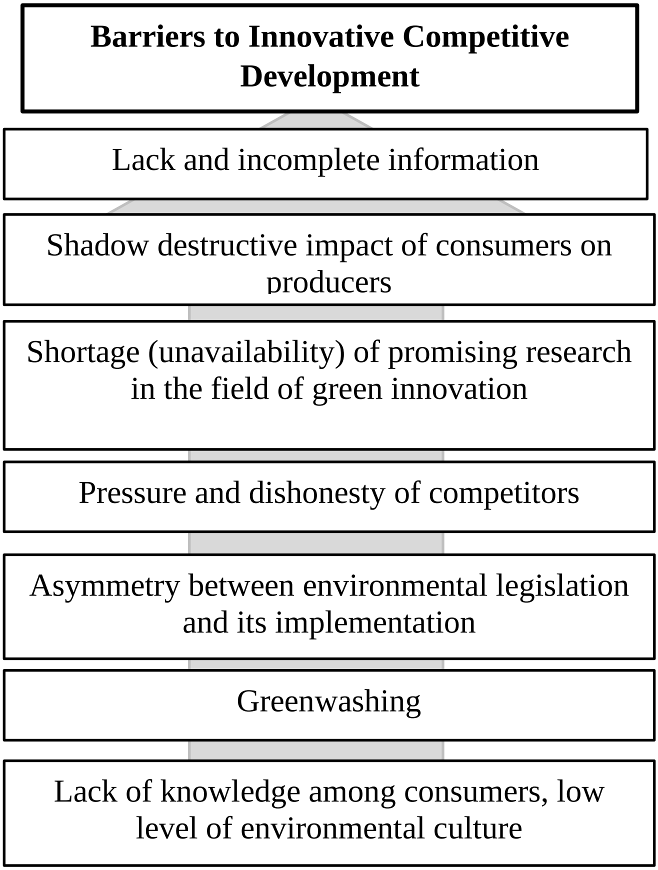

Figure 2.3 Barriers to the promotion of innovative competitive development

Source: compiled by the authors.

3. Lack (inaccessibility) of promising research on green innovations. Thus, when companies try to become socially responsible, they may face the risk that environmentally responsible actions today will be recognized as harmful and

environmentally hazardous soon. For example, modern producers of refrigerators and air conditioners have replaced environmentally harmful chlorofluorocarbon (CFC) compounds with hydrofluorocarbon (HFC), which has also been a greenhouse gas over time. Thus, limited scientific knowledge and the results of the latest research at any time will guarantee the company no confidence that the implemented green innovations or improved products will not harm the environment.

4. Pressure and dishonesty of competitors. Reacting to competitive pressure can force all followers to make the same mistake as a leader. An example is Mobile Oil (USA), a world-famous producer of motor oils, which has begun to claim that plastic garbage bags are biodegradable. However, the time it takes, is incompatible with the time lags that characterize environmental recovery. So, the company has been sued by several US states for using dishonest deceptive advertising claims. Thus, unjustified pursuit of competitors can have costly consequences for businesses (Bannon, 2003).

5. Asymmetry between environmental legislation and its implementation. Developed countries show that there is a significant amount of legislation governing environmental issues. Governments in many countries try to protect green consumers and enable consumers to make better decisions and motivate them to be more responsible for the environment. However, there are always difficulties at different levels of government in establishing policies that cover all environmental issues.

6. Greenwashing. The enterprises-producers of "green products" use distorted false data about the quality and

environmental benefits of goods to form an environmentally conscious image (Pimonenko et al., 2019).

7. Deficit of consumers' knowledge of environmental problems, the real level of anthropogenic pressure on the environment, the degradation of natural resources. Despite the fact that environmental issues are often present in the media, consumers still have superficial information about the scale of destructive impact and the level of environmental and economic damage. At the same time, despite consumers' awareness of environmental issues, they are not willing to pay a higher price for green goods and services.

Consumers believe that they are not obliged to improve the environment and seek to place such responsibility on individual industries and the state. Thus, according to an American survey, it was found that more than 50% of American adults say they would do more for the environment if they only learned how? In this perspective, education is crucial for companies seeking to provide a green competitive advantage in the market.

The formation of green competitive advantages in a market environment requires companies to identify key targets and benchmarks that must be provided to achieve the relevant goals.

From a broad point of view, green competitiveness will be ensured by the production of green goods and services and in general environmentally oriented activities of companies.

Accordingly, strategies for building and promoting green competitiveness should be based on the following approaches (Figure 2.4):

- product (commodity), when the production of innovative green goods, which by their features do not harm the environment, and in the consumption, do not increase the anthropogenic impact on the environment, minimize consumption waste;

- process (technological), which ensures the ecological purity of production processes: minimization of environmental pollution, reducing the resource intensity of production, the possibility of industrial waste reuse.

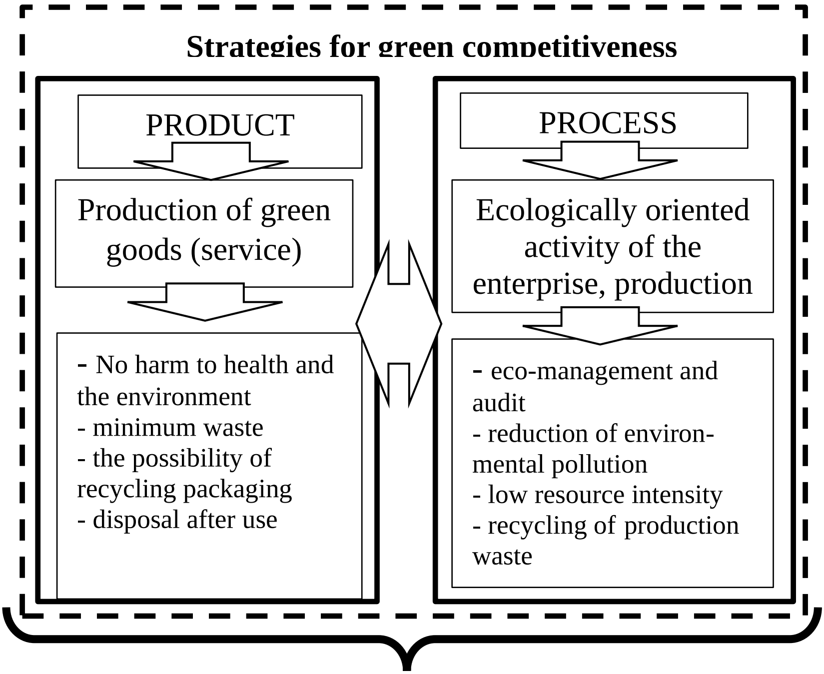

Figure 2.4 - Approaches to the formation of green competitiveness

Source: compiled by the authors.

The results of domestic and foreign scientists' research systematization revealed the lack of systematic, multi-vector and diversified approaches to understanding the essence of green competitiveness of enterprises, its main determinants, and the principles of its typology.

The formation of green competitive advantages should be based on appropriate principles that will ensure its maximum implementation and promotion. These principles include:

– dissemination (informing about the importance and value of green consumption, the formation of environmental awareness and green consciousness of consumers,

– promotion of the green image of the enterprise, popularization of green economic activity);

– transparency (declaration of reliable and transparent information on the results of environmentally oriented activities, availability of environmental reporting, ensuring the inclusion of stakeholders in the green competitiveness of enterprises and transparent communication with them, avoiding greenwashing);

– convergence (ensuring synchronicity and mutual coordination of production and technological, socio-economic, marketing, information and management subsystems of the enterprise during the formation of green competitiveness of enterprises, integration of strategic and instrumental marketing support);

– adaptability (ability to respond quickly and flexibly to changes in endogenous / exogenous parameters of the competitive environment);

– preventiveness (ensuring the practice of preventing socio-environmental and economic conflicts during the formation of green competitiveness of enterprises);

– consistency (research and evaluation of green competitiveness of enterprises in the relationship and interdependence of its components).

Analysis of research on green competitiveness (Tceplit et al., 2014) has identified key strategies that can be used to build green competitive advantage. Moreover, the relevant strategies characterize enterprises in terms of completeness and systematic implementation of strategies to promote green competitiveness

1. Illusory green strategy. In this case, the company begins to implement environmentally friendly management, taking responsibility without advertising or promoting their green initiatives. It focuses on reducing costs and improving the efficiency of environmental activities and thus, it creates a competitive advantage in terms of costs. It organizes the work according to the regulations but does not provide profits related to the green segment of consumers. Such enterprises do not promote the development of green products since they consider it too complex and unpromising.

2. Conservative green strategy. Implementing appropriate strategies, companies occasionally use green strategies to prevent in times of crisis or protection from competition. Companies try to create a green image and know that green market segments are promising and profitable. Their environmentally oriented activities are fair and sustainable, but the formation and provision of green competitive advantages is sporadic and temporary since its intention is not to differentiate itself from the competition through environmental activities.

3. Shadow green strategy. Using such strategies, companies invest in systemic long-term green projects that require significant financial and other resources. At the same time, these green marketing strategies are seen as an opportunity to produce green innovative products and technologies to meet the consumers' needs and the formation and strengthening of

competitive advantages. The shadowy nature of this strategy is that the environmental benefits of the product are emphasized and encouraged secondarily.

4. Extremely green strategies. Relevant strategies are implemented by companies that integrate environmental issues into business processes and product life cycles. Such enterprises use special markets (market gaps) through specialized distribution channels.

The content and key features of the green competitiveness formation are determined by the level of their manifestation, which led to the separation of the following types:

- global (results are found at the level of national economies);

- sectoral (results are determined by the potential of the industry to implement environmentally-oriented development strategies);

- regional-territorial (results are determined by reserves and spatial capabilities of territories for formation and development);

- entrepreneurial (results are determined by providing green competitive advantages of a particular enterprise).

It is substantiated that the peculiarities of the impact made by the endogenous and exogenous parameters of the market environment and the heterogeneity of its development determine specific strategies for green competitiveness of enterprises (resource conservation, pollution prevention, convergence of operational and environmental values), which define the patterns of behavior of enterprises during their formation (one-dimensional, dual, triumvirate) (Chygryn et al., 2020).

3. SMART GRID: PAN-EUROPEAN NETWORK DEVELOPMENT

3.1 Issues of security and integration processes in the EU and in partner countries

Integration processes between the EU and partner countries have been long viewed through the prism of opportunities for economic and energy security, cooperation and economic growth. The level of stability in the EU's Eastern European partner countries has a direct impact on security in the EU, including by guaranteeing energy independence and harmonizing international mobility (General Secretariat of the Council, 2009; General Secretariat of the Council, 2010).

The development of cooperation programs focuses on environment, sustainable energy, society, employment, and other welfare values in the EU (European Commission, 2011). The updated security regulations already outline in more detail the objectives of economic cooperation between the EU and third countries. Improving access to third country markets and improving investment and trade opportunities for EU companies come to the fore (European Parliament, Council of the European Union, 2014; EEAS Press Team, 2016). The 2017 Joint Commission and External Action Service Communication rethinks economic security issues and outlines measures to achieve economic resilience (European Commission, European External Action Service, 2017a). In particular, the integration policy of the neighborhood draws attention to the need to protect critical infrastructure critical infrastructure (such infrastructure is associated primarily with security of gas and electricity security of the gas and electricity supply for Ukraine), cybersecurity and resilience to hybrid threats cyber-security and resilience against hybrid threats. The understanding of the role of EU external action in shaping economic sustainability has also changed. Unfortunately, the European Union is not isolated from the negative influences of its external partners and the strengthening of resilience in partner countries “can also contribute to strengthening resilience within the Union itself”. And as five of the six Eastern partner countries have suffered from conflict, the EU’s role in ensuring peace and stability in the region is growing (European Commission, European External Action Service, 2017b; EEAS Press Team, 2018).

In the scientific world, academic research focuses mainly on assessing the impact of certain components of economic security on the EU economy. Undoubtedly, an important and important aspect of European security is its energy component. There is considerable interest in institutional innovations caused by the creation of the European Union’s single energy market and changes in foreign energy policy (Prontera, 2018; Abrhám, Britchenko, Jankovic, & Garškaite-Milvydiene, 2018). Also, much of the research is devoted to the impact of immigration policy on security in Europe. Interestingly, research has not shown a link between immigration policy and macroeconomic indicators. However, researchers have determined that anti-immigration policy directly affects the state of national security and the level of terrorism in the country (Young, Loebach, & Korinek, 2018).

The scientific papers on European economic security express some pessimism about the possibility of ensuring economic security in the Union. Scholars are calling for greater economic and financial cohesion in the EU (Ene, 2018; Ignatov, 2018). Ignatov (2018) analyzed the issues of economic security and competitiveness in Europe and found a significant dispersion of dispersed European policies between the national interests of leading governments in the European Union. As a result, he concluded that he was unable to effectively address the current security challenges in its current institutional form within the European Union.

In Ukraine, the basic principles of state policy aimed at protecting economic security were laid down in the Law of Ukraine “On Fundamentals of National Security of Ukraine” (Verkhovna Rada of Ukraine, 2003) and the Decree of the President of Ukraine “On the National Security Strategy of Ukraine” (President of Ukraine, 2007). In 2015, an updated national security strategy was adopted (President of Ukraine, 2015). And in 2018 – a new law on national security (Verkhovna Rada of Ukraine, 2018), which defined the principles of planning and regulation in the field of national security and defense of Ukraine. The Ministry of Economic Development and Trade of Ukraine has developed methodological recommendations for the systematic assessment of the level of economic security of Ukraine (Ministry of Economic Development and Trade of Ukraine, 2013).

The solution of Ukrainian economic security issues has been widely reconsidered by Ukrainian scholars. Babets (2015) in his work determined that the indicator of foreign economic security of Ukraine for the period 2006-2014 has increased. She suggests that, among other things, for Ukraine these results were obtained due to the reduction of technological dependence and the growing share of exports of innovative products. Kubaienko (2018) sees in the cooperation between the European Union and Ukraine not only economic benefits, but also opportunities for conflict resolution and countering threats to international security. However, due to significant regional disparities in Ukraine, he notes the need to monitor integration processes in the regions using the European Integration Progress Index. According to the researcher, prompt response to the monitoring results will improve the integration processes in Ukraine.

However, integration into the European space also contains certain dangers for Ukraine. It is necessary for the country to comply with the requirements of international standards and agreements, while protecting national economic interests (Jankovska, Tylchyk, & Khomyshyn, 2018). There are also significant socio-demographic problems in Ukraine that negatively affect the state of Ukraine's economic security. In recent years, Ukraine's population has tended to decline, mainly due to increased migration flows of Ukrainians to more developed countries and rising death rates. Imperfect health care system and environmental problems in the middle of the country, significant risks in the energy sector, increase the level of environmental and social tensions and are threats to Ukraine's economic security (Satyr, 2016). Last but not the least, national economic security depends on the innovation component.

Significant assistance comes from the European institutions for Ukraine's integration into the European Union. However, investment is still being made in view of the need to address imbalances within the EU, one of which is excessive migration from 'States of Fragility'. To address the root causes of migration, the EU has proposed the implementation of the European External Investment Plan, which aims to create sources of financing for development of these countries. As foreign direct investment per capita is almost five times lower in vulnerable countries than in non-fragile countries, this situation, combined with significant security concerns, exacerbates poverty, leading to forced migration from fragile regions. (European Commission, Secretariat-General, 2016). All these signs and consequences are inherent in the Ukrainian economy. After the escalation of the military conflict in Ukraine, there was a significant outflow of foreign investment (Kolosok, Dementov, Korol, & Panchenko, 2018; Ponomarenko, Zinchenko, Khudoliei, Prokopenko, & Pawliszczy, 2018), falling living standards and increased migration from Ukraine. The level of investment and innovation security of Ukraine is declining every year and has already become dangerous for the country (Zakharkina, Myroshnychenko, Smolennikov, & Pokhylko, 2018). Babets (2015) believes that to ensure Ukraine's European integration, it is necessary to modernize Ukrainian production and introduce leading innovative technologies to promote Ukraine's innovation progress. Kubaienko (2018) expresses the same opinion in his work. However, in Ukraine insufficient attention is paid to the development of innovations (Sytnyk, 2017; Haber, Bukhtiarova, Chorna, Iastremska, & Bolgar, 2018).

Insufficient funding for innovation is also common in EU countries. According to researchers (Gretschmann & Schepers, 2016), over the past twenty years, EU countries have lost the innovation lead, and lag Japan and the United States in the level of technological development.

The joint communication of the Commission and the External Action Service in 2017 (European Commission, European External Action Service, 2017a) provided for the use of a common international knowledge base to share and implement results in international cooperation under Horizon 2020 and involve non-member countries. to the EU, in research related to sustainability and innovation (European Commission, Directorate-General for Regional and Urban Policy, 2017).

In addition, the European External Investment Plan envisages the development of energy and social infrastructure, the promotion of information and communication technologies, the implementation of sustainable development goals and investment in the environment, and others (COM/2016/0581, 2016).

The EU has invested heavily in strengthening and strengthening all six Eastern Partnership countries and building their infrastructure. The EU has funded projects to improve the situation in the field of common energy security in Europe, as well as in such areas as critical infrastructure, cybersecurity, strengthening the security and defense of the EU's eastern partners, the development of strategic communications between countries. In 2017, within the framework of the Eastern Partnership program, the program “20 results by 2020” was approved. This program aimed to solve key problems of countries in the field of economy, rule of law, development of critical infrastructure. Since then, trade with all Eastern Partnership countries has increased, CO2 emissions have been reduced through funding for EU initiatives in the field of local energy and measures to combat climate change (EEAS Strategic Communications Division, 2019).

3.2 Priority areas for the deployment of smart energy networks

The idea of creating a unified pan-European energy network has been around for a long time. In recent years, the EU has significantly stepped up its efforts to build new and deploy existing networks, increase their capacity, and reduce bottlenecks at the borders of EU member states. In the European Union, the norms and conditions of the internal market (both the gas market and the electricity market) are being harmonized, the requirements for the activities of market participants are being liberalized, and its competitiveness and flexibility are being increased. Measures for free trade in energy and energy resources are being implemented, security and consumer protection are being strengthened.

Building effective rules for the functioning of the energy market involves creating the necessary infrastructure and removing barriers and barriers to the free flow and trade of energy, harmonization of legislation and convergence of tax and tariff policies between countries. The European Union and its Member States have gradually transformed internal energy markets through the introduction of energy packages (Table 3.1).

The first energy package called for the creation of common rules for the internal market in electricity and gas.

The second energy package regulated the possibility for consumers to freely choose electricity and gas suppliers. This increased the level of competition in the EU internal market.

Table 3.1. Chronology of the adoption of energy packages (Package) in the EU

	First Energy Package	Second Energy Package	Third Energy Package	Fourth Energy Package	Fifth Energy Package
Directive	• 96/92/EC • 98/30/EC	• 2003/54/EC • 2003/55/EC	• 2009/72/EC • 2009/73/EC	• (EU) 2019/944	• ongoing
Regulation		• (EC) No 1228/2003	• (EC) No 713/2009 • (EC) No 714/2009 • (EC) No 715/2009	• (EU) 2019/941 • (EU) 2019/942 • (EU) 2019/943	• ongoing

Source: compiled by the authors based information European Parliament (2021)

The third energy package was aimed at strengthening cross-border cooperation, competition in the retail electricity and gas markets. *The fourth energy package* set standards for the consumption of renewable energy sources, the decarbonisation of the EU energy sector in accordance with the Paris Agreement and strengthened the oversight functions of ACER (The European Union Agency for the Cooperation of Energy Regulators) in cross-border regulatory cooperation. Comprehensive risk management measures have been introduced, subject to cross-border cooperation between EU member states; crisis management rules; methodology for monitoring and assessing security of energy supply. Finally, in 2021, the fifth energy package was unveiled, the norms of which are still being debated (European Parliament, 2021). The aim of the package was to reduce greenhouse gas emissions in Europe by 55% by 2050.

The ambitious path to the decarbonization of the economy determines the need to ensure the target conditions for the functioning of the market by building the appropriate infrastructure in compliance with safety procedures and the appropriate level of generating capacity. That is, capital investments are required for the radical transformation of energy infrastructure. In the EU, long-term investment planning in the development of electricity networks is carried out by ENTSO-E. Given changes in market conditions and needs, ENTSO-E develops long-term 10-year investment plans every two years, which are reviewed by ACER. Similar plans, but for the development of gas infrastructure, are implemented by ENTSOG.

Infrastructure development planning is carried out in the EU in accordance with the policy of TEN-E (the Trans-European Networks for Energy). At present, TEN-E priorities include three thematic areas:

- smart electricity grids deployment;
- cross-border carbon dioxide network;
- smart gas grids.

TEN-E has also identified three priority corridors, containing a total of 10 projects: priority maritime corridors for the EU, priority electrical corridors and corridors for hydrogen and electrolyzers (COM/2020/824, 2020).

In total, € 5.35 billion was allocated for the financing of projects of common interest (PCI) in 2014-2020 (European Parliament, 2021). The projects were funded under the Connecting Europe Facility (CEF-E). An overview of projects of common interest is presented in Fig. 3.1.

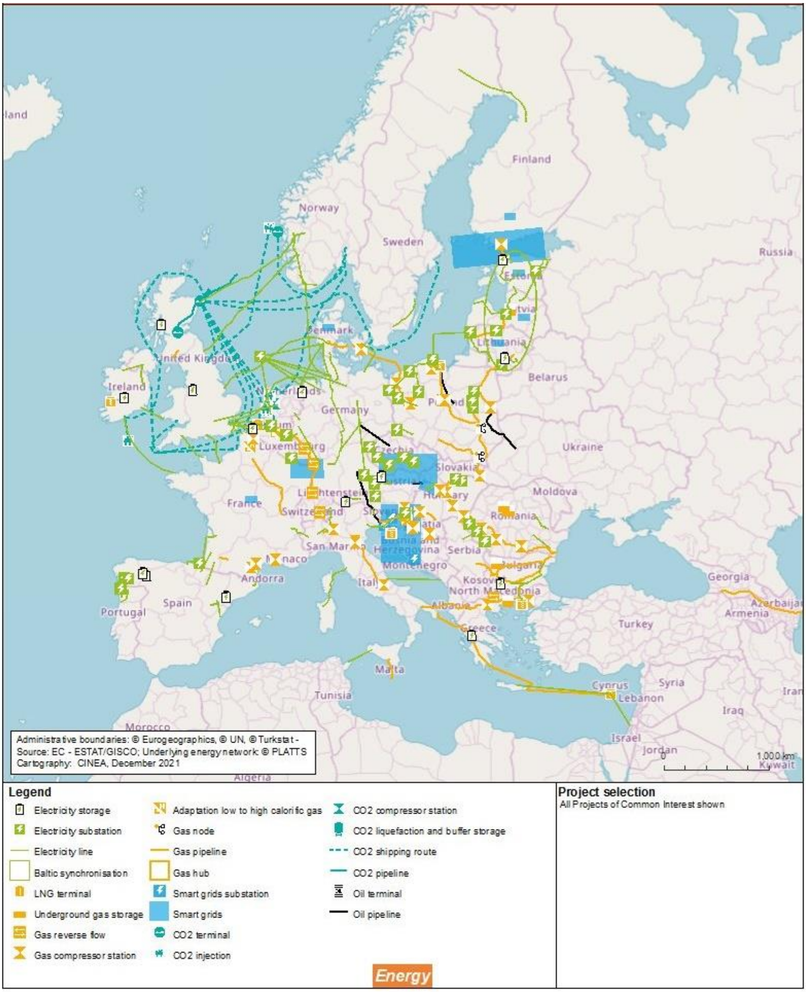

Figure 3.1. Projects of common interest

Source: PCI Transparency platform. © PLATTS for the underlying grids for electricity, gas and oil, 2016 © European Union, 2021

3.3 Overview of smart energy grid development projects

As a result of EU energy policy and relevant financial programs to support "green" initiatives, there is an increase in micro-installation connections to low-voltage networks. However, it cannot be said that existing networks can fully withstand such a load. There are several important reasons that complicate the work of networks. The scale of the pan-European energy system should consider the capacity not only within national economies, but also the capacity of cross-border interconnectors of EU member states, technical requirements for networks and features of their deployment, scenarios of energy demand and system capacity.

According to Rumpf (2020), the capacity of cross-border interconnectors is insufficient. Network operators may limit the capacity of interconnectors to balance the internal market, thus avoiding overloading the internal energy system. This situation cannot but affect the possibility of deploying "green" initiatives and trade in energy resources between member states. Despite the norms for the liberalization of the energy market in the EU, part of the market is still partially alienated. The borders between EU member states still contain obstacles to free trade in energy resources (Rumpf, 2020).

Also, there are other technical problems. According to the pilot evaluation of PV inverters common in the EU, it was found that all inverters did not meet the requirements for reliable operation of transmission and distribution networks (Chmielowiec et al., 2021).

It is worth noting that the evolution of energy networks is not possible without proper investment in its deployment. However, in the financing of trans-European energy network development projects, one can see some conservatism both in the choice of projects and in the definition of the reference energy network. ENTSO-E estimates that funding for the deployment of energy networks is insufficient. Thus, in the EU in 2030-2040 it is planned to create additional capacity of 14 GW by financing TYNDP projects. However, according to ENTSO-E, 43 GW of additional capacity needs to be generated during this period for the energy system to function properly. In the previous 10-year periods, the same situation is with underfunding of projects. And the logical consequence of total underfunding is a delay in the deployment of networks, technology development, which will catalyze the need for even greater financial compensation for projects in the coming periods. Unfortunately, about half of the existing capacity needs can be met through TYNDP projects, while the rest is now just a concept (ENTSO-E, 2021).

Rumpf (2020) obtained similar conclusions in his study. In the future, the scientist expects network congestion, which will only grow. Due to the rapid deployment of renewable energy sources, the number of bottlenecks in the grid is projected to increase. This situation is caused, not least, by the reluctance of most stakeholders to change the working conditions of national energy systems. Currently, there is a monopoly in the energy sector with a high level of market concentration. Unfortunately, the current level of monopoly in the industry does not contribute to the effective separation of related wholesale markets and increased competition. And this, in turn, can contribute to unproductive wholesale energy prices, as the prices of national monopoly energy producers are not reduced by competition. Due to bottlenecks in the network, efficient foreign energy producers are being pushed out of national energy markets. This reduces the economic benefits that consumers can derive from market integration in the EU (Rumpf, 2020).

Smart grid projects have various goals, among which, in our opinion, are the integration of renewable energy sources and reduction of greenhouse gas emissions, creating access to energy for all stakeholders, deploying transnational efficient and secure energy networks. However, of course, the EU's goals for building energy networks are much broader.

According to the ETIP SNET report, the level of achievement of the European Energy Transition objectives was assessed. The report provides a detailed analysis and contribution of smart grid development projects to the development of pan-European energy priorities. According to the report, although the projects contain mainly the results of research on public awareness and perception of energy transformations, adaptive energy behavior of consumers / users (including studies of energy communities), but the level of project contribution is assessed as low. Research on the development of the system economy, including the creation of new business models, is acceptable, although it varies from program to program. There is a high rate of project contribution in the study of digitalization. The results of the projects focused on the analysis of data exchange protocols, standardization and interoperability, interfaces and applications for an efficiently functioning energy market. The dominant area of research carried out in the projects is the work on flexibility, both hardware solutions and the energy system as a whole. Issues of systems operation are also covered by research in projects. However, it cannot be said that such studies are exhaustive (European Commission and ETIP SNET, 2021). According to ETIP SNET (2020), in the period 2020-2030, promising smart grid projects will be funded in the context of DER monitoring and control, sustainable energy use options, flexibility methodology (ETIP SNET, 2020).

In 2021, the requirements for energy projects were updated in connection with the adoption of the "fit-for-55" package of initiatives. The package of legislative initiatives was adopted to achieve ambitious goals in the field of renewable energy production, energy efficiency, primary and final energy consumption, carbon reduction and other goals to be achieved by 2030.

The BRIDGE initiative is one of those EU initiatives aimed at ensuring a sustainable energy transition in Europe, building smart grids, energy storage systems, and digitalising energy. During the initiative (since 2015), 90 projects have been implemented, of which only 36% have already been completed. The rest is implemented and involves stakeholders not only in EU countries but also outside the EU. In terms of the number of participants, the largest number of internal stakeholders in the EU in BRIDGE projects came from Spain, and the largest number of external stakeholders came from Norway (Table 3.2).

Table 3.2. Priority areas of BRIDGE projects in the field of smart grids

The project name	Countries of interest	The project goal
SMILE	Italy, United Kingdom, Portugal, Denmark, Netherlands, Greece	smart grid demonstration projects in islands
FLEXITRANSTORE	Belgium, Greece, Bulgaria, Cyprus, Hungary, Spain, France, Ireland, Slovenia, Croatia, Portugal, Albania	flexible energy grid
IElectrix	France, Austria, Germany, Hungary, Greece, Spain, Denmark, Belgium	integration of RES in smart grids
MUSE Grids	Italy, Spain, Denmark, Belgium, Netherlands, Ireland	smart energy systems
RENAISSANCE	Belgium, Spain, Italy, Greece, Poland, United Kingdom, Netherlands	energy communities, DSOs
REACT	Spain, Ireland, Netherlands, Germany, Austria, Sweden, Italy, United Kingdom, Greece, Serbia, France	cloud-based ICT platform
SDN-microSENSE	Greece, Serbia, Spain, Norway, Bulgaria, France, Sweden, Cyprus, United Kingdom, Luxembourg, Germany	secure communication channel between smart grid operators
ebalance-plus	Germany, Poland, Spain, Turkey, United Kingdom, Greece, Portugal, Italy, France, Denmark, Germany	smart grid architecture model
EUniversal	Germany, Poland, Belgium, Portugal, United Kingdom, Spain, Norway	implementation of a universal market enabling interface

Table 3.2. Continued

The project name	Countries of interest	The project goal
FlexiGrid	Netherlands, Sweden, Belgium, Romania, Sweden, Bulgaria, Turkey, Switzerland	deploy smart grid technologies
PARITY	Spain, Cyprus, Greece, Belgium, Sweden, Switzerland, Austria	smart grid monitoring and management tools
X-FLEX	Slovenia, Bulgaria, Greece, Cyprus, Austria, Spain	solutions for network operators and final consumers/prosumers
FARCROSS	Belgium, Greece, Bulgaria, Hungary, Austria, Romania, Croatia, Bosnia and Herzegovina, Albania, Spain, Romania, Ireland, Luxembourg, Germany, Cyprus, Slovenia, United Kingdom	increase cross-border capacity
BD4NRG	Greece, Germany, Luxembourg, Belgium, Spain, Slovenia, Italy, Portugal, Netherlands, Latvia, Romania, Austria, Turkey, Cyprus	architecture for smart energy
ReDREAM	Spain, Belgium, Italy, Croatia, United Kingdom, Greece, Spain, Germany	user-centric ecosystem
SENDER	Greece, France, Austria, Spain, Italy, Norway, France, Finland	smart grid standardization
FLEXGRID	Greece, Spain, Norway, Cyprus, Croatia, Germany, Denmark, Austria	smart grid architecture

Table 3.2. Continued

The project name	Countries of interest	The project goal
HYPERRIDE	Sweden, Germany, Czech Republic, Switzerland, Austria, Italy	hybrid grid architectures
TIGON	Greece, Spain, France, Portugal, Belgium, Finland, Bulgaria, Italy	DC-based hybrid grid topology
IANOS	Portugal, Finland, United Kingdom, Netherlands, Italy, French Polynesia, France, Greece, Spain, Belgium	smart energy router, hybrid transformer, fog-enabled intelligent device

Source: European Commission et al., 2021 © European Union, 2021

The BRIDGE projects explore five key technologies, of which, as seen in Figure 2.2, the leading ones are consumer technology and networking technology. In the development of projects related to consumer technologies, the results are significantly superior in the field of demand response and smart metering (Figure 2.3). Regarding network technologies, in this area most of the developments and research have been performed in order to effectively manage, control and monitor networks. Solutions for building micro-networks are also common (Figure 2.4). Figure 2.5 shows the small-scale storage technologies studied in the projects. BRIDGE projects include battery and electric car technologies. As for generation technologies (Figure 2.6), photovoltaic technologies, technologies in the context of wind turbines and microgeneration are most often considered in projects. It should be noted that digitization technologies are used in almost all BRIDGE projects (European Commission et al., 2021).

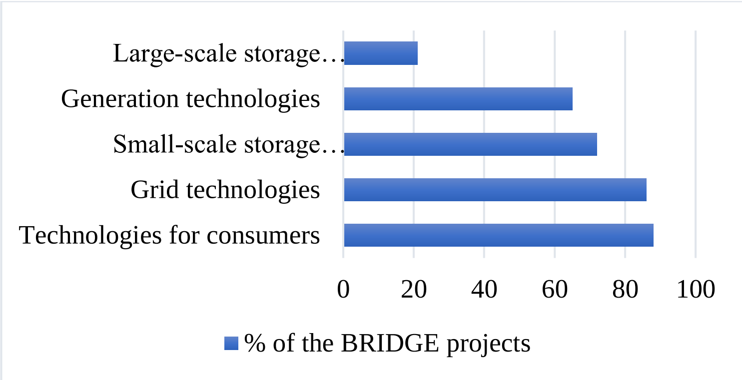

Figure 3.2. Technologies and services addressed by BRIDGE projects

Source: European Commission et al., 2021 © European Union, 2021

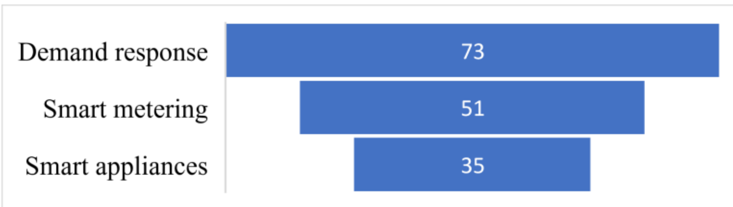

Figure 3.3. Technologies for consumers addressed by BRIDGE projects

Source: European Commission et al., 2021 © European Union, 2021

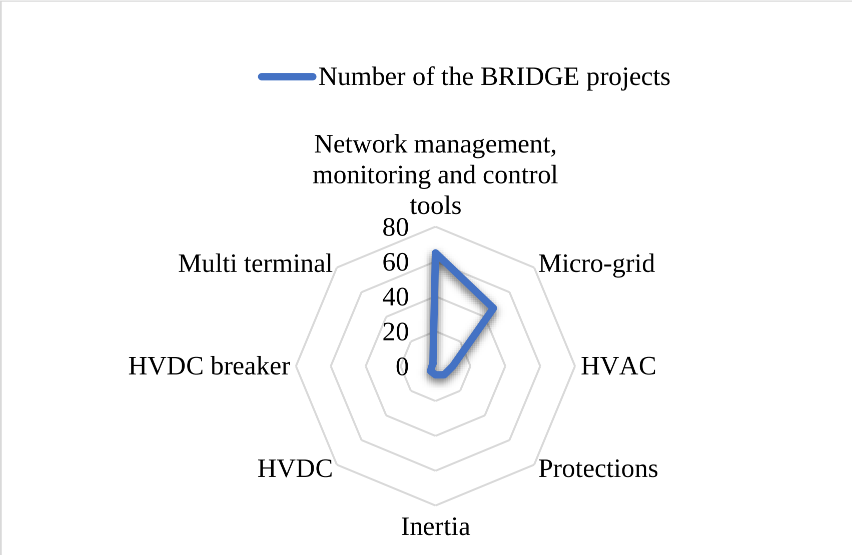

Figure 3.4. Grid technologies addressed by BRIDGE projects

Source: European Commission et al., 2021 © European Union, 2021

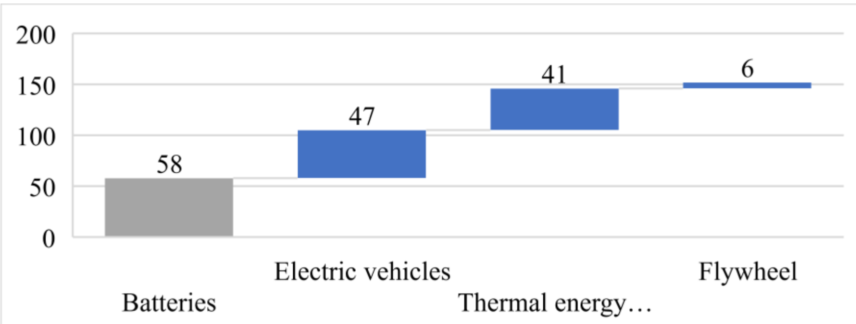

Figure 3.5. Small-scale storage technologies addressed by BRIDGE projects

Source: European Commission et al., 2021 © European Union, 2021

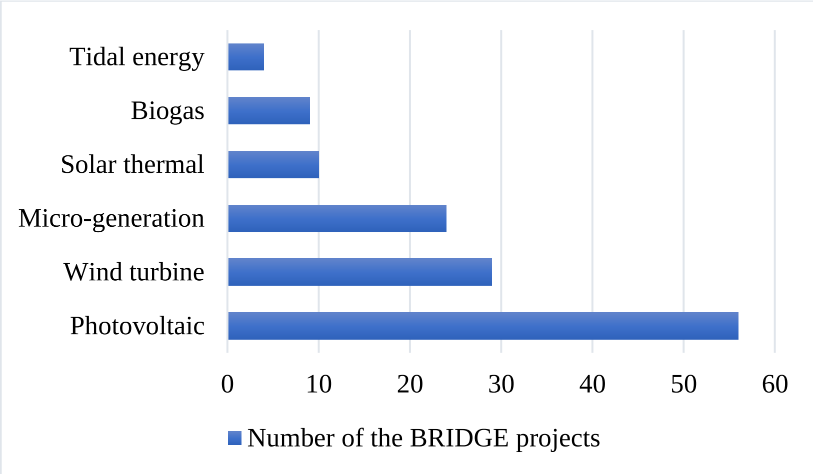

Figure 3.6. Generation technologies addressed by BRIDGE projects

Source: European Commission et al., 2021 © European Union, 2021

If we consider cross-border smart grid projects, according to the new list of PCIs, six such projects will be funded (Table 3.3, Figure 3.7).

Table 3.3. Priority areas of PCI projects in the field of smart grids

The project name	**Countries of interest**	**The project goal**
SINCRO.GRID	Slovenia, Croatia	to increase the security of operations of the electricity systems
ACON	Czechia, Slovakia	to foster the integration of the electricity markets
Smart Border Initiative	France, Germany	to support energy transition strategies and market integration

Table 2.6 Continued

The project name	Countries of interest	The project goal
Danube InGrid	Hungary, Slovakia	the project enhances cross-border coordination of electricity network management, with focus on smartening data collection and exchange
Data Bridge	Estonia, Latvia, Lithuania, Denmark, Finland, France	to build a common European Data bridge Platform
Cross-border flexibility project	Estonia, Finland	to support RES integration and increase security of supply

Source: Regulation (EU) No 347/2013 (2013)

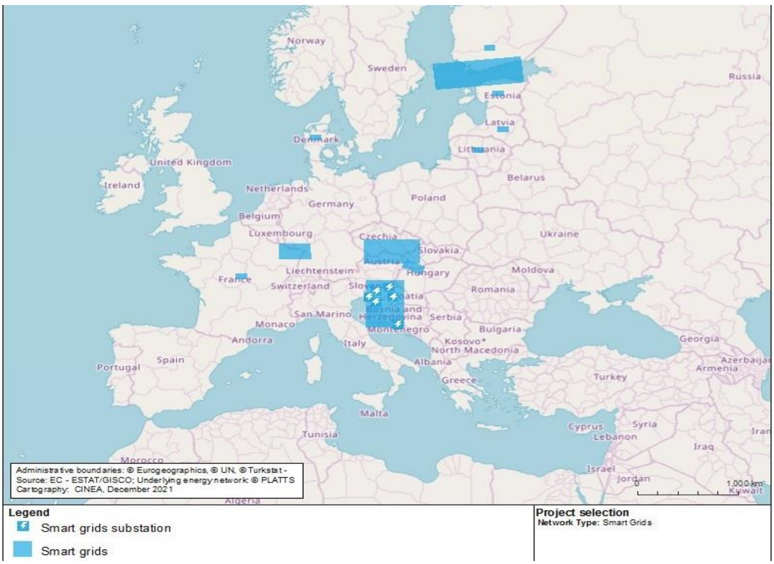

Figure 3.7. Projects of common interest in the priority thematic area of smart grids

Source: PCI Transparency platform. © PLATTS for the underlying grids for electricity, gas and oil, 2016 © European Union, 2021

Within these smart grid infrastructure projects, energy efficiency, security and integration are expected to increase for only twelve EU countries. However, these projects are essential to reduce bottlenecks between EU countries and achieve climate goals.

4. DEVELOPMENT OF SUSTAINABLE BUSINESS MODELS OF ENERGY SECTOR TRANSFORMATION

4.1 Trends in sustainable transformations

The existing aggravation and challenges in the EU energy sphere necessitates the transformation of the energy system in accordance with the theory of energy justice, the involvement of new economic agents to ensure the integrity of the cross-border energy market. Such strategic changes are being implemented to improve the efficiency, security and flexibility of the European energy system, the implementation of the 2015 Paris Agreement and the 2030 Agenda for Sustainable Development (Regulation 1227/20 2021). Ukraine is one of the countries that has embarked on the path of integration its energy system with the EU system with its green modifications. Meeting commitments in line with sustainable development goals requires appropriate measurements, including through an extensive system of indices. It is very important to conduct a comparative analysis both within individual countries and regions and at the global level. Of particular importance will be the analysis of the need to balance complex energy systems. However, in the modern literature there is no single view of such a dimension.

In the work of Firoiu et al. (2019) the authors emphasize the dualism of the world order and the achievement of sustainable development goals, when there is a significant gap between the most developed countries and those developing countries. The EU also has a gap in the implementation of sustainable development. As of 2016, none of the countries of Central and Eastern Europe was characterized by a favorable situation based on the results of sustainable development. And the worst situation in terms of meeting the targets was in Romania and Bulgaria, which belonged to the group of middle-income countries (middle-income countries) (Raszkowski and Bartniczak, 2019). And in the following years this situation did not change. Countries in Western and Northern Europe are doing better in the direction of sustainable development goals, while in Eastern Europe the situation is worse. Stanujkic and others. (2020) explain this phenomenon by the duration of work on the practice of sustainable development. The countries of Eastern Europe later joined the EU and accordingly did not property address the issue of sustainability in their policies. In addition, these countries primarily address poverty, high mortality, low per capita incomes, and only then sustainability (Stanujkic, 2020).

Nevertheless, integrated indicators, while not considering certain country-specific aspects, make it much easier to understand sustainable development. However, there is a need to expand and update the number of indicators for analysis (Firoiu et al., 2019; Breu et al., 2021). Puertas and Bermudez (2020) point out that the existing SDG index is more sensitivity to progress by developed countries than by developing ones. The efforts of developing countries are critical to achieving the common goal of sustainable development. The authors suggest using an adapted version of the global index (so-called GSPI), which considers the population and area of the country, and more clearly shows the contribution of developing countries. McArthur and Rasmussen (2019), while studying Canada’s sustainable development trajectories, concluded that less than half of the indices can be quantified at the national level (78 indices). According to the authors, other indices cannot be evaluated. At the same time, Guijarro and Poyatos (2018) evaluating the index for the EU-28, for the same reason refused to use only 15 indices (thus, making calculations based on 154 indicators). Hegre et al. (2020) indicate a weak coverage of these indicators, which greatly complicates their analysis. And data control will also be complicated by existing differences in development theory (Fukuda-Parr and McNeill, 2019). Eisenmenger et al. (2020) argue in their work that the monitoring of sustainable development should be based primarily on absolute rather than relative indicators. The authors emphasize the need to measure the absolute values of resource use, waste, and emissions into the environment. Korkovelos et al. (2019) note that in the last several years, the amount and quality of information related to the implementation of SDG7 is growing. However, according to the authors, much of the data needed for good socio-economic planning is still not available.

Coronil and Gil (2019) conducted a topic-modeling of Twitter posts posted by the Spanish government on its account. Their research shows that government account subscribers have commented more on the SDG with a focus on prosperity and the economy than on sustainability. However, the authors note that this may be due to the lack of awareness of the Spanish population about environmental issues, and in other countries such as Iceland and Norway, such a problem does not exist.

There are also related studies related to the testing of the “environmental Kuznets curve”, which should identify the relationship between industrial growth and environmental quality. However, the results of the hypothesis test in countries with different income levels (high-, low- and middle-income countries) do not give unambiguous answers (Liu, 2020; Maneejuk, 2020.

Local authorities are not always able to collect and process information on all the many indicators of sustainable development goals, as they are limited in resources and powers (Patole, 2018), they do not always see their expediency. Based on this, Hansson et al. (2019) assume that local authorities will provide reports on indicators that are easy and convenient to measure and that meet national and local development priorities. In the future, according to the authors, lists of key indicators may be introduced for local use, as was done in the United States (so-called SDSN index). And such integrated indicators will guarantee the achievement of the desired results. Lyytimaki et al. (2020) point to similar results they obtained in interviews with civil servants in Finland and Germany. Respondents emphasize the insensitivity of indicators to the local context, the danger of focusing on convenient indicators, the possibility of significant variation and different interpretations of the results. According to Selomane et al. (2019) slightly less than 40% of sustainable development indicators have an internationally accepted calculation methodology in the presence of regularly published data.

It is important to assess the contribution to sustainable development in terms of individual countries, but also in different types of economic activity. In this case, it becomes possible to stimulate and refocus industries that do not allow to achieve these development priorities. Scientists are actively conducting research on the areas and structure of indices for certain activities. And the number of publications is only growing. Recent studies examining the contribution of companies by type of activity include the van Zanten and van Tulder (2021) study. They classified economic activities according to the level of positive and negative impact on the achievement of sustainable development goals. Based on this target, the authors were able to identify four groups of activities: with a high degree of positive and low negative impact; with a high degree of negative and low positive impact; with a high degree of negative and positive impact, and with a low degree of negative and positive impact. Naturally, the authors include “renewable electric power generation, transmission and distribution” in the first group, and "mining of coal and lignite" in the second group.

Janikowska and Kulczycka (2021) are concerned about the possible negative effects of rising demand for mining due to the transition to a low-carbohydrate economy. Although more minerals are imported to achieve the principle of climate neutrality, demand for existing raw materials may still be insufficient in the future.

If we consider the automobile industry, then in assessing the contribution to sustainable development can be identified Lisowski et al. (2020). The authors selected 31 indexes, grouped by three indicators: “environmental impact, direct impact, and automobile impact” (Lisowski et al., 2020).

In the energy sector, the assessment of sustainable development is carried out from different points of view: from identifying the benefits of deploying micronetworks to the possibility of implementing sustainable business models. The scientific community actively discusses not only climate goals, but also analyzes the costs and benefits of integrating renewable energy sources, distributed energy systems, digitalization of energy with the active use of cloud technologies, IoT, smart demand management systems and more.

4.2 Principles of smart grid concept development

Dynamic technological development, greening processes of production and consumption, high level of information technology penetration in various economic activities cause the development and introduction of smart grid technology. This concept is spreading worldwide as a process of introducing modern innovative technologies into power systems to increase their efficiency, environmental friendliness and reliability.

The main goal of the investigation is to study the increasing tendency to analyze smart grid concepts and approaches by scientists. Thus, authors identified the quantity tendency in google search and in the scientific papers which focused on the analyses of issues connected with smart grid strategies; emphasizing the main subject areas under analyses of their implementation strategies; clustering the papers on the main directions for investigations with a purpose to identify the further options for analyses were provided.

The search queries in the Internet environment were analyzed using the Google Trends toolkit to form a terminological basis and study the dominant trends in the development of the smart grid concept. A fragment of the analysis is presented in Figure 4.1.

The Google Trend tool allows you to build a query map showing the popularity of the term by country. The dark color means a high probability of finding the term.

Google Trend allows you to compare search terms using a map that shows their popularity in color. In this case, the popularity of the search term is correlated with the total number of Google searches for a certain period in a particular country

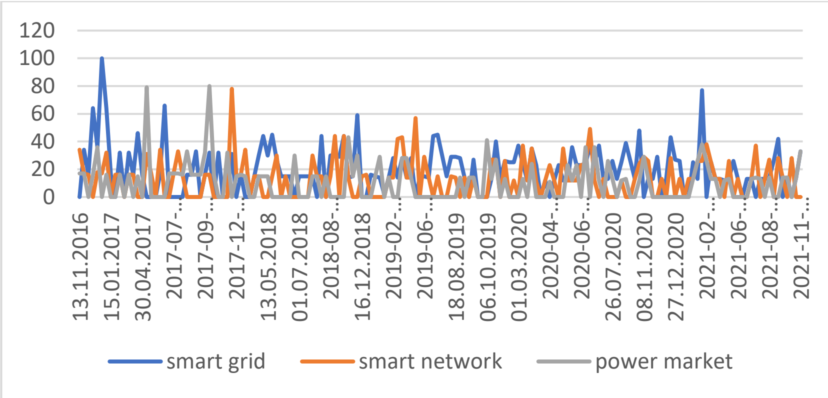

Figure 4.1. The analysis results of search queries on the Internet in the scientific field of the categories "smart grid", "smart network", "power market" using the trend analysis tools

Sources: created by the authors with the help of Google Trends.

The study results show that the category of "smart grid" is the most widely used in the scientific field in Canada, the USA, Brazil, Australia; smart network category - in Canada, Russia, Iran, Saudi Arabia; power market category - in France, Denmark, Germany (Figure 4.2). As for the business sphere, the popularity distribution of the relevant search queries has a slightly different structure (Figure 4.3). The “smart grid” category is most used in Germany, Belgium, Brazil, and Finland; smart network category - in France, Israel, Morocco, Germany; power market category - in Canada, USA, Australia, India, Italy.

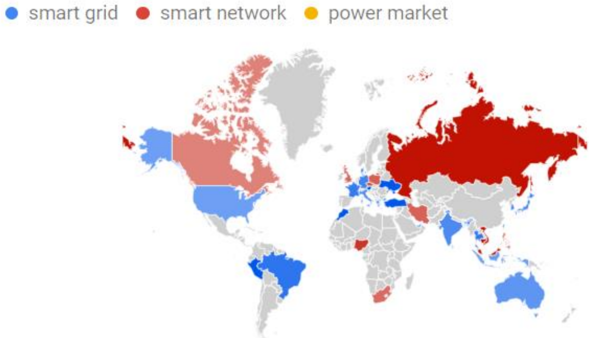

Figure 4.2. Map of the request intensity for various definitions "smart grid", "smart network", "power market" in the world in the scientific field

Sources: created by the authors with the help of Google Trends.

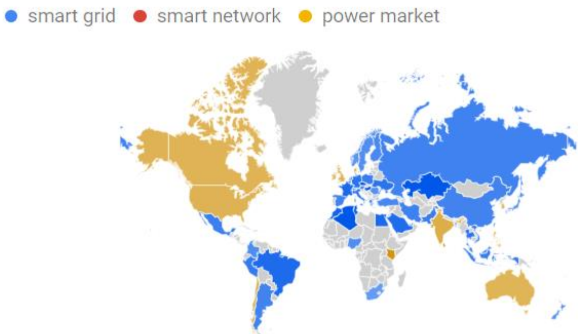

Figure 4.3. Map of the request intensity for various definitions "smart grid", "smart network", "power market" in the world in the business sphere

Sources: created by the authors with the help of Google Trends.

The results of the share of queries “smart grid”, “smart network”, “power market” by countries in the business and industrial sectors are presented in Table 4.1.

Table 4.1. The share of requests by country in the business and industrial sectors

Category	Countries					
	China	USA	Canada	Australia	Germany	Ukraine
Smart grid	63%	43%	39%	44%	77%	76%
Smart network	0%	8%	13%	9%	3%	11%
Power market	37%	49%	48&	47%	20%	13%

Source: compiled by the author using Google Trends.

Using the Scopus analysing tools, more than 2000 papers from the Scopus base were reviewed. The period from 2000 till 2020 was chosen for the analysis. The Scopus screening tools showed that in 2006 the numbers of articles which focused on smart grid strategies began to increase. In 2020 in comparison with 2006 the quantity of articles increased more approximately on 60 times (Figure 4.4).

China (13506), United States (11128 papers), India (4867), Germany (3476), United Kingdom (3142), Italy (2955), Canada (2556), Australia (2060), Iran (1816), Spain (1640) represented the investigated area on the international level.

The most academic researchers were in the following institutions: State Grid Corporation of China, North China Electric Power University, China Electric Power Research Institute, Tsinghua University (China), Ministry of Education China, Aalborg University (Canada), Shanghai Jiao Tong University (China), COMSATS University Islamabad (Pakistan), Delft University of Technology (Netherlands), University of Waterloo (Canada), Politecnico di Milano (Italy) etc.

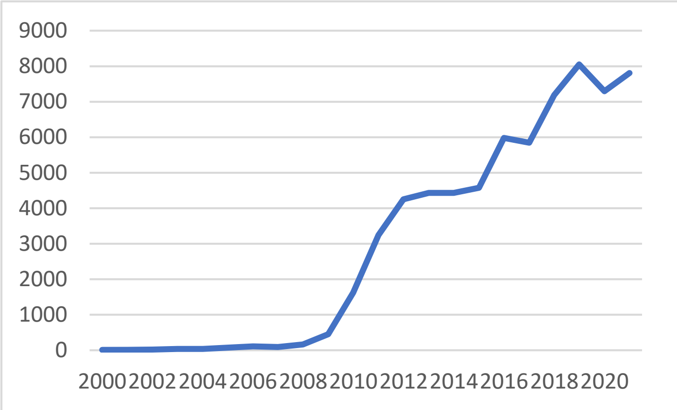

Figure 4.4. The results of the publication trend analysis in the field of omnichannel strategies in marketing
Sources: created by the authors on the base of Scopus

Figure 4.5 describes the international academic representation of smart grid.

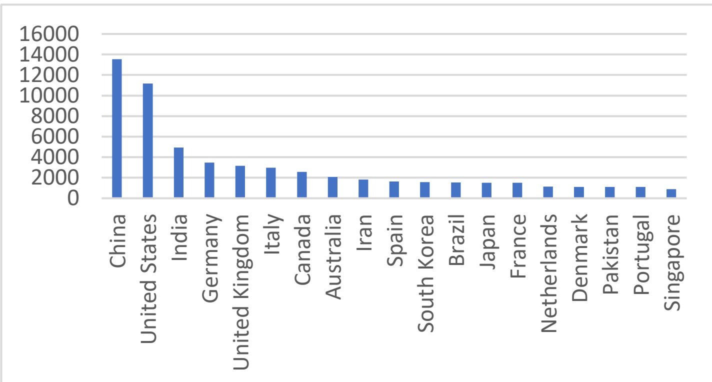

Figure 4.5. International academic representation of the category “smart grid”
Sources: created by the authors using Scopus

The main subject areas (Figure 4.6) related to the smart grid development include computer science, engineering, energy, mathematics, environmental and social science etc.

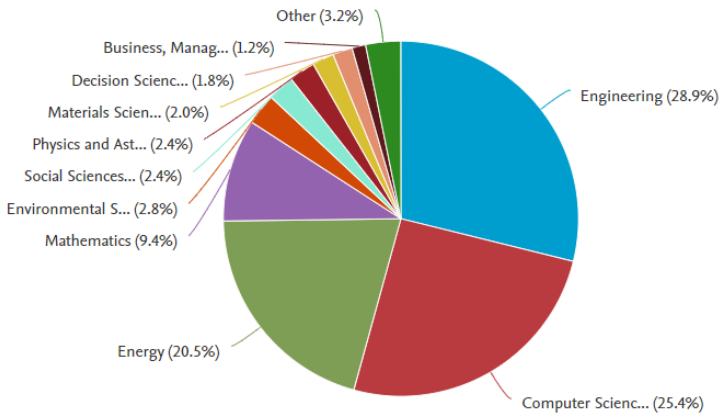

Figure 4.6. The subject area in Scopus to analyze the smart grid

Sources: compiled by the authors using data from Scopus

One should note that the percentage of environmental science is 8%. It shows the low implementation of the marketing strategies in environmental economics, sustainable development, and green production.

The citation analysis with the help of VOSviewer 1.6.13 tool revealed the most authoritative scientists and researchers as well as eight clusters of research teams that had the most significant influence on the smart grid theory (Figure 4.7).

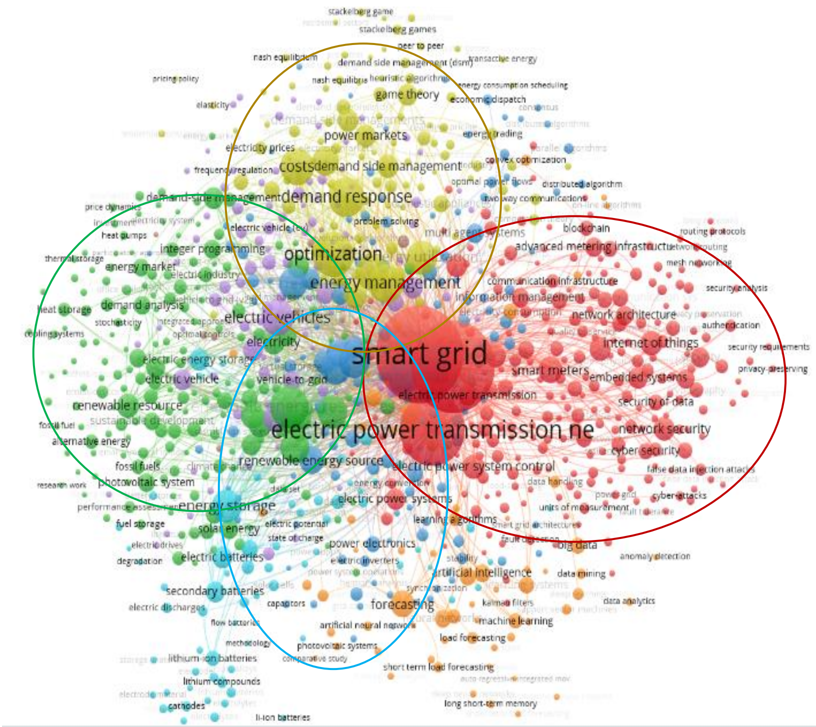

Figure 4.7. The results of bibliometric analysis of structural and functional environment to form and develop the smart grid theory.

Sources: compiled by the authors using the data from Scopus and VOSviewer tool.

The clustering results presented in Figure 4.8 indicate the powerful clusters related to the categories of "smart grid", "renewable energy resources", "energy management" and "energy storage".

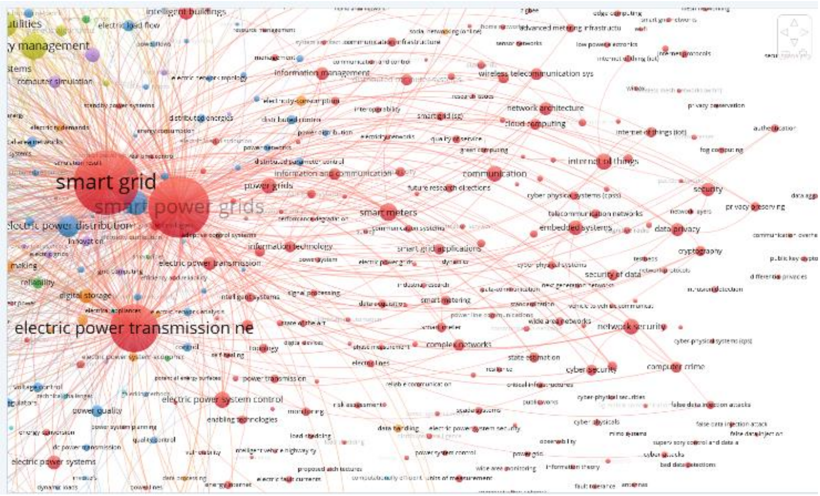

Figure 4.8. The results regarding bibliometric analysis of structural and functional environment to form and develop the smart grid theory with close areas

Sources: compiled by the authors using the data from Scopus and VOSviewer tool.

The biggest red cluster (Figure 4.8) includes three subclusters, which describe categories related to “smart grid”, “smart power grids”, “electric power transmission”.

The red cluster: information technologies, internet of thing, power networks, security data, communication capabilities, cyber security, computer crime, electric power transmission, power grids, communication infrastructure, intelligent buildings, cloud computing, electronic power system control, blockchain, data privacy etc.

A big green cluster relates to renewable energy resources, sustainable development, alternative energy, electric vehicle, climate change, energy storage, solar energy, environmental impact, electricity generation etc. The significant cluster related to energy management contains the following categories: optimization, costs, demand size management, energy utilization, power markets, electricity prices, real-time prices etc.

Besides, VOSviewer software also provides the ability to display the time horizon of the appearance of the studied categories, which are more common in scientific publications of the Scopus database (Figure 4.9).

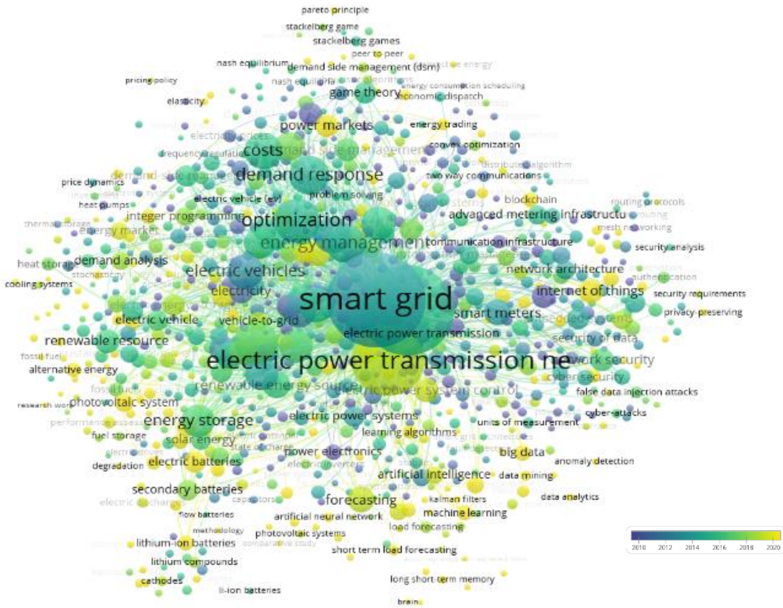

Figure 4.9. Terminological map of the categories that are most common in publications on green competitiveness in the period from 2010 to 2020.

Source: composed by the authors using VOSviewer 1.6.13.

Thus, the approximation to the blue colour in the figure indicates a greater "maturity" of the publication, and respectively, scientific articles close to the "yellow colour" are more modern. The results of visual reflection regarding the time actualization of the smart grids show that the first studies dealt with the topic of electric vehicles, and then the orientation shifted to the electric power transmission.

Table 4.2 systemized the most cited authors whose scientific interests relate to the smart grid concept.

Table 4.2. The TOP-10 the most cited authors

No	Authors	Title	Journal	Citation
1	Farhangi H.	The path of the smart grid	IEEE Power and Energy Magazine	2061
2	Mohsenian-Rad A.-H., Wong V.W.S., Jatskevich J., Schober R.	Autonomous demand-side management based on game-theoretic energy consumption scheduling for the future smart grid	IEEE Transactions on Smart Grid	2014
3	Palensky P., Dietrich D.	Demand side management: Demand response, intelligent energy systems, and smart loads	IEEE Transactions on Industrial Informatics	1891
4	Fang X., Misra S., Xue G., Yang D	Smart grid - The new and improved power grid: A survey	IEEE Communications Surveys and Tutorials	1827
5	Siano P.	Demand response and smart grids - A survey	Renewable and Sustainable Energy Reviews	1368

Table 4.2. Continued

No	Authors	Title	Journal	Citation
6	Güngör V.C., Sahin D., Kocak T., Ergüt S., Buccella C., Cecati C., Hancke G.P.	Smart grid technologies: Communication technologies and standards	IEEE Transactions on Industrial Informatics	1743
7	Ipakchi A., Albuyeh F.	Grid of the future	IEEE Power and Energy Magazine	1316
8	Ellabban O., Abu-Rub H., Blaabjerg F.	Renewable energy resources: Current status, future prospects and their enabling technology	Renewable and Sustainable Energy Reviews	1819
9	Lund H., Werner S., Wiltshire R., Svendsen S., Thorsen J.E., Hvelplund F.	4th Generation District Heating (4GDH). Integrating smart thermal grids into future sustainable energy systems.	Energy	1165
10	Zakeri B., Syri S.	Electrical energy storage systems: A comparative life cycle cost analysis	Renewable and Sustainable Energy Reviews	867

Sources: created by the authors on the base of Scopus

At the same time, terminological visualization allows us to explore the features of citation between scientists in the relevant field of research. Figure 4.10 identifies twelve clusters.

In the first cluster, the most authoritative authors are from the Beijing Institute of Technology (China) – Wang Y. His scientific publications (Wang et al., 2011a, 2011b) are devoted to issues of smart grid security standards. In the second cluster, the author Yi Xu from the Carolina State University (USA), whose research papers (Xu et al., 2011) deal with technology of energy internet, is the most cited. In the third cluster, scientific articles by Wang X. form the Hong Kong Polytechnic University (Zhou et al., 2016) are devoted to smart home energy management systems.

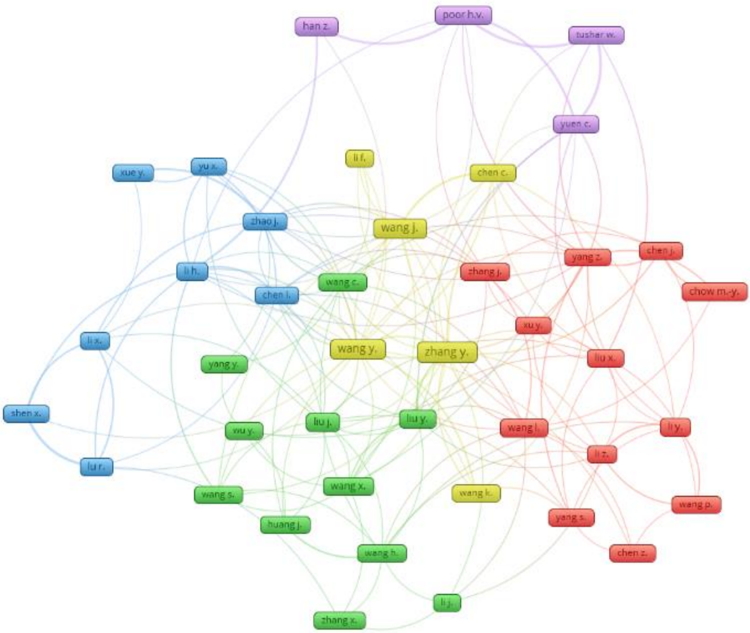

Figure 4.10. Visualisation of the network of the most cited scientists in the field of smart grid
Source: composed by the authors using VOSviewer 1.6.13

4.3 Sustainable business models and environmental and economic effects of smart grid deployment

With the adoption of the UN Sustainable Development Goals in January 2016, global sustainability benchmarks now apply in different sectors and national contexts. Priorities for sustainable development goals allow public and private organizations to evaluate their activities, strategies, and business results for compliance with environmental and climate development priorities. However, the advantage for sustainable business within the dominant economic paradigm is not apparent, which emphasizes the need for new analytical structures and tools (Sullivan et al., 2018).

According to a study by Nosratabadi et al. (2019), the scientific literature describes four main approaches to developing sustainable business models. Accordingly, the authors systematize scientific work according to the following models: "designing a sustainable value proposition, designing sustainable value creation, designing sustainable value delivering, and generating sustainable partnership networks." Unfortunately, most studies of sustainable business models use a qualitative approach rather than a quantitative one. Looking at current research results, it can be argued that quantitative research on this topic is insufficiently studied. This situation exists even though quantitative analysis methods make it possible to use a system of indicators to investigate the factors that stimulate or hinder enterprises from implementing sustainable business models. Quantitative methods are also a flexible tool for assessing the impact on businesses' social and environmental performance (Nosratabadi et al., 2019).

Bidmon & Knab (2018) identify three prominent roles of sustainable business models:

- in a situation of the stable socio-technical regime, existing business models hinder transitions, strengthening the stability of the current system;

- in the situation of the existence of an intermediate link between the technological niche and the socio-technical regime, business models, on the contrary, stimulate transitions, contributing to the process of stabilization of technological innovations;

- in non-technological niche innovations, new business models stimulate sustainable transformation by creating a significant part of the innovation regime (Bidmon & Knab, 2018).

Energy production and consumption require the implementation of sustainable business models. However, sustainability is a complex phenomenon, especially in high-tech sectors that need the integration of diverse knowledge to ensure sustainable innovation (Rossignoli & Lionzo, 2018). Among such knowledge may be the construction of regional energy cooperatives.

According to the Klagge & Meister (2018) survey, most energy cooperatives (following the example of Germany) are actively working with the new regulatory environment to ensure sustainable development and develop business models that are independent of public support and can lead to new strategies for changing interfaces between the state, the market and civil society.

In their work, Lozano and Reid (2018) investigated the role of investors in electricity generation the introduction of sustainable business models. According to the results of their work, the main challenge in the future for the viability of utilities in the energy sector is the integration of renewable technologies. Loock (2020) argues that digital technologies contribute to business model innovation by removing bottlenecks in integrating sustainable energy technologies into existing energy systems. According to a study by Karami and Madlener (2021), successful business models of electricity suppliers mainly focus on improving consumers' energy efficiency and self-sufficiency. At the same time, the work of Biancardi et al. (2021) found that transmission system operators (TSOs) are more conservative in their perception of innovation and change in their current business model than operating system operators. According to the authors, grid companies tend to avoid investing in innovation and deploying smart grids if they are not adequately encouraged to implement such innovations.

One of the main reasons for introducing new, sustainable business model smart technologies in the energy sector is that alternative (renewable) energy sources can have a minimal negative impact on the environment. Moreover, the urgency of solving environmental problems is one of the key priorities of every country in the world. Therefore, it is not surprising that the number of publications on the study of sustainable business models and smart technologies is growing (Figure 4.11). Moreover, according to the analytical platform SciVal, 17% of publications on this topic are in the top 10% of the world's most cited publications (and 2.9% - in the top 1% of the most cited).

The most cited papers on SciVal T.8491 have been published in four journals: Journal of Cleaner Production, Sustainability, Technological Forecasting, and Social Change, and Journal of Business Research. In general, the share of works published in the top 10% of journals is 23.3%.

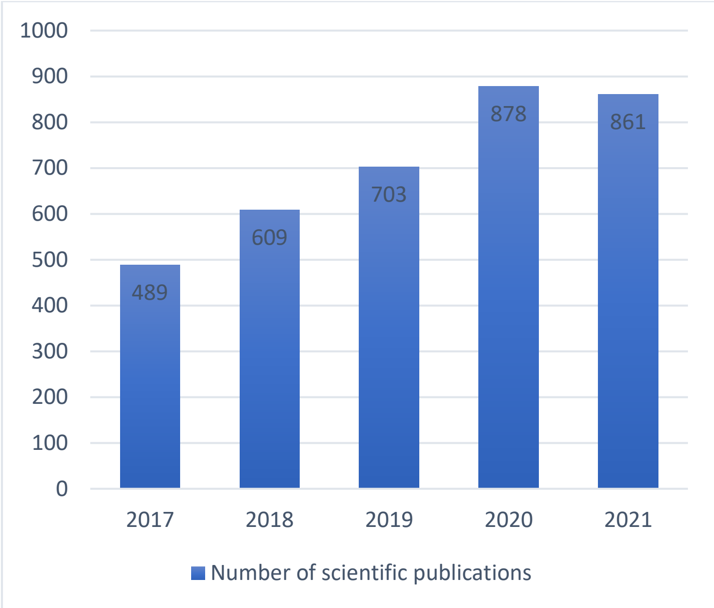

Figure 4.11. Number of scientific publications indexed by the Scopus® database on SciVal T.8491 "Innovative business models; Sustainable business; Digital Transformation" for 2017-2021

Source: built by the authors based on data © 2021 Elsevier B.V., the source of the data is SciVal @ https://scival.com/

Research on sustainable business models is being conducted around the world. However, the most cited are those published by Cambridge University, Delft University of Technology, and the University of Erlangen-Nuremberg. At the same time, scientists from the University of Aarhus provided the greatest achievements on these issues (Table 4.3). Among scientists, Bocken Nancy M.P. from Maastricht University (Table 4.4).

If we consider the academic community's conceptualization of sustainable business models, the fundamental research of this concept involves consideration of various aspects. In recent years, innovative steel business models have been closely linked to the study of digital transformation, Industry 4.0, cloud technology, the Internet of Things, and the adaptation and dissemination of sustainable business models (Figure 4.12).

Table 4.3. The most active institutions on the topic SciVal T.8491 "Innovative business models; Sustainable business; Digital Transformation" for 2017-2021

№	The institution	Number of scientific publications	Number of citations
1	Aarhus University	53	232
2	Delft University of Technology	52	1719
3	University of Cambridge	49	1896
4	Polytechnic University of Milan	41	687
5	Lund University	35	1109
6	Lappeenranta University of Technology	32	696
7	University of St. Gallen	32	479
8	Technical University of Munich	30	138
9	University of Oulu	30	192
10	Friedrich-Alexander University Erlangen-Nürnberg	29	1119

Source: built by the authors based on data © 2021 Elsevier B.V., the source of the data is SciVal @ https://scival.com/

Table 4.4. Top 5 most cited authors on the topic SciVal T.8491 "Innovative business models; Sustainable business; Digital Transformation" for 2017-2021

№	The researcher	Number of citations	Number of citations per publication
1	Bocken, Nancy M.P.	1400	46,7
2	Lüdeke-Freund, Florian	1049	95,4
3	Voigt, Kai Ingo	936	58,5
4	Evans, Steve	930	71,5
5	Kiel, Daniel	857	95,2

Source: built by the authors based on data © 2021 Elsevier B.V., the source of the data is SciVal @ https://scival.com/

In the context of smart grids, sustainable business models are considered from the standpoint of the study of distributed generation various decentralized energy technologies, from demand management technologies to energy storage technologies in the system (Dranka and Ferreira, 2020). Yes, Sikorski et al. (2019) evaluate and prove the effectiveness of the construction of virtual power plants the possibility of integration into a single system of distributed energy resources and energy storage systems. Chen et al. (2020) describe the methodology of operation and control of network micro-networks given the massive deployment of smart grids. Paukstad and Becker (2021) systematized business models of smart grids based on the Internet of Things. Xu et al. (2021) proposed an approach to the deployment of smart grids based on blockchain technology.

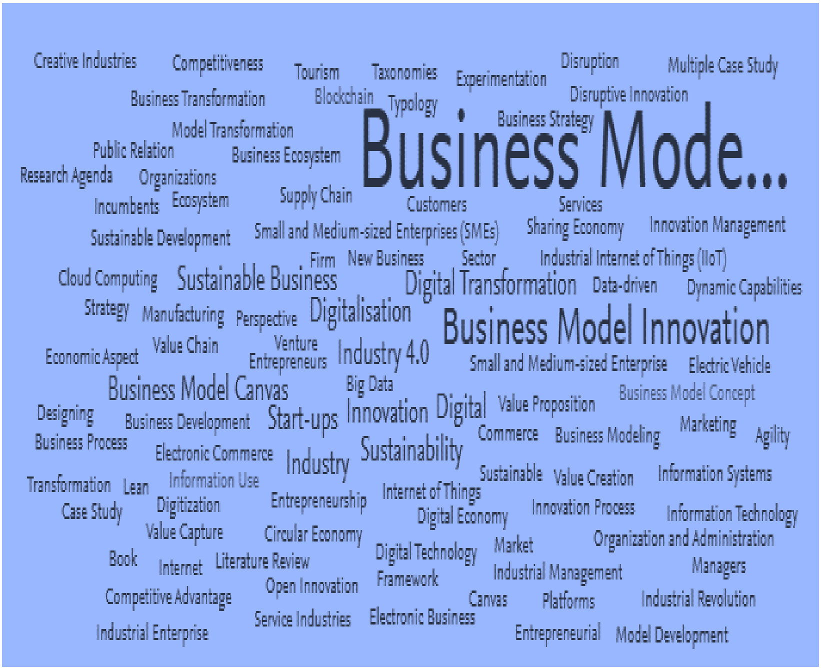

Figure 4.12. Keyword cloud of scientific publications indexed by the Scopus® database on SciVal T.8491 "Innovative business models; Sustainable business; Digital Transformation" Source: © 2021 Elsevier B.V., the source of the data is Scopus® https://www.scopus.com/

Deployment of smart grids has several positive effects, including a positive impact on the environment:

–application of clean technologies - the technology of "smart" energy networks involves, as a rule, the integration of renewable energy sources in centralized and decentralized energy consumption systems;

–reduction of greenhouse gases - the use of "smart" energy networks reduces emissions;

–conservation of resources - the use of renewable energy sources can solve the problem of energy shortages (Sun et al., 2011; Vakulenko, 2019).

The development of "smart" power grids involves using more efficient technological processes and equipment. This is the reason for their economic profitability for implementation in the energy sector. The minimum amount of funds spent on energy production through alternative energy sources is at the stage of operation. American economist Jeremy Rifkin defined this as energy with "zero variable costs."

The study found that the development of smart grids has a more positive than negative impact on the economy. There are several features that are most important in the formation of the economic effect:

–when deploying networks, there are no costs for processing raw materials equipment;

–the deployment of smart grids is cost-effective for both consumers and suppliers;

–the minimum amount of the expenses for troubleshooting power lines;

–no costs for landscape restoration after fossil mining;

–there are no costs for equipment for cleaning air, ocean, land, and waste disposal.

–the problem of lack of resources is solved;

–dependence on other energy-rich countries decreases (Sun et al., 2011; Vakulenko, 2019).

5 THE CONCEPT OF OPTIMIZING FUNDING SOURCES FOR SMART GRIDS

5.1 Funding for smart energy and sustainable development

From a historical retrospective, the state's role in intensifying investment and innovation processes qualitative transformation of environmental transformations is unconditional. However, local factors can also catalyze the success of reforms. And to a large extent, their outcome depends on the level of cooperation and synergy between public authorities, private companies, and public organizations.

Management processes that enhance energy efficiency and investment can also stimulate energy innovation. The number of studies on green innovation has more than increased ninefold since 2008 and will continue to grow (Panchenko et al., 2020). Promising in the field of green innovations are cloud computing and ERP systems; smart grids (Barbier, 2020); energy efficiency, cyclical economy (Sun et al., 2019).

In Ukraine, the issue of green innovation and investment is also given due attention, especially in energy efficiency. Many scientists are aware of the need to balance energy demand and justify tariff efficiency to reduce heat losses and reduce energy consumption. In particular, to transition to green energy production, researchers (Kolosok et al., 2020a; Labandeira et al., 2020; Mentel et al., 2018) carry out regional differentiation of electricity tariffs in 13 regions of Ukraine, where the most significant energy capacities are concentrated.

A scientists performs an analysis of the benefits of financing green investments to achieve sustainable development goals. They proved the relationship between green investment and the country's performance on the path to sustainable development. Consequently, the justification of the effectiveness of state policy in the energy sector should be based on sustainable development goals indicators.

Given Ukraine's European integration orientation, five EU sub-indicators, described in detail in the paper (Kolosok et al., 2020b), were selected for the integrated assessment of Ukraine's energy policy effectiveness.

The source of statistical data for the model's input variables was the State Statistics Service of Ukraine. Unfortunately, the Ukrainian statistical office does not publish statistics on sustainable development goals, which is completely identical to the EU statistical methodology. Therefore, annual data from the Ukrainian Statistics Service for 2000-2019 were collected and calculated as indicators for the model under Directive 2012/27 / EU, Directive (EU) 2018/2002, Regulation (EC) No 1099/2008, data descriptors European Union Statistics Office. Missing or unknown data for individual years for the model were filled using the moving average method.

Since the range of data varies greatly and contains different measures, it was decided to normalize them. It was necessary that each parameter contributed to the proportional contribution to the optimization result for the correct operation of the model. Min-max normalization (5.1) was used to scale the data to a fixed range [0,1] (Kolosok et al., 2020b):

$$x_{norm\ it} = \frac{x_{it} - \min(x_{it})}{\max(x_{it}) - \min(x_{it})} \quad (5.1)$$

where x_{it} and $x_{norm\ it}$ are the original and normalized value of the *i*-sign for time *t*;

max (x_{it}) and min (x_{it}) are the maximum and minimum values of the *i*-sign for time *t* in the range *x* (Kolosok et al., 2020b).

After normalization of the data, histograms were constructed to select the best model for rapid assessment of energy efficiency in Ukraine (Figure 5.1).

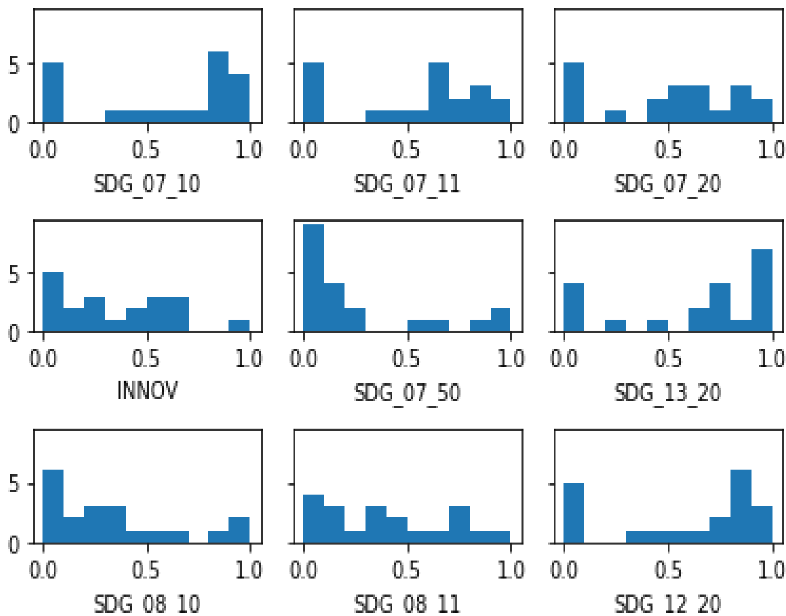

Figure 5.1. Histograms for input model variables
Source: Kolosok et al. (2020b).

According to the results obtained, it is impossible not to see differences in data distribution. Data are not centered, have several peaks and differences in averages (Figure 5.2). The distribution of values with a skew to the left prevails, because their averages are less than the median. Analysis of variance statistics also shows some variations in values, from 0.270 for the indicator of innovation costs to 0.372 for the indicator of primary energy consumption (Kolosok et al., 2020b, Kolosok et al., 2020c).

	SDG_07_10	SDG_07_11	SDG_07_20	SDG_07_30	SDG_07_50	SDG_13_20	SDG_08_10	SDG_08_11	SDG_12_20	INNOV
count	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000
mean	0.596	0.542	0.499	0.294	0.268	0.632	0.325	0.408	0.577	0.347
std	0.372	0.344	0.329	0.325	0.339	0.354	0.311	0.310	0.368	0.270
min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25%	0.256	0.252	0.216	0.042	0.023	0.436	0.069	0.149	0.251	0.131
50%	0.762	0.656	0.545	0.181	0.130	0.760	0.240	0.373	0.753	0.302
75%	0.880	0.771	0.748	0.398	0.357	0.909	0.443	0.675	0.867	0.574
max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Figure 5.2. Descriptive statistics of variables
Source: Kolosok et al. (2020b)

Taking into account the results of descriptive statistics of all indicators, the usual least-squares model was chosen to assess the effects of Ukraine's energy policy, which in general looks like this (5.2):

$$y_t = X_t \beta_i + \varepsilon_t \tag{5.2}$$

де y_t – $p \times 1$ vector of the dependent variable in time *t*;

X_t – $p \times q$ matrix of explanatory variables in time *t*;

β_i – $q \times 1$ vector of unknown coefficients (i = 1,..,q);

ε_t – p×1 vector of errors of time variables t (Kolosok et al., 2020b).

The linear function of the input variables is presented below (5.3):

$$\text{SDG\_07\_30}_t = \beta_1 + \beta_2 \cdot \text{SDG\_07\_10}_t + \beta_3 \cdot \text{SDG\_07\_11}_t + \beta_4 \cdot \text{SDG\_07\_20}_t + \beta_5 \cdot \text{SDG\_07\_50}_t + \beta_6 \cdot \text{SDG\_13\_20}_t + \beta_7 \cdot \text{SDG\_08\_10}_t + \beta_8 \cdot \text{SDG\_08\_11}_t + \beta_9 \cdot \text{SDG\_12\_20}_t + \beta_{10} \cdot \text{INNOV}_t + \varepsilon_t \quad (5.3)$$

where energy productivity, SDG_07_30t, is a function of primary energy consumption, SDG_07_10t, final energy consumption, SDG_07_11t, final energy consumption in households per capita, SDG_07_20t, dependence on energy imports by-product, energy consumption, SDG_07_50 SDG_13_20t, real GDP per capita, SDG_08_10t, the share of investment in GDP by institutional sectors, SDG_08_11t, the productivity of resources and domestic consumption of materials, SDG_12_20t, expenditure on the innovation of industrial enterprises by innovation, INNOVt, time t; *β1..β10* - coefficients of the OLS model; *εt* - errors of variables in time t (Kolosok et al., 2020b).

According to the proposed model, the question was tested: "Does any of the variables Xt help explain energy productivity in Ukraine over the past twenty years?" by substantiating hypotheses:

$H_0 : \beta_1 = \beta_2 = .. = \beta_{10} = 0;$
$H_a : \exists\, \beta_i \neq 0,\ i = 2,..,10.$

To find variables that better describe the relationship to energy efficiency policy, a strategy of moving from a general to a specific model was chosen. After obtaining significant values for all model variables, the regression coefficients were tested to prove the hypotheses using the RESET and Jarque-Bera tests.

The methodological tool for the study was the use of Python programming language 3.6.11 and the statsmodels package, which was used to perform calculations and verification of the model.

Before conducting the simulation, the relationship between the results of energy efficiency policy (an indicator of which is SDG_07_30) and endogenous indicators of a carbon-neutral economy was tested using scatter plots. As shown in Figure 5.3, there is a strong positive linear relationship between energy efficiency and two of the nine indices. These are 'dependence on energy imports by product' (SDG_07_50) and 'real GDP per capita' (SDG_08_10). The energy efficiency indicator can integrally measure the effectiveness of state regulatory interventions in the energy sector and is an indicator of the success or failure of energy reforms. In this case, according to the presented data, such a connection may indicate the coverage of energy needs with the growth of real GDP production due to net energy imports in the country. Or it may indicate some overstatement of tariffs for energy resources in Ukraine compared to the tariffs of neighboring countries. Concerning the cost of innovation in the energy sector, this index will not allow a linear description of the dependence, as there are extraneous points in the area of increasing the cost of innovation (Kolosok et al., 2020b, Kolosok et al., 2020c).

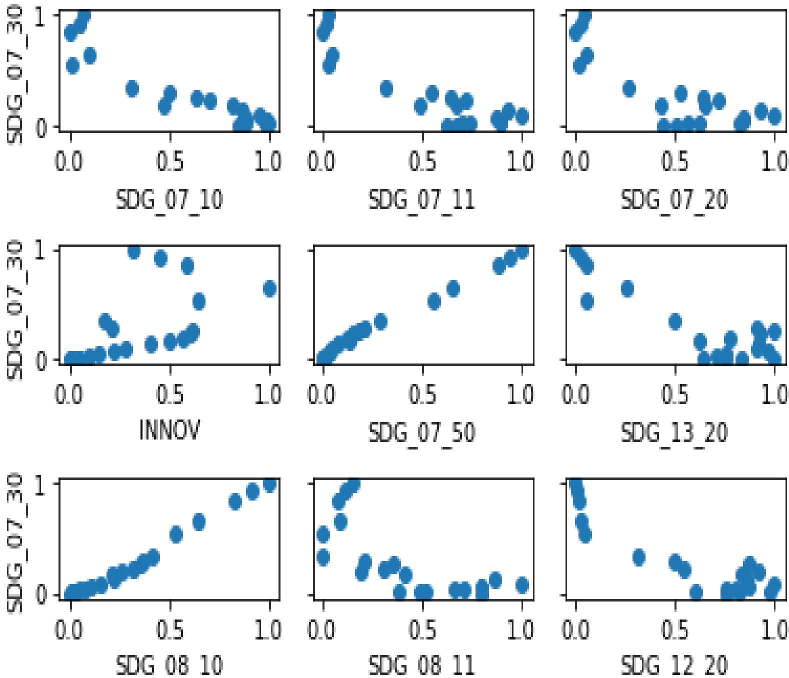

Figure 5.3. Scattering graphs for input model variables
Source: Kolosok et al. (2020b)

Seven rounds of optimization were performed using the strategy for calculation indicators from a general to a specific model. The search was completed when significant values of the p-estimate were obtained for all model variables (with a significance level of α = 0.05%).

After the first round of optimization (Figure 5.4), the variable SDG_08_11 (Figure 5.5) was excluded because the p-score for this variable was the largest.

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0112	0.008	1.416	0.187	-0.006	0.029
SDG_07_10	0.0035	0.013	0.273	0.791	-0.025	0.032
SDG_07_11	-0.0449	0.058	-0.772	0.458	-0.175	0.085
SDG_07_20	0.0202	0.038	0.533	0.606	-0.064	0.105
SDG_07_50	0.5269	0.017	31.123	0.000	0.489	0.565
SDG_13_20	0.0044	0.004	1.000	0.341	-0.005	0.014
SDG_08_10	0.4622	0.015	30.365	0.000	0.428	0.496
SDG_08_11	-0.0004	0.005	-0.070	0.945	-0.012	0.011
SDG_12_20	0.0031	0.004	0.849	0.416	-0.005	0.011
INNOV	-0.0022	0.004	-0.591	0.567	-0.011	0.006

Omnibus:	1.258	Durbin-Watson:	2.484
Prob(Omnibus):	0.533	Jarque-Bera (JB):	0.773
Skew:	0.475	Prob(JB):	0.680
Kurtosis:	2.842	Cond. No.	329.

Figure 5.4. Results of the first round of optimization

Source: based on data from the State Statistics Service of Ukraine, www.ukrstat.gov.ua.

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0116	0.006	2.039	0.066	-0.001	0.024
SDG_07_10	0.0042	0.008	0.527	0.609	-0.013	0.022
SDG_07_11	-0.0480	0.036	-1.348	0.205	-0.126	0.030
SDG_07_20	0.0220	0.027	0.828	0.426	-0.037	0.081
SDG_07_50	0.5261	0.012	42.840	0.000	0.499	0.553
SDG_13_20	0.0045	0.004	1.122	0.286	-0.004	0.013
SDG_08_10	0.4626	0.014	34.062	0.000	0.433	0.492
SDG_12_20	0.0030	0.003	0.926	0.374	-0.004	0.010
INNOV	-0.0024	0.003	-0.766	0.460	-0.009	0.004

Omnibus:	1.238	Durbin-Watson:	2.477
Prob(Omnibus):	0.538	Jarque-Bera (JB):	0.764
Skew:	0.472	Prob(JB):	0.682
Kurtosis:	2.836	Cond. No.	215.

Figure 5.5. The results of the second round of optimization

Source: based on data from the State Statistics Service of Ukraine, www.ukrstat.gov.ua.

For the model of the third round of optimization (Figure 5.6), the variable SDG_07_10 was excluded, and in the fourth round – SDG_08_11 SDG_07_20 (Figure 5.7).

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0106	0.005	2.037	0.064	-0.001	0.022
SDG_07_11	-0.0357	0.026	-1.370	0.196	-0.093	0.021
SDG_07_20	0.0144	0.022	0.665	0.518	-0.033	0.062
SDG_07_50	0.5277	0.012	45.752	0.000	0.503	0.553
SDG_13_20	0.0044	0.004	1.139	0.277	-0.004	0.013
SDG_08_10	0.4620	0.013	35.216	0.000	0.433	0.491
SDG_12_20	0.0035	0.003	1.163	0.268	-0.003	0.010
INNOV	-0.0020	0.003	-0.679	0.510	-0.008	0.004

Omnibus:	0.524	Durbin-Watson:	2.320
Prob(Omnibus):	0.770	Jarque-Bera (JB):	0.404
Skew:	0.312	Prob(JB):	0.817
Kurtosis:	2.692	Cond. No.	164.

Figure 5.6. The results of the third round of optimization

Source: based on data from the State Statistics Service of Ukraine, www.ukrstat.gov.ua.

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0077	0.003	2.685	0.019	0.002	0.014
SDG_07_11	-0.0185	0.004	-5.268	0.000	-0.026	-0.011
SDG_07_50	0.5238	0.010	53.802	0.000	0.503	0.545
SDG_13_20	0.0033	0.003	0.968	0.351	-0.004	0.011
SDG_08_10	0.4686	0.008	55.566	0.000	0.450	0.487
SDG_12_20	0.0032	0.003	1.091	0.295	-0.003	0.010
INNOV	-0.0005	0.002	-0.274	0.788	-0.005	0.004

Omnibus:	1.616	Durbin-Watson:	2.359
Prob(Omnibus):	0.446	Jarque-Bera (JB):	0.855
Skew:	0.507	Prob(JB):	0.652
Kurtosis:	3.009	Cond. No.	56.5

Figure 5.7. The results of the fourth round of optimization

Source: based on data from the State Statistics Service of Ukraine, www.ukrstat.gov.ua.

The optimization results in the fifth (Figure 5.8) and sixth rounds (Figure 5.9) were still not acceptable, and only in the seventh round where the initial requirements met (Figure 5.10).

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0076	0.003	2.779	0.015	0.002	0.013
SDG_07_11	-0.0183	0.003	-5.569	0.000	-0.025	-0.011
SDG_07_50	0.5246	0.009	58.289	0.000	0.505	0.544
SDG_13_20	0.0034	0.003	1.007	0.331	-0.004	0.011
SDG_08_10	0.4676	0.007	62.925	0.000	0.452	0.484
SDG_12_20	0.0031	0.003	1.100	0.290	-0.003	0.009

Omnibus:	2.346	Durbin-Watson:	2.338
Prob(Omnibus):	0.309	Jarque-Bera (JB):	1.303
Skew:	0.623	Prob(JB):	0.521
Kurtosis:	3.097	Cond. No.	52.0

Figure 5.8. Results of the fifth round of optimization

Source: based on data from the State Statistics Service of Ukraine, www.ukrstat.gov.ua.

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0092	0.002	4.221	0.001	0.005	0.014
SDG_07_11	-0.0171	0.003	-5.598	0.000	-0.024	-0.011
SDG_07_50	0.5184	0.007	79.359	0.000	0.504	0.532
SDG_08_10	0.4722	0.006	80.793	0.000	0.460	0.485
SDG_12_20	0.0030	0.003	1.081	0.297	-0.003	0.009

Omnibus:	2.268	Durbin-Watson:	2.342
Prob(Omnibus):	0.322	Jarque-Bera (JB):	0.791
Skew:	0.353	Prob(JB):	0.673
Kurtosis:	3.671	Cond. No.	33.9

Figure 5.9. The results of the sixth round of optimization

Source: based on data from the State Statistics Service of Ukraine, www.ukrstat.gov.ua.

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0103	0.002	5.221	0.000	0.006	0.014
SDG_07_11	-0.0152	0.003	-6.014	0.000	-0.021	-0.010
SDG_07_50	0.5167	0.006	80.862	0.000	0.503	0.530
SDG_08_10	0.4726	0.006	80.584	0.000	0.460	0.485

Omnibus:	0.844	Durbin-Watson:	2.229
Prob(Omnibus):	0.656	Jarque-Bera (JB):	0.066
Skew:	0.018	Prob(JB):	0.967
Kurtosis:	3.279	Cond. No.	30.1

Figure 5.10. The results of the seventh round of optimization

Source: based on data from the State Statistics Service of Ukraine, www.ukrstat.gov.ua.

Figure 5.11 presents all the results of OLS modeling for energy efficiency functions and selected endogenous indicators.

The seventh-round optimization model is shown below (2.6):

$$SDG\_07\_30_t = 0.0103 + 0.0152 \cdot SDG\_07\_11_t + 0.5167 \cdot SDG\_07\_50_t + 0.4726 \cdot SDG\_08\_10_t + \varepsilon_t \quad (2.6)$$

Considering the modeling results, increasing the dependence on energy imports by-products by 1% in Ukraine leads to an increase in energy productivity by 51.67% under other constant conditions.

The results of hypothesis testing for the seventh OLS model are presented in Table 5.1. Both the RESET test and the Jarque-Bera test show that the seventh model may be correct. A statistic of 1,199 and a p-score of 0.274 on the RESET test and a statistic of 0.011 and a p-score of 0.994 on the Jarque-Bera test lead to the conclusion that the seventh model is correct (and hypothesis H0 is rejected at 5% significance).

	Model1	Model2	Model3	Model4	Model5	Model6	Model7
SDG_07_10	0.0035	0.0042					
	(0.0130)	(0.0080)					
SDG_07_11	-0.0449	-0.0480	-0.0357	-0.0185***	-0.0183***	-0.0171***	-0.0152***
	(0.0582)	(0.0356)	(0.0261)	(0.0035)	(0.0033)	(0.0030)	(0.0025)
SDG_07_20	0.0202	0.0220	0.0144				
	(0.0379)	(0.0266)	(0.0217)				
SDG_07_50	0.5269***	0.5261***	0.5277***	0.5238***	0.5246***	0.5184***	0.5167***
	(0.0169)	(0.0123)	(0.0115)	(0.0097)	(0.0090)	(0.0065)	(0.0064)
SDG_13_20	0.0044	0.0045	0.0044	0.0033	0.0034		
	(0.0044)	(0.0040)	(0.0039)	(0.0035)	(0.0033)		
SDG_08_10	0.4622***	0.4626***	0.4620***	0.4686***	0.4676***	0.4722***	0.4726***
	(0.0152)	(0.0136)	(0.0131)	(0.0084)	(0.0074)	(0.0058)	(0.0059)
SDG_08_11	-0.0004						
	(0.0050)						
SDG_12_20	0.0031	0.0030	0.0035	0.0032	0.0031	0.0030	
	(0.0037)	(0.0033)	(0.0030)	(0.0029)	(0.0028)	(0.0028)	
Intercept	0.0112	0.0116*	0.0106*	0.0077**	0.0076**	0.0092***	0.0103***
	(0.0079)	(0.0057)	(0.0052)	(0.0029)	(0.0027)	(0.0022)	(0.0020)
INNOV	-0.0022	-0.0024	-0.0020	-0.0005			
	(0.0038)	(0.0031)	(0.0029)	(0.0019)			
R-squared	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
R-squared Adj.	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Standard errors in parentheses.
* p<.1, ** p<.05, ***p<.01

Figure 5.11. OLS regression simulation results
Source: Kolosok et al. (2020b)

Analyzing European energy efficiency policy issues is essential to understand the trajectory of the innovation movement of Ukraine's economy, adaptation of green innovations, and strengthening Ukraine's European integration aspirations. The goals of the energy market development strategy are to harmonize European standards of energy regulation, measure energy efficiency and energy saving, and build a sustainable energy system. Funding for green innovation has its advantages in achieving sustainable development goals.

Table 5.1. The result of testing the hypotheses of the OLS model of the seventh round of optimization

The test	Statistics	p-value	Test result
RESET	F= 1.199	0.274	H_0: Rejected
Jarque-Bera	JB= 0.011	0.994	H_0: Rejected

Source: Kolosok et al. (2020b)

Using OLS modeling for energy efficiency functions and selected endogenous indicators, variables were investigated to explain Ukraine's energy efficiency sources over the past twenty years. According to the results of OLS modeling, the efficiency of energy policy in Ukraine is influenced by such parameters as 'dependence on energy imports by products' (SDG_07_50), 'real GDP per capita' (SDG_08_10), and 'final energy consumption (SDG_07_11). Estimation of the last variable has a much smaller effect on the regression results and shows a negative relationship with energy efficiency. The model results were verified using RESET and Jarque-Bera tests and established the correctness of the proposed model (Kolosok et al., 2020b, Kolosok et al., 2020c).

5.2 Modeling the balance of electricity consumption in the electrical grid

The availability of open energy data is essential for analyzing the state of the energy system in real-time, forecasting internal processes, and, especially, for the development of energy policy at all levels of government. Creating access to a modern energy database is not a significant challenge for users. Still, it is also highly multidisciplinary, related to other aspects such as health, education, geography, and equality. The use of open data gives new perspectives to the scientific community and politicians in creating efficient energy systems. In addition, the expansion of open data, databases of networks such as electricity generation capacity, consumption, electrical loads, geo-referenced data help fill knowledge gaps and contribute to the goals of sustainable development in the energy sector and the Green Deal agenda. Ukraine also has commitments to several environmental, energy, and climate partnerships (COM / 2019/640, 2019).

Our study is based on the hourly electricity balance of the Integrated Energy System (IES) of Ukraine. The data were downloaded from the Open Data Portal of Ukraine. Considering the scatter plots of normalized data for the input variables of the model of the hourly power balance model of UES of Ukraine (Figure 5.12), visually there is a positive linear relationship between electricity consumption and total electricity production in Ukraine (E_TEP), indicating almost 100% electricity use in the domestic market E_UIM).

From the appearance of the histograms of the input variables of the balance of electricity consumption (Figure 5.13), it is clear that the data have different distribution functions. Data have both β-distribution and normal, multimodal, rectangular, and discrete data distributions. However, the distribution of values with a skew to the right prevails, as their averages are greater than the median (Figures 5.14 and 5.15).

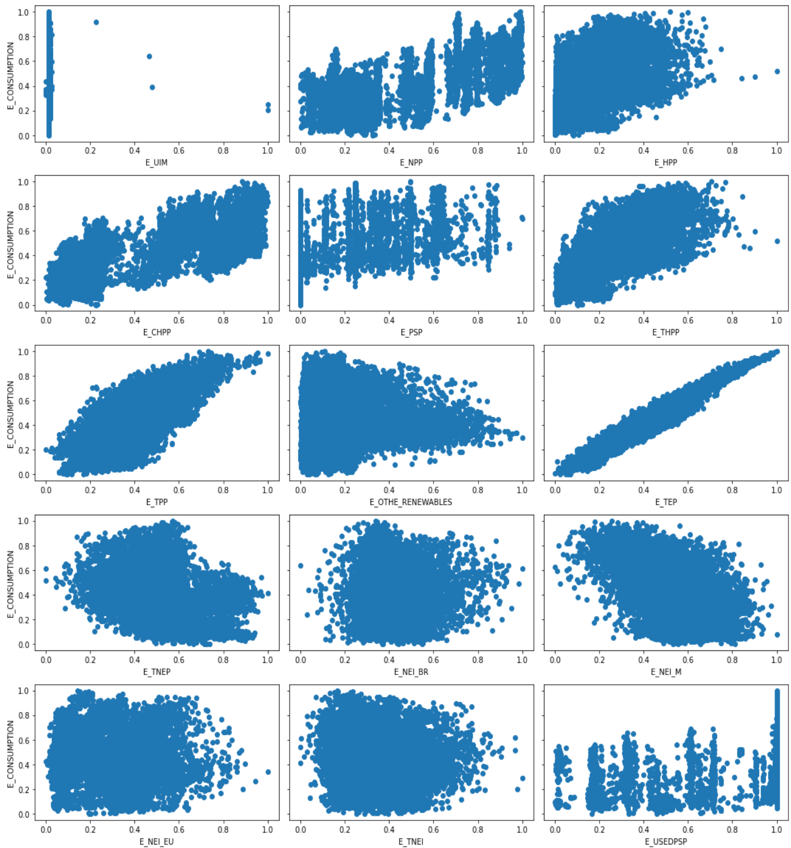

Figure 5.12. Scattering graphs for input variables of the electricity balance model

Source: based on data from the Open Data Portal, https://data.gov.ua.

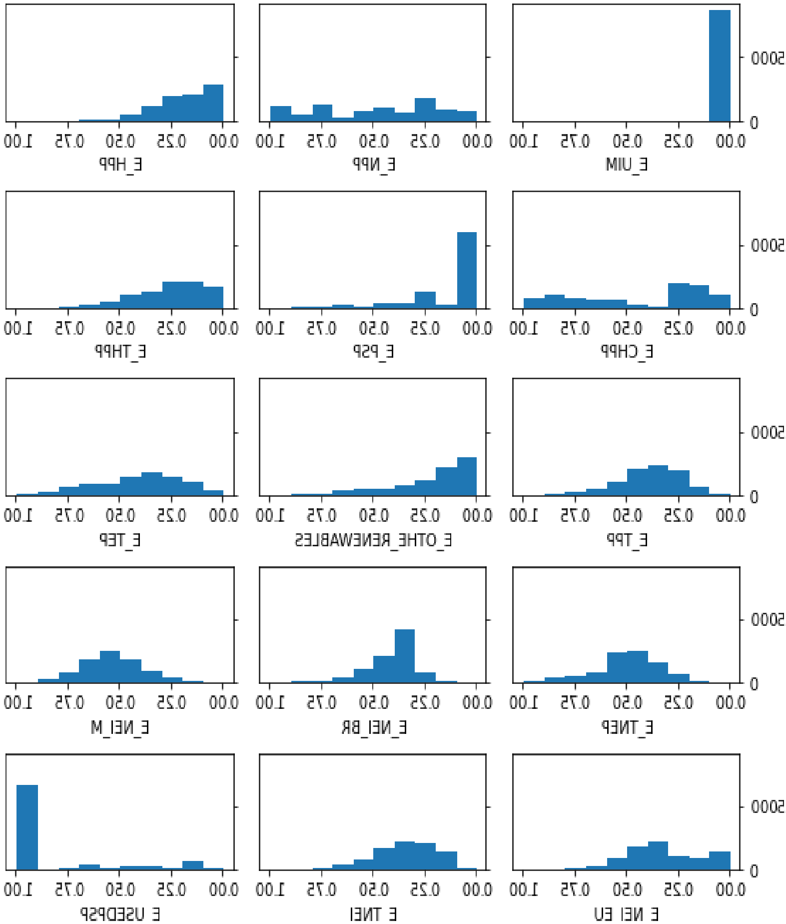

Figure 5.13. Histograms for input variables of the power balance model

Source: based on data from the Open Data Portal, https://data.gov.ua.

	E_CONSUMPTION	E_NPP	E_HPP	E_CHPP	E_PSP	E_THPP	E_TPP	E_OTHE_RENEWABLES	E_TEP
count	8759.000	8759.000	8759.000	8759.000	8759.000	8759.000	8759.000	8759.000	8759.000
mean	0.424	0.486	0.186	0.427	0.116	0.254	0.384	0.223	0.410
std	0.210	0.293	0.141	0.308	0.199	0.165	0.148	0.193	0.200
min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25%	0.286	0.233	0.068	0.174	0.000	0.125	0.279	0.075	0.261
50%	0.401	0.481	0.170	0.246	0.000	0.225	0.373	0.159	0.382
75%	0.566	0.738	0.280	0.727	0.247	0.367	0.475	0.321	0.551
max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Figure 5.14. Descriptive statistics of variables E_CONSUMPTION, E_NPP, E_HPP, E_CHPP, E_PSP, E_THPP, E_TPP, E_OTHE_RENEWABLES, E_TEP

Source: based on data from the Open Data Portal, https://data.gov.ua.

	E_TNEP	E_NEI_BR	E_NEI_M	E_NEI_EU	E_TNEI	E_USEDPSP	E_UIM
count	8759.000	8759.000	8759.000	8759.000	8759.000	8759.000	8759.000
mean	0.498	0.412	0.533	0.324	0.348	0.851	0.014
std	0.155	0.114	0.147	0.172	0.144	0.285	0.017
min	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25%	0.395	0.341	0.440	0.191	0.233	0.971	0.013
50%	0.485	0.385	0.540	0.342	0.338	1.000	0.013
75%	0.576	0.461	0.634	0.445	0.440	1.000	0.013
max	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Figure 5.15. Descriptive statistics of variables E_TNEP, E_NEI_BR, E_NEI_M, E_NEI_EU, E_TNEI, E_USEDPSP, E_UIM

Source: based on data from the Open Data Portal, https://data.gov.ua.

Therefore, for modeling purposes, the balance of electricity consumption can be described using the logarithmic function presented in (Kolosok et al., 2020a). Regression of OLS modeling of partial variables of the logarithmic function (Figures 5.16 and 5.17) allows us to draw the following conclusions:

- total electricity production in Ukraine described 93.1% of variation in electricity consumption (E_TEP), with the share of balancing in 2019 using nuclear energy production prevailing (E_NPP describes 41.9% of variation), as well as electricity production from fossil energy sources:
- variable E_CHPP described 54.7%, E_THPP described 53.9%, and E_TPP - 47.3% variation;
- Ukrainian electricity consumption is characterized by a rather small percentage of balancing electricity demand with renewable energy:
- 24.9% of the variation in energy consumption could be described by hydropower (E_HPP), although this type of energy production is quite flexible, and only 0.4% - using other renewable energy sources (E_OTHE_RENEWABLES).

The general modeling of electricity balancing results is presented in Figure 5.18.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
E_CHPP			0.000***				
			(0.000)				
E_HPP		0.000***					
		(0.000)					
E_NPP	0.000***						
	(0.000)						
E_OTHE_RENEWABLES							0.000***
							(0.000)
E_PSP				0.000***			
				(0.000)			
E_THPP					0.000***		
					(0.000)		
E_TPP						0.000***	
						(0.000)	
Intercept	9.058***	9.606***	9.412***	9.676***	9.481***	9.220***	9.702***
	(0.008)	(0.002)	(0.003)	(0.002)	(0.003)	(0.006)	(0.002)
R-squared	0.419	0.249	0.547	0.175	0.539	0.473	0.004
R-squared Adj.	0.419	0.249	0.547	0.175	0.539	0.473	0.004
N	8759	8759	8759	8759	8759	8759	8759
p-value	0.42	0.25	0.55	0.17	0.54	0.47	0.00

Standard errors in parentheses.
* p<.1, ** p<.05, ***p<.01

Figure 5.16. OLS simulation results (E_CHPP, E_HPP, E_NPP, E_OTHE_RENEWABLES, E_PSP, E_THPP, E_TPP)
Source: based on data from the Open Data Portal, https://data.gov.ua.

	(8)	(9)	(10)	(11)	(12)	(13)	(14)
E_NEI_BR			-0.000***				
			(0.000)				
E_NEI_EU					-0.000***		
					(0.000)		
E_NEI_M				-0.002***			
				(0.000)			
E_TEP	0.000***						
	(0.000)						
E_TNEP		-0.000***					
		(0.000)					
E_UIM							-0.000
							(0.001)
E_USEDPSP						0.000***	
						(0.000)	
Intercept	8.676***	9.759***	9.714***	9.599***	9.703***	9.748***	9.712***
	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)	(0.002)	(0.002)
R-squared	0.931	0.066	0.002	0.236	0.001	0.217	0.000
R-squared Adj.	0.931	0.066	0.002	0.236	0.001	0.217	-0.000
N	8759	8759	8759	8759	8759	8759	8759
p-value	0.93	0.07	0.00	0.24	0.00	0.22	0.00

Standard errors in parentheses.
* p<.1, ** p<.05, ***p<.01

Figure 5.17. OLS regression simulation results (E_NEI_BR, E_NEI_EU, E_NEI_M, E_TEP, E_TNEP, E_UIM, E_USEDPSP)

Source: based on data from the Open Data Portal, https://data.gov.ua.

If we consider the case of Ukraine, the generation of electricity is generally focused on the domestic market. Peak and the most significant variations in the production and consumption of electricity are traditionally observed in the winter months. Conversely, the minimum level of electricity generation and consumption was found in the warmest period: from May to October.

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	8.7343	0.002	5109.373	0.000	8.731	8.738
E_NPP	9.371e-06	1.99e-07	46.995	0.000	8.98e-06	9.76e-06
E_HPP	3.686e-07	4.39e-07	0.840	0.401	-4.91e-07	1.23e-06
E_CHPP	1.204e-05	7.95e-07	15.143	0.000	1.05e-05	1.36e-05
E_PSP	-5.445e-07	5.26e-07	-1.034	0.301	-1.58e-06	4.87e-07
E_THPP	1.186e-05	2.92e-07	40.565	0.000	1.13e-05	1.24e-05
E_TPP	9.389e-06	1.42e-07	66.284	0.000	9.11e-06	9.67e-06
E_OTHE_RENEWABLES	1.788e-05	2.5e-07	71.538	0.000	1.74e-05	1.84e-05
E_TEP	4.851e-05	9.1e-08	533.130	0.000	4.83e-05	4.87e-05
E_TNEP	-6.815e-05	1.35e-05	-5.056	0.000	-9.46e-05	-4.17e-05
E_NEI_BR	-1.69e-05	3.53e-06	-4.781	0.000	-2.38e-05	-9.97e-06
E_NEI_M	4.579e-05	4.11e-06	11.131	0.000	3.77e-05	5.39e-05
E_NEI_EU	-1.99e-05	3.54e-06	-5.625	0.000	-2.68e-05	-1.3e-05
E_TNEI	8.998e-06	1.01e-05	0.890	0.373	-1.08e-05	2.88e-05
E_USEDPSP	3.939e-07	1.35e-05	0.029	0.977	-2.6e-05	2.68e-05
E_UIM	-5.876e-05	3.7e-05	-1.587	0.113	-0.000	1.38e-05

Omnibus:	951.175	Durbin-Watson:	0.187
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1285.884
Skew:	-0.907	Prob(JB):	5.94e-280
Kurtosis:	3.483	Cond. No.	3.80e+17

Figure 5.18 Results of general OLS regression simulation of electricity consumption balance
Source: based on data from the Open Data Portal, https://data.gov.ua.

But if you look at renewable energy production, there are noticeable differences between electricity consumption and renewable energy production. This situation arises in connection with generating electricity from new renewable energy sources (Kolosok et al., 2020a).

CONCLUSIONS

Following the Sustainable Development Goals, the problem of reconciling socio-ecological and economic contradictions and introducing environmentally friendly products, technologies, and industries is recognized by the world expert community as a global priority of the world level.

The monograph considers the implementation of sustainable business models in the context of careful consideration of stakeholders' environmental, social and economic interests, leveling internal systemic contradictions that arise in the process of their collaboration at all stages of the life cycle of green energy management.

One of the main priorities of today is the development of energy-efficient technologies that stimulate energy independence and coherence of all stakeholders (organizations - energy market participants), which have the authority to regulate, control, and promote the introduction of clean energy generation.

The practical value of this monograph is that it describes the basic concepts and structural relationships of the eco-energy economy and contains a set of control parameters that make it a tool for its scaling in different countries, industries, and regions.

The study results presented in the monograph are the necessary basis for accelerating the process of achieving the goals of sustainable development as one of the steps towards an environmentally neutral economy. This work is comprehensive, thorough research that summarizes the results of studies of the environmental and economic impact of energy transformations.

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