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FACULTY OF INTERNATIONAL RELATIONS**

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**INNOVATIVE POLICY IN ENERGY
INDUSTRY OF UKRAINE**

Dissertation

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Mariya Kuznetsova

**UNIVERSITY OF ECONOMICS IN BRATISLAVA
FACULTY OF INTERNATIONAL RELATIONS**

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Dissertation

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ABSTRAKT

KUZNETSOVA, Mariya: *Innovative policy in energy industry of Ukraine*. – Ekonomická univerzita v Bratislave. Fakulta medzinárodných vzťahov; Katedra medzinárodných vzťahov a hospodárskej diplomacie. – Školiteľ záverečnej práce: prof. Ing. Martin Grešš, PhD. – Bratislava: FMV, 2024, 145 s.

Hlavným cieľom diplomovej práce je vytvoriť inovatívnu politiku pre udržateľný rozvoj a dlhodobé efektívne fungovanie energetického trhu na Ukrajine, berúc do úvahy moderné geopolitické výzvy a príležitosti. Práca je rozdelená do niekoľkých kapitol. Prvá časť je venovaná teórii inovácií a udržateľnosti, ako aj metodológii výskumu. Druhá časť poskytuje prehľad energetického trhu na Ukrajine, jeho historické, geopolitické a ekonomické pozadie. Ďalšia časť práce vysvetľuje súčasné trendy a potenciálne scenáre rozvoja založené na špičkových technológiách a prevádzkových postupoch. Záverečná kapitola sa zaoberá prezentáciou koncepčných záverov a diskusiou o dizertačnej práci.

Táto práca dokazuje, že energetický sektor na Ukrajine je jedným z najzraniteľnejších, ale zároveň najvýznamnejších segmentov hospodárstva v rámci súčasných geopolitických výziev. Ukrajinský energetický priemysel čelí bezprecedentným hrozbám spojeným s vážnym poškodením infraštruktúry, poklesom dopytu po elektrine, nedostatkom paliva, prevádzkovými komplikáciami, systémovou nestabilitou a investičnou neistotou. Napriek týmto značným výzvam Ukrajina zostáva na ceste k plnému členstvu v Európskej únii. Táto práca zdôrazňuje, že na pokračovanie synchronizácie ukrajinského energetického systému s kontinentálnou Európou, ako aj na zabezpečenie dlhodobej cezhraničnej efektívnosti, je potrebné stanoviť inovatívnu politiku pre udržateľný rozvoj energetického trhu na Ukrajine na základe odôvodnených princípov, ktorá zohľadní strategické odporúčania pre zmenu palivového mixu a prevádzkové inovácie s cieľom zabezpečiť odolné oživenie Ukrajiny.

Kľúčové slová: inovatívna politika, trvalo udržateľný rozvoj, trh s elektrinou, medzinárodné vzťahy.

ABSTRACT

KUZNETSOVA, Mariya: *Innovative policy in energy industry of Ukraine*. – University of Economics in Bratislava. Faculty of International Relations; Department of International Economic Relations and Economic Diplomacy. – Supervisor: prof. Ing. Martin Grešš, PhD. Bratislava: FMV, 2024, 145 p.

The main aim of the thesis is to establish innovative policy for sustainable development and long-lasting efficient performance of energy market in Ukraine taking into account modern geopolitical challenges and opportunities. The work is divided into several chapters. The first part is dedicated to the theory of innovation and sustainability as well as research methodology. The second part provides an overview of the energy market in Ukraine, its historical, geopolitical and economic background. The next part of the thesis explains the current trends and potential development scenarios based on high-end technologies and operational practices. The final chapter deal with the presentation of conceptual conclusions and discussion of the dissertation.

This thesis demonstrates that energy sector in Ukraine is one of the most vulnerable but significant segments of the economy in scope of current geopolitical challenges. The Ukrainian energy industry has faced unprecedented threats connected with severe infrastructure damages, decline in electricity demand, fuel shortages, operational complications, systemic instability and investment uncertainty. Regardless of these considerable challenges, Ukraine remains on a trajectory toward full membership in the European Union. This thesis emphasizes that in order to continue the synchronization of Ukrainian energy system with Continental Europe as well as ensure long-term trans-border efficiency an innovative policy for sustainable development of energy market in Ukraine is to be set on a grounded basis taking into account strategic recommendations for fuel mix shift and operational innovations to provide resilient recovery of Ukraine.

Keywords: innovative policy, sustainable development, electricity market, international relations.

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LIST OF ABBREVIATIONS

CBAM	Carbon Border Adjustment Mechanism
CCUS	Carbon Capture, Utilization and Storage
CHP	Combined Heat and Power Plants
EBRD	European Bank for Reconstruction and Development
EU	European Union
GDP	Gross Domestic Product
HPP	Hydro power plant
NPP	Nuclear power plant
RES	Renewable Energy Sources
TPP	Thermal power plant
TSO	Transmission System Operator
ENTSO-E	European Network of Transmission System Operators for Electricity
SPP	Solar Power Plant

INTRODUCTION

Modern geopolitical conditions for the world economy functioning are uncertain due to the influence of various risk groups – from natural and systemic to informational and reputational. For different states and regions social well-being and environmental safety remain priority areas, whereas their achievement is possible owing to the systemic transformation of competitive markets and gradual activation of informatization and digitalization processes.

Under the global political reshaping, military impacts and development challenges in the context of a continuous increase in the production potential of countries and regions, innovative approach is becoming the most significant one in scope of influencing sustainable economic security. The state competitiveness in general is determined by the capability of industrial enterprises thoroughly develop and introduce innovations, including decision-making, into their activities. At the same time, the economy of Ukraine today is based, to a large extent, on the raw material industries and military purposes where consistent innovation is not a priority. Moreover, strong geopolitical factor due to military threats and wartime implications cause alterations not only to the Ukrainian economy, but also European partners. Since in countries with a high level of economic development it is the introduction of innovations that is an influential factor in ensuring stable economic growth, in Ukraine innovation should become a necessary precondition for creating recovery mechanisms in the energy sector to ensure its long-term geopolitical security.

One of the most effective ways to manage risks and implement adaptation mechanisms is to ensure the sustainable development of modern industries based on economic efficiency, social responsibility and environmental awareness. Particularly relevant in modern conditions is the achievement of a synergistic effect from the combination of these elements in the activities of energy companies, as energy independence and energy efficiency are key priorities for the comprehensive development of Ukraine and other countries in the strategic prospect. As the global energy system is to function in the synchronous unity of all actors in international

markets, it is impossible to achieve sustainable development of the energy industry without innovative support for the above-mentioned systemic transformations.

Wartime reality brought a new vision on global future. Grounded shifts took place within all industrial and social sectors. High level of uncertainty is inevitable under such circumstances. Energy sector, especially electricity generation, is not exceptional. The one thing is clear: a brand-new global leadership is to be established in order to prevent irreversible geopolitical complications. Mutually beneficial collaboration as well as sustainability priority constitute the way countries have to move in the upcoming development. The unprecedented market shifts arose by means of chain effects caused by world interactions. In order to set up a new normal there is to be total data transparency on energy and climate that will enable crucial decision-making, investments and democratic stakeholder engagement. Moreover, a practical roadmap for further net zero is to be updated taking into account already existing downward trends and unmet explicit goals. Comprehensive measures will enable thorough data, information and model analysis in order to contribute to capacity building support and measure prioritization as well as development of robust energy and climate strategies within the modern sustainability paradigm.

This research seeks to construct a comprehensive conceptual framework that systematically elucidates the range of current geo-political as well as national risks and business opportunities as regards establishing innovative sustainable development policy in energy generation market in Ukraine. The framework will be developed through a synthesis of existing academic literature and empirical insights generated from up-end field experts as well as existing experience never seen in any country due to geopolitical constraints.

Through a critical analysis of existing peculiarities, damages and associated risks, challenges and prospective benefits, this dissertation aims to provide an innovative concept for sustainable development in order to assure long-term resilience of energy market in Ukraine. Ultimately, the research aspires to contribute to broader goals of strategic economic recovery, social progress as well as ecological compliance in geopolitical scope.

The dissertation will be structured and organized in the following way. The **theoretical framework** places a major focus on the grounded analysis of scientific literature and is structured into three subsections. The first subsection provides an outlook of modern innovation as well as constitutes innovative policy milestones. The second subsection represents the literature review on sustainability concept within its evolution from the historical perspective. It describes development marks from initiatives and declarations to practical implications and guidelines. The third subsection is aimed at sustainable management as a key prerequisite of efficient and innovative business development particularly in energy industry. The fourth subsection is to demonstrate the main aspects of energy industry, its history, features, local aspects, challenges and opportunities. Moreover, the comparative analysis of two energy systems taking place in Ukraine is also comprehensively examined. In the third subsection huge focus is placed on innovative policy model and its potential implications to energy sector in Ukraine.

The **main aim of the dissertation** is to establish innovative policy for sustainable development and long-lasting efficient performance of energy market in Ukraine taking into account modern geopolitical challenges and opportunities. The **research methodology** chapter is to demonstrate the scope of methods as well as practical instruments used to facilitate and obtain the key findings and answer the research questions. The **findings** with the focus on empirical work over the problematic under discussion are represented following the logic of both conceptual development of innovative policymaking and recommendations based on market analysis and forecasting that can be applied in practice. This section gives answers to the research questions, lists possible challenges and threats as well as provides instructions to follow in the long-term prospects taking into account various aspects of domestic energy market following geopolitical implications. The **conclusion** sums up the initial aims and findings of the research. It details the probable directions of innovative sustainable development of energy market in Ukraine as well its contribution to the global energy security.

1. THEORETICAL FRAMEWORK

Energy in general as well as electricity in particular are regarded as major prerequisites for open and non-open conflicts among countries on the global arena. Moreover, energy deficit is considered to become a huge strategic prevalence of some countries over others. Natural potential as well as generating capacities constitute enormous political advantage of the key energy market actors all over the world. Energy dominance of some regions sets up unprecedented market advantage as it enforces other countries to build up unique transition collaboration schemes in order to separate various markets and functional processes.

Energy sector in Ukraine is one of the most vulnerable and crucial sectors of economy taking into account modern geopolitical challenges. At the same time, the Ukrainian energy industry has already faced a list of new, even more threatening challenges, such as nuclear terrorism with the seizure of nuclear power plants as well as numerous damages to critical infrastructure – electrical and gas networks. Moreover, there is a critical decrease in demand for energy products due to the fact that a huge part of Ukrainian population left the territory of the country. Thereby, a lot of business premises and production facilities are left behind because of the lack of demand and workforce as well as high operational risks due to constant attacks and regulation uncertainty. All these crucial shifts lead to more critical reduction in the level of payments in the energy system, and the decision to continue synchronizing the energy system of Ukraine with the energy system of Continental Europe, despite the hostilities throughout the country, the fuel crisis etc. Nevertheless, Ukraine is considered to become a full-scale member of the European Union in the upcoming prospect despite the abovementioned challenges.

Under the contemporary conditions Ukraine is regarded as both victim and innovator in scope of the ongoing war. On the one hand, constant damage of production facilities causes irreversible shifts in the domestic market. On the other hand, such a vulnerable position may open new horizons and bring unprecedented innovations to already existing business practices thus leading to a different market model.

1.1 Innovation as a complex notion in modern economy

The transition economy is characterized by instability of the institutional environment under significant structural changes. Society develops through the introduction of innovations, and the relevant institutions stimulate or restrain the socio-economic processes of their straightforward implementation. They are a set of various factors and mutually dependent processes that are fixed both informally (in behavioral patterns) and formally (in regulations).

Innovation is a complex research object, as it presupposes a unique set of properties as well as cause-and-effect relationships. The epistemological cognitive aspect is associated with the logic of unity development and contradictions of the elements. A deep analysis of modern scientific literature enables to highlight a number of key aspects of the potential role of innovation:

- as a driving force of scientific and technological progress and sustainable development;
- as a complex system of states and connections which does not possess the signs of constancy and is in constant motion;
- as a process of comprehensive knowledge transformation into a final product with atypical properties and added value;
- as interaction sphere of development theory and practice;
- as a socio-cultural phenomenon providing the basis for the creation of fundamentally new ways to meet the limitless needs of society.

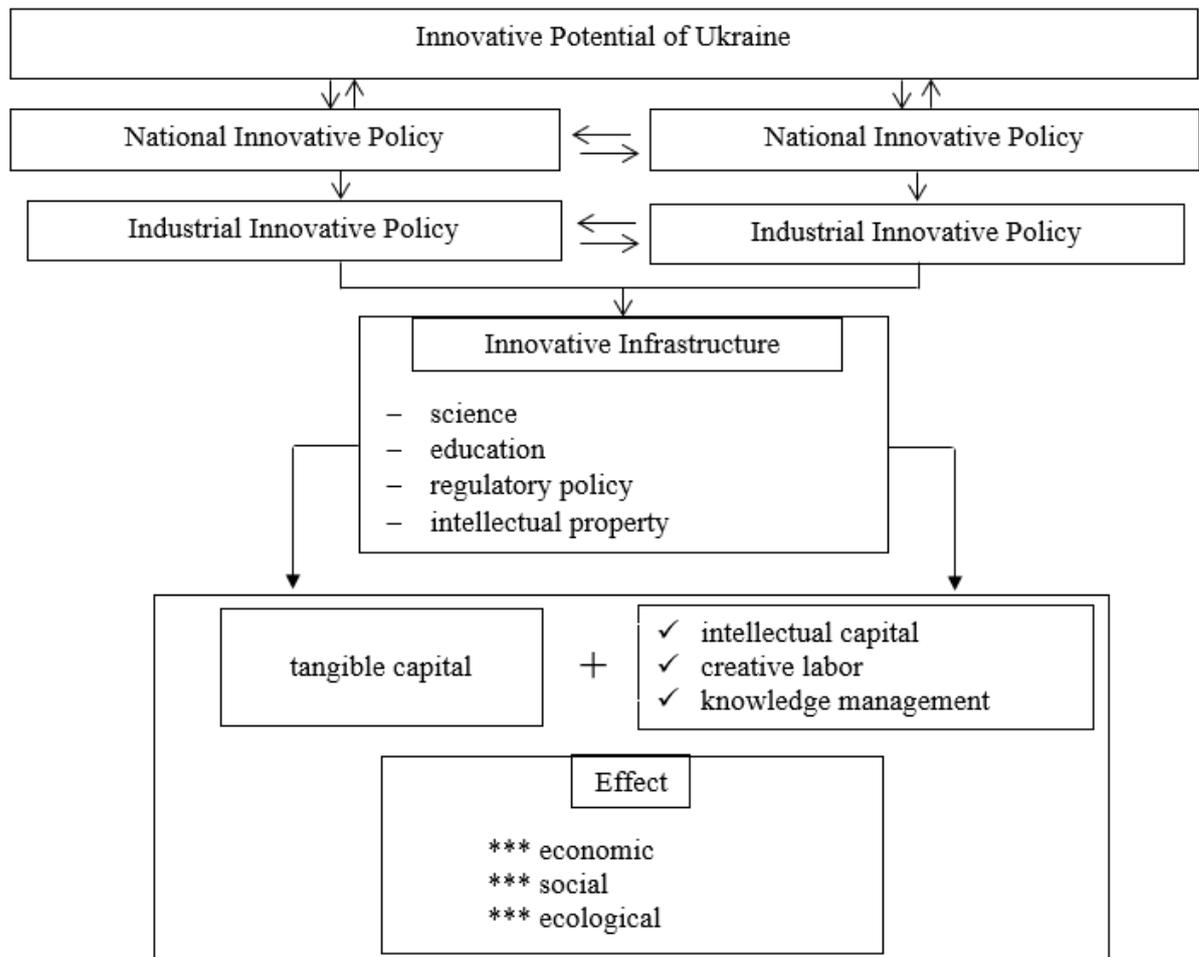
Innovations go a long way of implementation from the object of scientific research or idea to the system of social relations, ending up the resulting effect. Innovation activities ensure the creation of a new product, its improvement and market entry. It is a dynamic system aimed at saving limited resources, reducing production costs, increasing labor productivity and efficiency in general. Modern approaches and methods ensure an increase in the competitiveness of industries or regions as well as the formation of a powerful potential for the development of productive forces as well as organizational and technological systems.

The progressive economic development of any country depends on the effectiveness of innovative potential use of, first of all, specific knowledge and scientific advancements. Investments in intangible assets, technology and artificial intelligence are key to realizing both disruptive and institutional transformations. Information and reliable means of its protection are of particular importance in the post-industrial society. Through the coordination of the efforts of science, education, business and state, a process of high-quality interaction of all agents with material and informational flows takes place, which lays the foundation for the formation of an innovative type of economy as well as cross-border mechanisms for the development of intellectual capital and comprehensive knowledge accumulation.

In market conditions a significant reform of social relations and relevant institutions is expected. An innovative economy ensures the objectivity of interaction between state, business and society through the organization of high-tech production as well as the construction of managerial and regulatory rules. The institutions of civil society, liberalism, competition lay the grounds for the commercialization of science and knowledge in order to develop a competitive market and optimize risks. The intensification of scientific and technological progress and the implementation of principles of post-industrial society are impossible in conditions of insufficient efficiency of institutional mechanisms for promoting the development of an innovative economy with an imbalance between basic (property, power) and derivative (competition, price) institutions. An effective system provides for the attraction of intellectual labor and social capital (Figure 1).

The innovation process is a complex system of interrelated elements that, in a synergistic unity, create a qualitatively new product of social production and consumption. Both in economic theory and managerial practice, the product or service creation is preceded by the presence of an unmet need, which arises as a result of social life.

Figure 1. Conceptual mechanism for the innovative potential implementation in Ukraine in the context of sustainable development



Source: own compilation.

The growth in demand initiates the development of practical solutions for the idea implementation, given the limited resources. In order to create a high-quality product public-private incorporation as well as cross-border cooperation take place. As a rule, this interaction is a crucial characteristic at the stage of diffusion of innovations, when their gradual entry into various industries and spheres develops outside the country of origin. In modern conditions of the galloping development of technology all around the world there is a reduction in the time limits for the search of conceptual solutions and the selection of technological justifications, while the organization and improvement of any production is procedurally long and economically costly.

The effectiveness of the innovative process organization as a logical result of the implementation of innovative activities by enterprises, especially in the energy

sector, depends on many factors. In particular, despite the relative typicality of general mechanisms for creating and mastering innovations, a distinctive feature is the need to respond to a request from key external stakeholders (society, communities) for green production.

1.2 Sustainability concept: origins and further application

Innovative component in modern energy policy is inextricably linked to the modern paradigm of *sustainability*. Sustainable development was predominantly a concept of global development with a focus on solving crucial socio-economic issues on a planetary scale. The theoretical and practical basis for the emergence of sustainable development concept was the theory of social welfare, because the term *development* was often identified with the concepts of *welfare* and *prosperity* (well-being).

In the 1970s and 1980s several concepts appeared simultaneously, reflecting the socio-political views of people in different countries of the world. This was due to the active spread of the ideas of environmentalism and a critical rethinking of human habits and lifestyles.

Initially, the concept of sustainable development put forward the idea of the need to ensure such conditions so that future generations would inherit the Earth with all its capabilities not worse than those that exist today. The ideas of social justice were defined as fundamental principles for further processes of social development. In addition, special attention was paid to environmental issues, in particular, awareness of the limited availability of world resources, especially mineral resources.

The most widely used definition of sustainable development in scientific circles is that proposed in 1987 by the International Commission on Environment and Development (the so-called Brundtland Commission). According to this approach, sustainable development is interpreted as the process of meeting the needs of the present generation without compromising the ability of future generations to meet their own needs.

At the famous conference on environment and development, held under the auspices of the UN in Rio de Janeiro (Brazil, 1992), the strategy for the transition of humanity

to a new stage of development – *sustainable development* – was approved. This stage reflected the transition to a new phase of global development of socio-production relations, based on the understanding of the need for structural changes in the attitude of human to the surrounding world and the methods of using natural resources.

As a result of the conference in Rio de Janeiro, an action program was announced aimed at creating conditions for the qualitative development of civilization through comprehensive partnerships. This versatile approach provided for the improvement of the international division of labor and trade while taking into account three main aspects: social, environmental and economic.

Within the international legal framework, the basic principles for the development and phased implementation of program actions aimed at ensuring sustainable rates of economic growth were determined. This included the primary requirement to provide the poorest segments of the population with the necessities of life and to create conditions for productive activity.

In 2000 United Nations adopted 8 Millennium Development Goals (UN, 2000) aimed at improving the living standards of Third World countries, especially combating poverty and hunger as well as reducing mortality rates. The 2002 World Summit on Sustainable Development laid the foundation for defining a new world order, formally endorsing the primacy of sustainable development concept as a prerequisite for qualitative changes within three directions – economic, environmental and social. In 2012 the United Nations Conference on Sustainable Development (Rio+20) launched the process of identifying sustainable development goals based on 8 Millennium Development Goals. Rio+20 placed high emphasis on such issues as green economy and policy discussion on giving financial support for measures to implement sustainable development programs worldwide by 2015. Due to constant changes in the priorities for achieving several goals or their complex at once, the list of these goals was extended in 2015 (UN, 2015). Eventually, 17 Sustainable Development Goals and 169 targets were proclaimed and a particular time lag (by 2030) for reaching these goals was also set. According to the stated goals, socio-economic and political actors are able to choose among alternative and

complementary methods and practices of doing business, thereby encouraging the process of innovative techniques generation and highlighting the ways of ensuring the conscious life of citizens as well as sustainable development of business and society within the framework of international benchmarks.

The United Nations has defined the key principle of gradual future transition to civil society (sustainable and inclusive) by means of *ensuring that no one is left behind* (UN, 2017). It envisages the revision of key concepts of economic development, focusing on the priority of social component in the prevention of discrimination in all forms – inequalities of opportunities, inequalities of outcomes (Holden, Linnerud, Banister, 2014).

The social paradigm of sustainable development differs significantly from the paradigm of an industrial (economic) society, which is based on the priority of economic growth through the widespread use of industrial methods of production, including agriculture (Verhun, Tarasenko, 2014). Among scientists there are lots of opinions on the conceptual essence of sustainable development, as most scholars and practitioners consider it as a guide to action and a panacea for today's global problems, but there is the opposite view – describing it as a manipulation of public consciousness to maintain economic growth only in particular countries and prevent such development in developing countries (Derkach, 2009). Accordingly, the concept itself is not only about goal, but a powerful basis for the formation of new social relations (Sidliar, 2015; Plachciak, 2010; Gram-Hanssen, 2014).

At the micro level ensuring the company sustainable development is reflected in the achievement of goal set (social, economic, technical and environmental) on the basis of consistent implementation of the principle of responsibility to the society both current and future. In this case the profit is not the ultimate goal to focus on. It is one of the economic goals, the latter are key guidelines for future changes and are enshrined in international directives. Over years the sustainability context, mainly declared at World Commission on Environment and Development (1987) and World Summit on Sustainable Development (2002), has been successfully incorporated into modern business practice, despite the global imperative status. However,

positive shifts within energy companies, if any, are insufficient for complex market-based changes in structural forces and competitive advantages on the inter-governmental level.

Since the concept of sustainable development encompasses the solution of numerous problems related to the functioning of modern society, in order to identify key areas of future structural transformations, the *triple bottom line* is gradually being introduced into scientific circulation (Rogers, Hudson, p. 5). Its main principle is the effective combination of three components – economic, environmental and social. Without proper integration of these criteria it is impossible to achieve a full-fledged relationship between the business sector, the environment and society in the context of sustainable development. The triple bottom line is already considered one of the most important and most promising metaphors of modern scientific thought at the beginning of the 21st century. In terms of its content, it creates a solid basis for assessing business efficiency, success rate of goal set and organizational performance, taking into account economic, social and environmental factors. Triple bottom line also serves as a practical basis for ensuring sustainable development.

The main goal of the comprehensive implementation of the concept of sustainable development is to achieve economic stability and environmental security in the long term through critical identification and conscious recognition of prioritized economic, environmental and social problems, as well as their targeted solutions, taking into account the existing natural resource potential and level of technological development of society.

At the initial stage, the concept of sustainable development was considered exclusively as a strategy for the future development within the global context. Over time, it started being extensively used to explain socio-economic processes at the level of the national economy. However, it is undeniable that the development of any economic system is based on property, particularly private property. Therefore, business involvement is a necessary condition for the successful implementation of sustainable development strategies at both micro- and macro- levels.

After extensive literature review and business practice analysis in this dissertation we can distinguish several scientific approaches to the definition of sustainable development of business (Table 1).

Table 1. Scientific approaches to category definition of sustainable business development

Approach	Definition
• value-based	- a state of achieving socially recognized value guidelines for building a socially responsible business - an element of creative development, which involves designing new value for a conscious consumer based on qualitative improvement of the enterprise
• business value	sustainability as a phenomenon based on achieving a high risk-balance of enterprise activities should ensure long-term competitiveness and contribute to goodwill increase and additional business monetization
• cost-effective	implementation of certain global initiatives is a highly costly and long-term process, the positive effect of which may not be financially tangible
• philanthropic	modern enterprise is to function in inseparable unity with stakeholders, especially those groups that are remotely interested and most vulnerable in order to build a sense of social attachment and loyalty
• resource-based	initiative to achieve sustainable development has a key prerequisite – the limitation of non-renewable resources, which requires an intensification of the search for new ways of efficient production and economical consumption for the future
• philosophic	sustainable development of the enterprise involves the formation of a new type of thinking among both employees and contractors as well as potential consumers by organizing environmentally and socially responsible chains of interaction

Source: own compilation.

In the conditions of a modern market economy progressive companies are actively looking for new approaches and opportunities to overcome both external challenges – such as the impact of globalization on the world economy, the instability of the business environment, constant changes in interstate regulation and international agreements – as well as internal factors, in particular, market requirements and

expectations. All innovative approaches today are inextricably linked to the integration of the principles of corporate social responsibility and sustainable development into the strategic management of the company. At the same time, the lack of clearly defined conceptual approaches and applied tools for assessing the existing level of sustainability and the corresponding industry potential indicates the need to provide enterprises with knowledge and practical mechanisms that will allow them to function more effectively in the future based on the principles of sustainable and circular development.

Table 2. Scientific approaches to assessing the level of sustainable business development

Approach	Main characteristic
functional	is carried out on the basis of detailed analysis of organizational effectiveness of business activities as a system of well-established processes and functional relationships
managerial	effectiveness of existing management excellence is assessed in the context of a wide object range – from employees and production facilities to knowledge and information
expert	assessment procedure involves leading industry experts and sustainable development consultants to form a single professional opinion on the effectiveness of relevant enterprise policy implementation
quantitative	a comprehensive system of indicators is under analysis based on the type of business activity in three blocks – economic, social and environmental
business value	determination of positive impact of the implementation of sustainable development initiatives on company value
behavioral	degree of the company influence on changing consumer value expectations and needs is assessed as a consequent result from the creation of a new value proposition and business awareness

Source: own compilation.

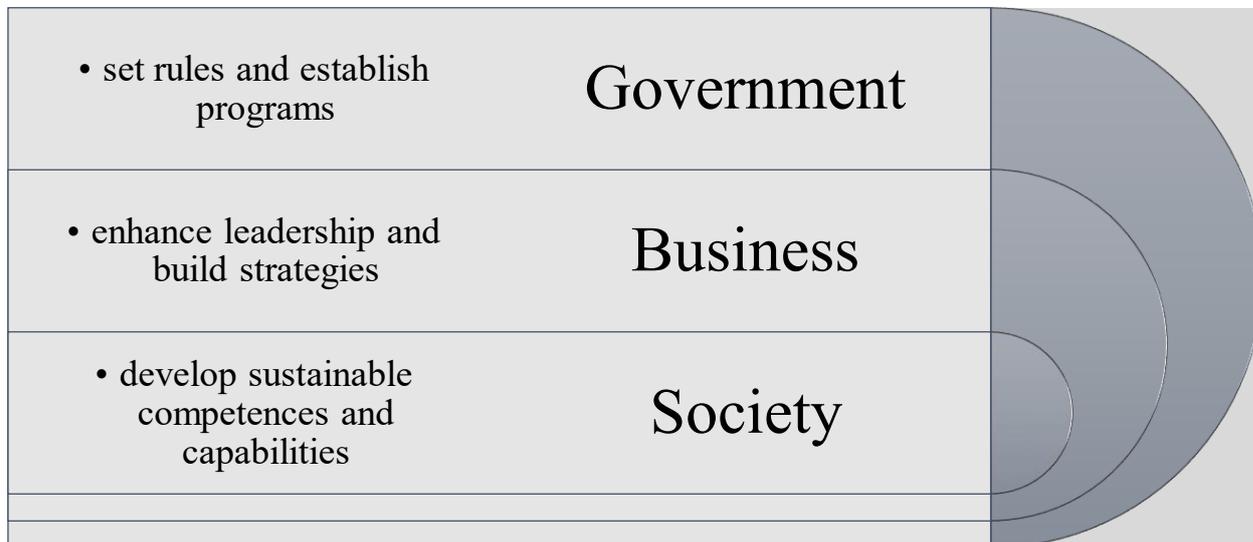
In business scope sustainable performance management is generally assessed through two key lenses: the integration of social and environmental aspects into business strategy and sustainability reporting. In practice, most sustainable initiatives are implemented through the use of resources, technologies and corporate motivation. The latter includes areas such as sustainable supply chain management,

corporate social responsibility codes of conduct and standardization systems. Companies present the outcomes of their activities in reports – guided by declared GRI principles – which combine financial metrics with logical descriptions of key operational processes.

When shifting the focus from businesses to individuals, it’s important to recognize that business stakeholders drive production across regions, relying on human labor as a crucial factor in overall development. Individuals are expected to create and engage with innovative approaches to action, research and education. Thus, they are both recipients of knowledge (provided by institutions and authorities) and active contributors when applying that knowledge in practice.

Ultimately, the independent individual plays a central role as both a supporter and catalyst for innovation. Through personal actions society as a whole is fostering sustainable development skills and competencies, ensuring that shifts in behavior, habits and ethical values are fully embraced.

Figure 2. Multi-stakeholder network chain priorities



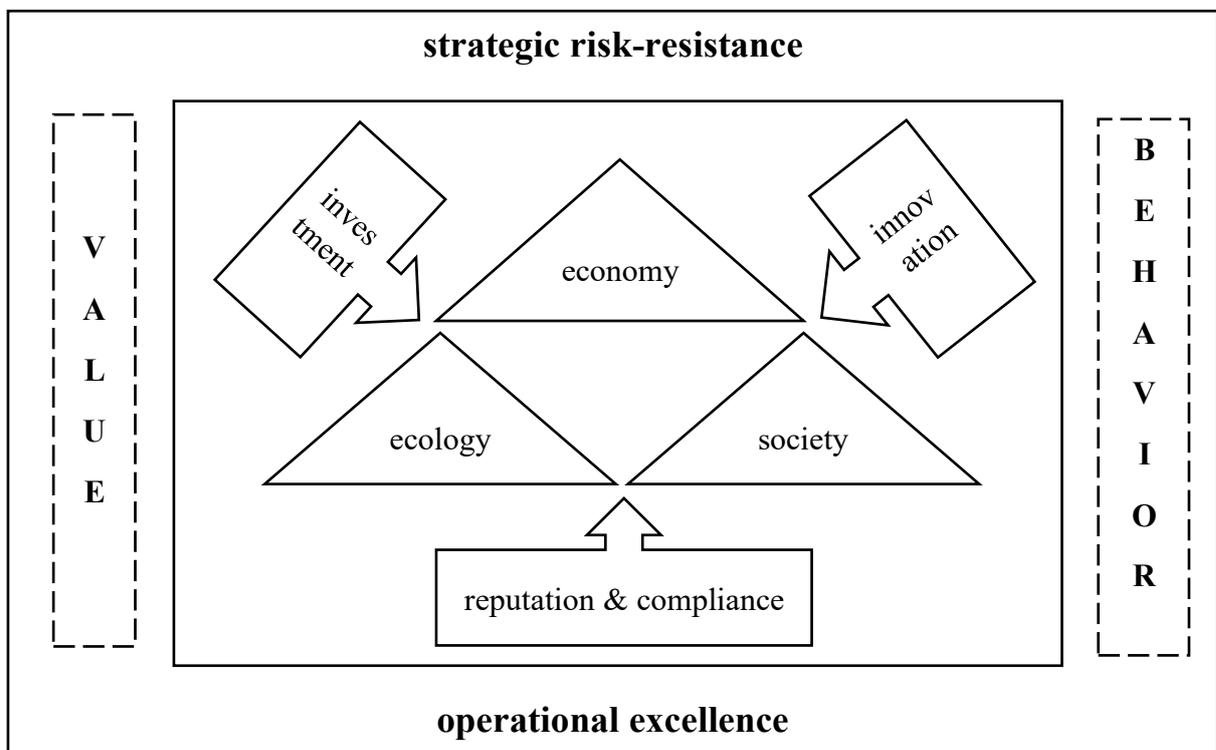
Source: own compilation.

To accomplish a wide range of goals and foster collaboration among diverse actors, one of the most critical elements is the information-sharing process, characterized by strong engagement and support. Beginning at the international governance level, the existing frameworks for business operations and public sector management provide a foundation for more targeted actions by agents at lower levels.

Contribution to global goals and objectives serves to close the gap between learning and development by reshaping sectoral boundaries and enhancing the roles of higher education institutions and social support organizations (Figure 2).

In order to implement global initiatives to protect the environment and combat climate change, an enterprise, regardless of its type of activity or form of ownership, is to develop a systemic policy with a priority on implementing those goals that are achievable at this stage of activity, but defining a benchmark for joining all 17 goals to achieve a comprehensive positive impact. A model of innovative sustainable development of an enterprise, which involves focusing on three blocks (investments, innovations and reputation) is given below.

Figure 3. Unified model of innovative sustainable business development



Source: own compilation.

Innovative sustainable business development is required in any industry due to modern geopolitical circumstances in order to set up a new business paradigm. Energy industry is one of the most required following the modern consumerism trends. The continuous transformation of global energy markets, especially electricity generation, is mainly based on the restructuring of energy balance which occurred in response to gradual shifts in world energy consumption centers.

Tremendous technological progress with lots of innovative advances has also contributed to the ongoing transition from traditional fuel-based production to clean and conscious energy generation. This matter is consistently linked to sustainability. Indeed, renewable energy base with solar energy, wind power and biofuels as well as energy efficiency are the twin pillars of current sustainable energy (Prasad, Sheetal, Venkatramanan, Kumar, Kannoja, 2019).

Historically, the global energy system has already undergone several main deployment stages, ending up focusing on the parallel vertically-integrated value-added chains that purposefully link resource and end-user centers within the energy structure. Following this system logic, petroleum products are broadly used in transport industry, whereas heat and electricity are generated from coal and natural gas. One more crucial point is *unbundling* (Dubois, 2009, Fuentes-Bracamontes, 2016), which is aimed at establishing electricity and gas networks with independent operating processes. Moreover, unbundling of the network stage intends to eliminate incentives for price discrimination against rivals and to foster competition in the retail segment (Heim, Krieger, Liebensteiner, 2020). Thus, new market rules are becoming more sector-oriented with specific procedures and codes (separate value chains, infrastructure, planning).

Ultimately, the urgent need for a coordinated policy in order to support such synergies led to the publication on 8 July 2020 of the European Commission Communication on an EU Strategy for Energy System Integration. The new strategy is particularly designed to strengthen the multi-sector transition towards a climate-neutral economy, including specific policies and legislative measures to move to a more integrated energy system.

The world community as well as the European Union have finally reached the understanding of insufficiency of this separation model, taking into account quite ambitious climate goals and preliminary directions. Moreover, achieving climate neutrality by 2050 in a cost-effective way is in danger of being failed due to the existing circumstances. The very first approach to be thoroughly investigated is sector coupling – under discussion at the EU level since October 2018. It is

painstakingly focused on the broad integration of electricity and gas markets by means of new ways on how to use the already present synergies in production, transportation and distribution. Thus, in combination with other industries it is considered as the concept of *sector integration* – the coordinated planning and operation of the energy system ‘as a whole’, across multiple energy carriers, infrastructures and consumption sectors. It is the pathway towards an effective, affordable and deep decarbonization of the European economy in line with the Paris Agreement and the UN 2030 Agenda for Sustainable Development (European Commission, 2020).

Following the green policy recommendations, provided by The International Renewable Energy Agency (IRENA, 2018), the most significant areas of intensive international collaboration in the future are:

- innovation in the integration and operation of the energy system (systemic innovation), which is key to integrating more variable renewable energy and electrifying end-use sectors;
- innovation in industrial processes – particularly cement, iron and steel, and chemicals, which together account for 17% of current carbon dioxide (CO₂) emissions;
- innovation in transport – particularly in freight and aviation – with total 11% of present CO₂ emissions.

Climate change and local air pollution are among the key drivers for energy transition worldwide. Local air pollution is a main driver in countries such as China and India. But also, in Europe, there is increasing attention for the harmful health effects of air pollution, largely related to energy supply and use. As projected, renewable energy and energy efficiency, combined with electrification of end-users, make up 94% of the emission reductions (Gielen, Boshell, Saygin, Bazilian, Wagner, Gorini, 2019). The challenge is that even though the outlines of a new environment have begun to emerge, the power industry operates with time horizons in the decades. The implication is high-stake strategic decision making under uncertainty, from utilities, regulators, investors, and an innovation imperative that

will vary considerably by market and company (Finkelstein, Frankel, Noffsinger, 2020). Energy transition will require a holistic innovation approach tailored to the needs of each renewable energy and energy efficiency technology since a wide range of approaches will be required across all sectors of the energy system. While aiming at increasing investment in R&D for low-carbon technologies benefits the energy transition, more attention can be paid to monitoring and verifying that those investments have the desired impact and R&D budgets and priorities are impact-driven (Gielen, Boshell, Saygin, Bazilian, Wagner, Gorini, 2019).

The abovementioned facts as well as directive goals for the international development and compliance of Ukrainian energy sector, several gradual changes are required in order to provide Ukrainian energy industry with modern competitive advantages within the new platform, particularly in electricity generation.

1.3 Sustainable energy management

In scope of sustainable energy concept there are many different definitions of *energy management* notion in modern science. Taking into consideration the most well-known ones, it should be noted that this term highlights the process of using less energy for the same or even increased output. It is predominantly being recognized as one of the most important and cost-effective solutions for reducing greenhouse gas (GHG) emissions produced as part of industrial processes (OECD, 2015). In fact, energy efficiency has the technical potential to reduce industrial energy use by about 20% (IEA, 2013).

Furthermore, the energy management policy influences organizational and technical procedures as well as behavior patterns in order to reduce the total operational energy consumption (thus also the energy required for the production), to use basic and additional materials economically and to continuously improve the energy efficiency in the company (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2012).

It is worth emphasizing that in modern scientific literature, there is also such a notion as *sustainable energy*, which defines the following parameters in the environment (Golušin, Munitlak, Vucenov, p. 26):

- management and interpretation of accepted theory, the existing experience, state regulations, navigation companies, the requirements of all stakeholders, level of education, awareness and commitment, general orientation toward social responsibility;
- energy – legislation, existing energy resources, new energy resources, energy efficiency, technology development, production and consumption levels, system stability, degree of self-sufficiency;
- sustainable development and acceptance of the concept at the state level, the ratification of the international agreement, the parameters of national sustainable development strategy, the list of priorities.

Current business perspective gives another approach to understanding the notion of *energy management*. It states that the scope of energy management should not only be limited to utility consumption by heating, ventilation and air conditioning (HVAC) systems in facilities or IT infrastructure, but must extend to optimization of waste management, building infrastructure, supply chain networks, product design, transportation networks and plant controls and equipment. Moreover, enterprises must embrace smart grid/meter systems and renewable energy sources to enact more effective cost-management strategies and utility consumption, thereby improving their long-term sustainability (Gehani, 2012).

Despite societal pressure and corporate responsibilities, energy management remains a significant challenge for many companies. This is largely due to the absence of consistent government support and concerns among CEOs regarding future investments in processes that may appear less productive. The need to overhaul existing operations within production facilities is often viewed as a risky and potentially unrewarding endeavor.

However, due to the Report by the Economist Intelligence Unit (2009), energy efficiency management is critical to businesses because they need to be:

- keeping costs under control during economic recession;
- brand positioning as green product providers;
- meeting increasingly stringent compliance requirements;
- improving the environmental footprint of their products/services;
- implementing stronger controls over suppliers of environmental standard.

In general, energy management in the form of implementing new energy efficiency technologies, new materials and new manufacturing processes and the use of new technologies in equipment and materials for business and industry is also helping companies improve their productivity and increase their product or service quality. Often the energy savings is not the main driving factor when companies decide to purchase new equipment, use new processes or new high-tech materials. However, the combination of increased productivity, increased quality, reduced environmental emissions and reduced energy costs provides a powerful incentive for companies and organizations to implement these new technologies (Turner, 2007; Rossiter, Jones, 2015).

In line with international recommendations and the findings of leading economists, energy management is recognized as the most effective and appropriate approach to meet the evolving demands placed on businesses by modern society regarding corporate activities and social responsibility. Managing energy consumption is not only about ensuring safety and quality but also about safeguarding the interests of all stakeholders, adhering to the principle of *leaving no one behind*. Furthermore, energy management requires active participation not just from corporations, but also from governmental and non-governmental organizations.

In general, several comprehensive programs have already been established within the global framework. Every country has its own opportunities and downsides in terms of energy independence and efficient consumption. That is why regional and local policies may become different to some extent. However, when speaking about global issues, i.e. greenhouse gas emissions or deforestation, some key principles and standards are needed in order to set the basis for implementing energy programs and reaching further improvement. International Organization by means of

particular standard (ISO 50001:2011) specified the most important requirements for companies to contribute consistently and effectively to energy performance and sustainable energy management.

This International Standard – ISO 50001:2011 – is based on the *Plan - Do - Check - Act* (PDCA) constitutes continual improvement framework and incorporates energy management into everyday organizational practices (ISO 50001:2011). In the context of energy management, the PDCA approach can be outlined as follows:

- PLAN: conduct the energy review and establish baseline, energy performance indicators (EnPIs), objectives, targets and action plan necessary to deliver results that will improve energy performance in accordance with the organizational energy policy;
- DO: implement the energy management action plans;
- CHECK: monitor and measure processes and key characteristics of operations that determine energy performance against energy policy and objectives as well as report the results;
- ACT: take actions to continually improve energy performance and energy management system.

The system outlined is designed to assess the current state of energy efficiency efforts and identify any gaps, while continuously monitoring and adjusting action plans within the company. This approach not only focuses on immediate improvements, but also provides a foundation for innovation, both in production processes and managerial practices.

In a broader sense a corporate energy management system can be implemented in two primary ways. The first focuses on optimizing existing business operations and production capabilities with the goal of reducing energy costs and increasing profitability. The second approach emphasizes non-financial changes within the company, such as fostering a shift in employee attitudes toward corporate values and business practices in a specific industry. This aspect is particularly important for supporting social initiatives, as it helps demonstrate corporate responsibility and

boosts engagement in various areas, ranging from business operations to employees' everyday lives.

Within business operations energy management is a multifaceted concept. It involves a range of strategies and practices designed to reduce inefficient energy use and promote sustainability wherever possible. However, the focus areas for improvement can differ based on the industry, the nature of business activities and the perspectives of corporate leaders, energy managers or external consultants.

All definitions considered it is possible to conclude that energy management is a modern concept, which focuses on improving the level of efficient energy consumption by means of innovative cost-effective strategies and green-thinking policies within countries and companies in order to achieve sustainable development and increase the competitiveness on the market.

Moving forward from the main theoretical implications to practical basics, it is obvious that every company is a complicated mechanism with own processes and specific operations. Fundamental patterns and energy management tools are common for all sorts of business activities. In order to cope with resistance to change it is important to highlight main obstacles while establishing new practice for sustainable development and accepting current market challenges (Figure 4).

Every challenge presupposes not only barriers, but also advantages and non-visible prospects. Efficient energy management policy enables companies to get the following benefits as a positive and motivating result of far-reaching transformation of business processes and corporate culture:

- less environmental pollution and carbon footprint;
- contribution to global climate change policies;
- increased productivity;
- cost reduction and production optimization;
- waste management;
- changes in behavioral patterns and social attitude (environmentally friendly and conscious).

It is worth highlighting that the most compelling reason for saving energy is reducing costs. Most organizations can save up to 20% on their fuel bills by better energy management and cost-effective investment measures. The Carbon Trust, for example, has seen good energy management result in savings of 5%-25%, with typical payback periods of two years or less, across a diverse range of companies. It is not unusual to save 5%-10% with just minimal capital expenditure (Carbon Trust, 2011). However, the issues of corporate reputation and competitiveness on the market are even more crucial because non-financial benefits bring unpredictable synergies to company performance and its further development.

Figure 4. Main obstacles to energy management system implementation

Financial

- lack of funding (own financial resources)
- insufficient government support
- limited opportunities for capital investment

Managerial

- inefficient investment allocation
- absence of clear delineation of responsibilities and competencies
- lack of specialists in energy management and audit

Procedural

- inadequate organizational or administrative support
- lack of complex policies and action plans

Information

- limited knowledge and information support
- lack of public awareness
- absence of well-known approaches and techniques

Source: own compilation.

Moreover, there is a distinct correlation between the strongest, most successful brands and those brands which score highly on the categories of Corporate Reputation, Leadership and Innovation. Environmental responsibility is one of the top characteristics of leading companies (Huang, 2011).

The current landscape of the business sector across various industries reveals certain trends that highlight key considerations for developing an effective business strategy focused on energy efficiency and sustainable growth:

- establish new corporate social responsibility policies that prioritize sustainable business practices;
- develop a forward-looking and sustainable business vision by integrating principles of sustainability and green practices;
- review existing production capacities and determine the extent of necessary upgrades or replacement of outdated equipment over a strategic timeframe (up to three years);
- identify potential business opportunities, including both financial gains and intangible benefits by adopting leading-edge technical standards over a five-year period;
- detect major gaps within the supply chain and implement improvements in procurement processes to lower costs;
- establish comprehensive energy audits to form a new energy management framework and integrate internal accounting practices into the existing corporate reporting system;
- ensure a continuous investment process for innovative company development, utilizing both internal resources and public funding opportunities;
- involve all employees, including management, in energy-saving initiatives by providing regular training on corporate green policies for both in-office and in-field activities;
- launch a dedicated program aimed at supporting social initiatives that foster mutually beneficial collaborative relationships between company, consumers and employees.

The energy market companies are also in scope of the abovementioned changes. For example, in modern thermal power plants, particularly with capacities of about 2400 MW, up to 20 thousand tons of coal can be burned daily. As a result of this process up to 100 tons of solid particles and approximately 120 tons of nitrogen oxides are released into the atmosphere. Coal combustion in boiler units of thermal power plants as well as in industrial furnaces and boiler rooms is accompanied by significant emissions of toxic compounds, such as:

- solid particles: dust, ash, soot;
- harmful gases: sulfur oxides (SO_2 , SO_3), nitrogen oxides (NO , NO_2), carbon monoxide (CO);
- oxides of heavy metals that may be contained in the feedstock.

One of the key parameters that affect the environmental safety of the electricity generation process is the quality of coal, namely its brand and the degree of preliminary enrichment. The use of low-grade coal significantly increases the level of environmental pollution. Such fuel causes not only excessive emissions into the atmosphere, but also side water and soil pollution near power generation enterprises. In particular, coal that has not undergone preliminary enrichment generates a third more toxic emissions, including sulfur oxides. The technological process of enrichment of raw materials is an important stage of preparation for coking, as it allows reducing the ash content of coal to the regulatory level (67%). Increased ash content, in turn, causes excessive fuel losses during combustion, activates slag formation, which negatively affects the efficiency of boiler units and worsens the efficiency of energy and metallurgical processes. Under such conditions there is a need for additional use of extra fuels to ensure the proper level of thermal energy generation required for the operation of power generators.

The problem of reducing the negative effects of the power plant operation in Ukraine remains unresolved. Thus, equipment for removing sulfur dioxide from flue gases is practically absent in Ukraine, so the concentration of sulfur dioxide in the flue gases of Ukrainian thermal power plants is high and depends mainly on the sulfur content in coal (which often exceeds 2%). As the main technology for cleaning thermal

power plant emissions from NO_x , the technology of selective catalytic nitrogen reduction has been adopted in the world, which uses the reaction of NO_x and ammonia (NH_3) with the formation of free nitrogen N_2 and water vapor on the surface of the catalyst. It is important that this technology can be applied to almost any power units and does not involve the formation of derivative by-products that require disposal (Kryzhanivskyj, p. 88). However, domestic enterprises do not pay due attention to modern requirements for environmental protection and low-carbon production and nominally installed filters are ineffective given the volumes of emissions produced.

A groundbreaking approach to lowering carbon dioxide emissions involves capturing, storing and utilizing CO_2 directly at its source – such as thermal power plants and industrial sites. This method of direct “air suction” represents an entirely new strategy in the fight against climate change. Unlike current practices that focus on replacing production and infrastructure with greener alternatives, this technique emphasizes the development of innovative nano-installations as part of advancing geo-engineering solutions.

Direct air capture technology provides two options for air purification:

- by absorbing the already released greenhouse gas with its subsequent separation from other substances in the air (sequestration) – a debatable method due to low CO_2 concentration as well as the high purchasing and operating costs associated with storing CO_2 under the action of compressors;
- through the carbon dioxide capture directly at the moment of its exit from the generation or filtering plants in order to prevent its mixing with other gases and compounds – a more effective and less expensive method, however, the feasibility of its mass application is due to the presence of large production capacities that produce CO_2 .

According to preliminary estimates conducted by international experts, the average cost of the specified *green mining* ranges from 100-1000 USD per ton. A wide range of values is due to the level of energy costs, the configuration features of a particular plant as well as the financial conditions for implementing such activities. For

example, Carbon Engineering company announced the possibility of mining at the level of 94-232 USD per ton, which significantly increases the efficiency of direct air capture technology use on industrial scale (INTERNATIONAL ENERGY AGENCY, 2020).

It is important to highlight that this technology is not the primary tool in the broader efforts to decarbonize the economy or achieve carbon neutrality. Instead, it serves as a foundation for sustainable industrial growth by enabling energy companies to convert the negative impacts of their operations into a green energy source that supports natural processes. As an alternative to traditional greening methods, direct air capture technology offers an innovative approach for energy companies to advance their social responsibility initiatives and promote sustainable development. Global business practices demonstrate that the main driver of innovative sustainable development and growth across industries lies more in operational changes than in massive investments in technology. The focus is on fundamental transformation of business operations through the effective management of people and resources. This makes programs foster mutually beneficial collaboration between business and government authorities especially critical under contemporary volatile conditions. Climate-related initiatives are shaping long-term impacts on carbon footprint reduction and energy sustainability. Most energy-saving projects offer short payback periods, making them highly appealing to entrepreneurs across industries. In addition, voluntary sustainability efforts significantly boost public support, enhance brand reputation and create a synergetic effect. Even though establishing efficient energy systems often requires substantial investment, such steps help CEOs identify financial incentives and set strategic priorities for future growth. Beyond basic regulatory compliance, adopting an energy management approach enhances a company reputation, strengthens customer loyalty and ultimately increases profitability. In many cases, energy management presents an easily accessible opportunity for businesses to capitalize on in the nearest term.

Professional corporate transformation demonstrates to both customers (B2C) and business clients (B2B) that the company is committed to a forward-thinking,

sustainable and human-centered vision. This reputation not only improves internal business efficiency but also boosts the company's competitiveness in the market. Thus, energy sustainability remains a key driving force behind sustainable business development worldwide.

1.4 Comparative analysis of old and new electricity market models in Ukraine

The model of the electricity market, existing for a long time in Ukraine, was built on the principle of wholesale purchase of this energy from its various producers for resale at prices set by the National Commission for Electricity Market – the *Single Buyer* model. The only trading platform for the interaction of all market participants was the wholesale electricity market, the operation of which was ensured by a special body – *Energorynok*.

According to the *single buyer* model, the load schedule was determined by directive, and the forecast balances of the system and the volumes of dispatching were established. It formed the value of the electricity generation volume as a whole. *Oblenergo* combined the functions of distribution and supply and was able to buy electricity from the wholesale market at a regulated tariff, whereas independent suppliers – at free prices, due to the peculiarities of the functioning of these participants within the existing model. *Oblenergo* provided electricity to both domestic and industrial consumers, while independent suppliers served mainly the industrial sector. *Oblenergo* operated only within the assigned territory and engaged in the transmission and distribution of electricity at a regulated tariff. According to the unregulated tariff, the relevant activities could be carried out by other independent suppliers without owning networks.

Relations in the field of pricing were also regulated. In particular, for generation companies the price of energy was determined separately for each entity. *Oblenergo*, buying electricity in the *Energy Market*, mainly sold it to consumers at a regulated tariff, while only a few companies operated at an unregulated tariff (contract prices).

It should also be clarified that the population received electricity at prices that were significantly lower than the market and the existing difference was repaid by the industrial sector. These tariffs were formed based on the weighted average energy consumption in a particular area per hour, regardless of the operating modes during peak periods or around the clock. Within the framework of this market model the process of cash flow was also clearly defined, from consumers to *Oblenergo* and *Energorynok* and then distributed to generators and *Ukrenergo* – the main network operator in Ukraine.

Comparative analysis of the old (*single buyer*) and new (*separation of monopolies*) market models are presented in Table 3.

Table 3. Comparative analysis of old and new electricity market models in Ukraine

<i>SINGLE BUYER MODEL</i>	COMPETITIVE MARKET – SEPARATION OF MONOPOLIES
requires targeted government regulation	self-regulation, leveling of system imbalances
contributes to corruption and lobbying	restricts the access of individual participants to the levers of influence in the market
weakens the financial mechanism of transaction control	causes relatively higher short-term costs associated with the long-term contract terms
does not require the participation of third parties	provides system transparency due to the multiplicity of relationship agents
creates a surplus of capacity, balance regulation and policy influence	facilitates the system balance (planned and actual volumes)
sets tariffs and prices for electricity, depending on the national development priorities of individual industries	enables pricing flexibility due to competitive market mechanisms
categorizes consumers with subsequent fixing of tariffs, eliminating the need for qualitative changes in the structure of the cost of products (services)	increases the role of economic incentives and competition for the rationalization and efficient operation of enterprises

Source: own compilation.

In the real absence of market liberalization for the interaction processes between market participants, any incentives to establish competition or improve the quality of services were also absent. To replace this inefficient model, a new model of the electricity market was introduced in July 2019, aimed at ensuring the functioning of six separate markets under the conditions of effective interaction of different types of suppliers and consumers. In particular, the new energy policy of Ukraine provides the launch of the following components within the competitive market model:

- *intraday market* (continuous trading within the current day of physical electricity supply);
- *day-ahead market* (short-term contracts regime);
- *balancing market* (provides the introduction of financial liability for violation of the balance of real and projected consumption to ensure sufficient capacity);
- *market of bilateral agreements* (long-term agreements outside the represented market segments);
- *market of ancillary services* (ensuring the reliability of the system by purchasing the operator of the transmission system of relevant ancillary services from existing suppliers).

The new market model is based on the process of property *unbundling*. Main structural changes are approved and set by the Third Energy Package. As the part of Ukrainian implementation of agreements with the European Union in the energy sector, the function of energy production should be separated from the function of its transfer.

The reform in the framework of corporate unbundling in Ukraine provides for a clear separation of functions of electricity distribution and supply in order to form a retail electricity market. The latter covers the range of relationships between the final consumer and the electricity supplier as well as the entities involved in the process of providing the relevant services. In particular, the legislative regulations clearly enshrined the legal status of the functional division of *Oblenergo* into two independent entities:

- distribution system operators (electricity distribution and network operation);
- electricity suppliers (provide only supply).

The reform also stipulates that the supplier formed as a result of the separation of distribution functions will perform the universal service supply functions formed as a result of the separation of the electricity supply function for two years. In each of the regions the state will designate one electricity supplier for household and small non-household consumers (universal service provider).

Another difference between the old and new market models is a radical change in the approach to the organization of system management processes. If the old model preferred a *top-down* approach with a centralized regulatory impact and a high level of monopolization, the new market is built on the principle of *bottom-up*, which stimulates demand for electricity from different groups of consumers and the intensification of the development of the competitive environment, provided that the interests of the consumer take precedence.

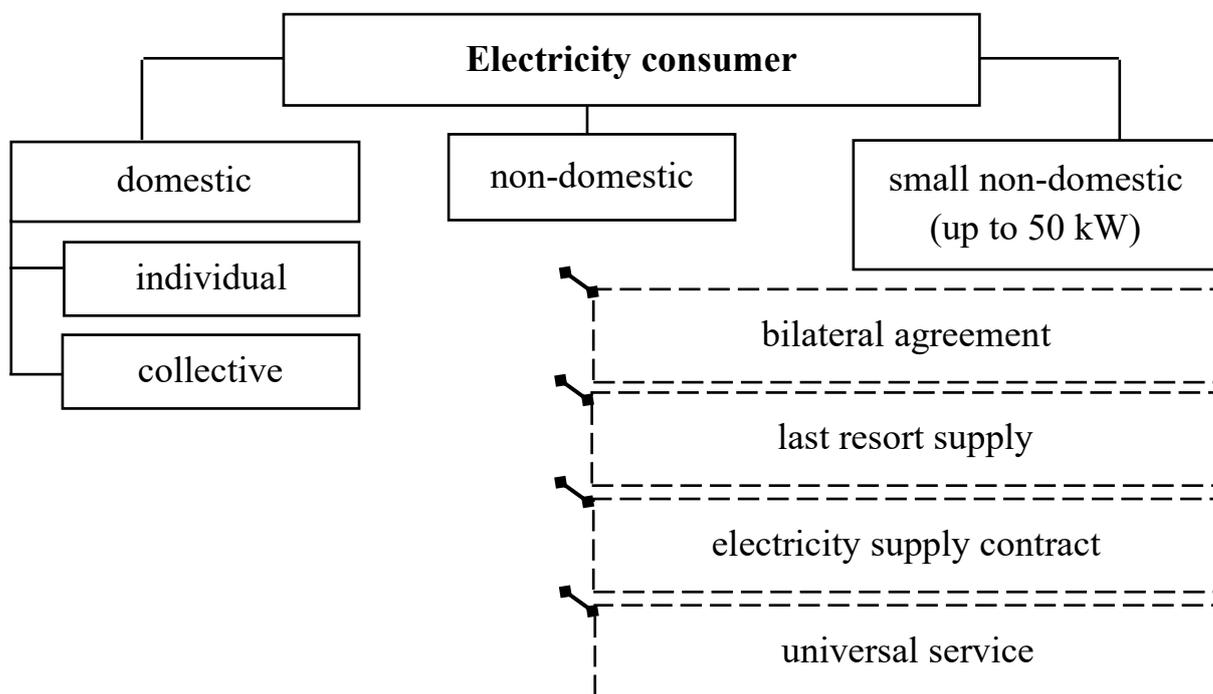
One of the determining factors of qualitative transformation of the electricity market is pricing. As the legislation provides the possibility of new entrants to the market and overcoming monopoly factors in the process of new market functioning, the development of competition will not only improve quality standards and range of services, but also lead to a possible price increase under the contract. Despite the volatility of the pricing process, this kind of flexibility in the wholesale market allows the consumer to choose a service provider and gradually change both their own demand and increase energy efficiency in general. The two-way effect of the relationship enables the consumer to influence suppliers and manufacturers, latently encouraging them to innovate and modernize as well as transform the entire generation structure.

It is the consumer who has the opportunity to choose between the average daily and hourly price, depending on the mode of own consumption. The efficiency of the system as a whole will be ensured by gradually reducing the energy consumption of

networks, overcoming imbalances and regulating generation capacity through price containment during peak periods.

The classification process of electricity consumers according to the new market model has become complex. Thus, instead of the two generally accepted categories – domestic and industrial consumers – there are already three groups of consumers. The general characteristic of the last is given in Figure 5.

Figure 5. Classification of electricity consumers and contract options for electricity purchase within the new electricity market model in Ukraine



Source: own compilation.

The *universal service* supplier contract is appropriate for small non-domestic consumers, consumers with a capacity of up to 150 kW as well as budgetary institutions. In general, the supply of electricity to household and small non-household consumers will be carried out at retail prices set by the National Commission for State Regulation of Energy and Public Utilities. The contract is standard and special conditions of interaction are defined in the commercial offer.

Under an *electricity supply contract* that is relevant to large consumers and industrial facilities, the terms of interaction and price are negotiable, whereas the consumer only chooses the option offered by the supplier.

Ukrinterenergo last resort supply for those consumers who have lost their own electricity supplier or did not choose it in time provides a much higher price compared to other sales contracts by establishing a large margin for the multiple services provided.

A *bilateral agreement* is a specific form of interaction between the consumer and the supplier, as it provides its conclusion between two independent market participants outside certain segments, causing high risks of such cooperation. The peculiarity is the fact that it is necessary to conclude an agreement on the settlement of electricity imbalances, as the level of responsibility of these participants from such independent interaction is much higher than under other agreements.

Market of bilateral agreements allows a certain supplier to buy electricity directly from the power plant. The day-ahead market and the intraday market, operating on the basis of the reformed energy market (the so-called *Guaranteed Buyer*) create conditions for the generation and sale of a certain part of the energy produced in order to maintain the efficiency of the system as a whole. The balancing market provides a daily balance of supply and demand for electricity to avoid possible system imbalances.

Given the opportunities for the development of different markets and the activities of participants, special focus within the new model is to establish mechanisms in order to ensure a high level of competition, free pricing and moderate power concentration in the electricity market. Due to the artificial distortion of prices in terms of different types of generation, when domestic thermal electricity is much more expensive than European, and the price of nuclear is significantly understated, the key priorities for creating a competitive model in Ukraine are free imports and access to new generation.

Ukrainian market is strategic for Europe. Taking into account the significance and relevance of increasing the national potential in the electricity sector, guidelines for increasing the competitiveness of Ukrainian generating enterprises are being formed on the global level (Table 4).

Table 4. Key trends and challenges in the global electricity generation market development

Trends	Challenges
1. Growth of the world population to 10 billion people (by 2070)	1.1. Growth in global demand for electricity (up to a third of current demand) 1.2. Provision of free and uninterrupted consumer access to electricity
2. Rapid economic growth and development of energy-intensive industries	2.1. Stable economic growth rates and quality of life 2.2. Implementation of energy-saving technologies 2.3. Digitalization of business processes
3. Galloping urbanization	3.1. Creation and development of smart cities with the ability to efficiently generate and store energy from various sources 3.2. Global transition of cities to 100% self-sufficiency in renewable energy – green cities
4. Development of new technologies within the transition framework to circular economy	4.1. Closed-loop recycling 4.2. Minimization of waste and pollution 4.3. Renewable energy development. 4.4. High transparency

Source: own compilation.

Nowadays it is extremely crucial for Ukraine to consider European market models but with an overview of the abovementioned trends. Thus, for example, *German energy market* represents one of the most advanced and dynamic systems within the European Union, reflecting a combination of liberalized market principles and state-led energy transition policies. The German model is governed by EU directives, national energy policies and a strong regulatory framework that promotes competition, sustainability and security of supply.

Germany’s energy market has been fully liberalized since the enactment of the Energy Industry Act in 1998, which was further reformed in accordance with the European Union’s Third Energy Package (EUROPEAN COMMISSION, 2023).

The unbundling of vertically integrated utilities has resulted in a clear separation between generation, transmission, distribution and supply. Four transmission system operators – 50Hertz, Amprion, TenneT and TransnetBW – manage the high-voltage transmission grid and ensure the stability and reliability of electricity transport across regions (AGORA ENERGIEWENDE, 2021). On the distribution level, numerous regional and municipal distribution system operators are responsible for delivering electricity to end consumers.

The wholesale market is structured around the European Power Exchange for day-ahead and intraday trading, and the European Energy Exchange for long-term contracts and derivatives. Market clearing is based on the merit-order principle, which prioritizes generation units with the lowest marginal costs, favoring renewable energy sources due to their near-zero operational costs.

The Federal Network Agency (Bundesnetzagentur, BNetzA) serves as the national regulatory authority, tasked with ensuring non-discriminatory grid access, monitoring network tariffs, and overseeing the development of competitive and transparent energy markets. German energy market is undergoing a profound transformation under the “Energiewende” (Energy Transition) strategy, which seeks to phase out nuclear energy (completed by 2022), reduce coal usage (planned phase-out by 2038 or earlier) and expand the share of renewables in electricity generation to over 80% by 2030. This transition is facilitated by feed-in tariffs (now replaced by auction schemes), priority grid access for renewables and investment in flexible generation and storage technologies (Federal Ministry for Economic Affairs and Climate Action, 2023).

The retail electricity market in Germany is characterized by a high level of competition with hundreds of suppliers offering various tariffs and service models. Consumers, including households and small businesses, have the right to freely choose their supplier. The emergence of prosumers – consumers who also produce electricity via rooftop solar panels – and the rollout of smart metering infrastructure reflect a shift toward decentralized and participatory energy systems.

The energy market in *the Czech Republic* operates within a liberalized framework that undoubtedly aligns with European Union energy directives. The Czech energy market model is characterized by unbundled electricity and gas sectors, competitive wholesale markets and regulated natural monopolies in transmission and distribution. The liberalization process began in the 1990s and has since been shaped by successive EU energy packages, particularly the Third Energy Package, which mandated legal unbundling of transmission system operators and enhanced consumer rights.

The electricity sector in the Czech Republic is dominated by the vertically unbundled yet still influential state-controlled company ČEZ Group, which remains the largest electricity generator. Generation is diversified, relying primarily on nuclear energy, followed by coal and renewable sources. As of 2022 nuclear power accounted for approximately 36% of electricity production with renewable energy sources making up around 15%, mainly from biomass, hydro and solar (INTERNATIONAL ENERGY AGENCY, 2022).

Despite the progress in market liberalization, challenges remain, including high dependency on fossil fuels (particularly lignite), the need to modernize grid infrastructure and slow deployment of renewable energy. The Czech Republic's decarbonization trajectory is also constrained by public and political resistance to rapid coal phase-out and the expansion of wind power due to permitting barriers.

France's energy market is characterized by a strong historical legacy of state intervention, centralized planning and a dominant nuclear sector. Over the past two decades, however, the French energy model has gradually evolved toward liberalization and market integration, particularly in response to EU-level directives. The interplay between national energy sovereignty and European market reforms defines the current structure of France's energy system. France's energy mix is dominated by nuclear energy, which accounted for more than 60% of electricity generation (COMMISSION DE RÉGULATION DE L'ENERGIE).

France's energy market represents a unique case within the EU: a largely decarbonized system due to its nuclear heritage, embedded within a liberalized but

still state-influenced framework. The challenge ahead lies in balancing market efficiency, decarbonization targets, and energy security within this hybrid model. Scientist Finon (2019) argues that France operates a “dual logic” model, combining a liberalized market framework with continued state control and intervention. This hybrid approach creates tension between competition principles and national policy goals. In general, France’s 2019 Energy and Climate Law set the goal of achieving carbon neutrality by 2050. It also committed to reducing the share of nuclear power to 50% by 2035, which implies an increase in renewables and greater grid flexibility. *Electricity market model of Poland* reflects some features of Ukrainian market and constitutes a complex interplay between legacy dependence on coal, efforts to liberalize the market under EU directives and growing pressure to decarbonize. Poland’s market liberalization was driven by compliance with EU energy directives, particularly the Second and Third Energy Packages. Full market opening for households occurred in 2007. However, the retail market remains partially regulated, with price controls for household customers continuing until 2024, although reforms are ongoing. While Poland has made significant steps in aligning its market with EU regulations, it retains a high level of state control and remains heavily reliant on fossil fuels. These structural tensions shape the unique path toward energy transition and integration with the European internal energy market. Polish energy sector remains partially liberalized and state-influenced with a significant concentration of assets in a few state-controlled companies (INTERNATIONAL ENERGY AGENCY, 2022).

Despite formal unbundling, vertical integration and state control persist, limiting the depth of competition. The national energy regulator – Urząd Regulacji Energetyki (2023) – oversees licensing, tariffs, and market integrity. The energy mix was still dominated by coal (over 60% of electricity generation), although the share of renewables – especially wind and solar – has grown significantly in recent years. However, recent geopolitical developments – particularly military actions in Ukraine and the push to eliminate Russian fossil fuel imports – have increased interest in energy independence and accelerated renewable and nuclear planning.

Slovakia's energy market demonstrates the predominant legacy of a centrally planned economy combined with progressive liberalization and strong integration into the European Union's internal energy market. The Slovak model is characterized by a high level of energy security, substantial nuclear energy reliance, and gradual diversification through renewables and regional market integration. Despite regulatory reforms, state involvement remains considerable, particularly in electricity generation and infrastructure ownership. Largely dominated by Slovenské elektrárne, which operates nuclear and thermal power plants. It is jointly owned by the Slovak state (34%) and private investors. There is also a well-known participation scheme in the European electricity market coupling, including the 4M Market Coupling with the Czech Republic, Hungary and Romania (Kotek, Országhová, Fröhlich, 2019).

Slovakia has a relatively balanced and low-carbon energy mix by European standards (Zgajewski, Nadolska, 2021). In 2023, over 60% of electricity was generated from nuclear power, supplemented by hydropower, natural gas, and a small but growing share of solar and biomass (INTERNATIONAL ENERGY AGENCY, EUROSTAT). Slovakia supports nuclear energy as a strategic low-carbon option. The commissioning of Mochovce Nuclear Power Plant Unit 3 in 2023 reinforces its nuclear-heavy generation mix. However, decarbonizing heat and transport sectors remains challenging due to high fossil fuel dependence in those areas. Leaving aside formal liberalization, effective competition is still limited, particularly in the household segment. Price regulation and limited consumer switching indicate an incomplete retail market liberalization.

Historically, the goal of establishing a common market to remove trade barriers among Member States originated with the Treaty of Rome in 1957. Nearly three decades later, the Single European Act of 1986 marked the first significant amendment to that treaty. This act laid the foundation for one of the European Union most notable accomplishments, as it mandated the implementation of measures to create an internal market by 31 December 1992. The European Single Market was officially launched on 1 January 1993, involving the 12 Member States of the

European Union at that time. Until the mid-1990s, the electricity industry remained largely under the control of state-owned or state-regulated, vertically integrated companies that held regional or national monopolies. Cross-border electricity trade was minimal, mainly because of insufficient infrastructure and the absence of clear regulations to facilitate such exchanges. In order to establish a new market model applicable to various countries there had to be a huge legislative mechanism to ensure standard compliance (Glachant, Newbery, Joskow, Anatolitis, Rio, Kitzing, Fitch-R, Szabo). Consequently, different energy packages appeared with further comprehensive regulatory improvement on a constant basis (Table 5).

Table 5. Distinctive characteristics of Energy Packages over 1996-2019

Principal feature	First Energy Package (1996-1998)	Second Energy Package (2003)	Third Energy Package (2009-2011)	Fourth Energy Package / Clean Energy Package (2018-2019)
Goal	market liberalization	deep market liberalization and transparency	competitive transparent markets	clean energy, decarbonization, consumer empowerment
Extent of market openness	only big consumers	all consumers	consolidated	flexible, green, consumer-driven
Regulatory body	national regulators with limited impact	powerful national regulators	Agency for the Cooperation of Energy Regulators + independent regulators	stronger influence of Agency for the Cooperation of Energy Regulators
International collaboration	limited	European Regulators' Group for Electricity and Gas	European Network of Transmission System Operators for Electricity and Gas + Agency for the Cooperation of Energy Regulators	comprehensive grid integration + developed European Network of Transmission System Operators for Electricity and Gas
Unbundling	accounting separation	legal separation	ownership separation	ownership separation + renewables
Renewable energy development	-	-	limited	32 % target

Source: own compilation.

The European energy market refers to the complex network of production, transmission, distribution and consumption of energy (primarily electricity and natural gas) across the European continent. It includes both national markets and cross-border trading mechanisms, with increasing integration through European Union initiatives. The Energy Union Strategy launched by the European Commission in February 2015 (EUROPEAN COMMISSION, 2015) is a major policy framework aimed at ensuring that the European Union has secure, affordable and sustainable energy. It emerged partly in response to geopolitical tensions (especially with Russia) and the need for low-carbon economy transition.

The strategy is built around five interrelated dimensions. The first block is focused on energy security, solidarity and trust. There is a huge need to reduce dependence on energy imports (especially natural gas from Russia), diversify energy sources, suppliers as well as routes and improve crisis response mechanisms and solidarity among member states. Second point is placed on a fully integrated European energy market in order to create a connected internal energy market, enhance cross-border energy infrastructure (interconnectors) as well as eliminate energy islands and remove regulatory barriers.

European Union also widely promotes the necessity of energy efficiency contribution to the coherent moderation of demand. In this scope it is important to improve energy efficiency, particularly in construction and transport, treat energy efficiency as an energy source and deliver initiatives on meeting the EU 2030 climate energy targets.

One more crucial direction – economic decarbonization. International community is currently focused on leading the global transition to a low-carbon economy as well as supporting renewables and phasing out fossil fuel subsidies in order to achieve reductions of harmful emissions under the Paris Agreement. But all up-to-date changes are not possible without rapid increase in research, innovation and overall market competitiveness. That's why it is preferable for various international stakeholders to promote breakthrough approaches (smart grids, storage), support the development of low-carbon technologies (extraction) and by means of such

measures strengthen the across-the-board European Union geopolitical leadership in clean energy innovation.

The strategy marked a shift from national to more coordinated, EU-level energy policy, aiming to make energy systems more resilient, competitive and sustainable. It was not just a response to energy security concerns but also a step toward leading global climate action.

The Clean Energy for All Europeans Package (2019) is a comprehensive set of legislative measures adopted by the European Union to help transition the EU energy system towards greater sustainability, energy efficiency and integration of renewable energy. It is a central part of the EU broader Energy Union Strategy and supports the European Green Deal for climate neutrality by 2050.

The European Green Deal (2019), presented by the European Commission on December 11, 2019, constitutes a strategic framework that seeks to achieve climate neutrality within the European Union by 2050. It integrates a broad set of policy initiatives aimed at advancing sustainable economic development while simultaneously confronting the challenges posed by climate change and environmental degradation. Achieving net-zero greenhouse gas emissions by 2050 is considered the main goal with an interim target of reducing emissions by at least 55% by 2030 compared to 1990 levels. Promoting sustainable agriculture and food systems, protecting and restoring ecosystems as well as natural habitats, ensuring the transition towards a green economy in a fair and inclusive way are also crucial for policy consistency and efficiency.

The Fit for 55 Package (2021) is another legislative framework designed to align the EU climate, energy, land-use, transport and taxation policies with the objective of reducing net greenhouse gas emissions by at least 55% by 2030 – as set out in the European Climate Law. Its overarching aim is to transform the EU economy and society for a just and sustainable transition toward climate neutrality by 2050.

Such regulations presuppose tightening the emissions cap, increasing the annual reduction rate from 2.2% to 4.2% as well as introducing an import tariff (carbon border tax) on goods like steel, cement and aluminum to prevent carbon leakage and

protect EU industries. It is important to enhance the EU-wide renewable energy coverage from 32% to 40% by 2030.

In terms of Ukraine in the European context, a significant development in its energy sector occurred in March 2022, when the Ukrainian power grid was successfully synchronized with the Continental European Network operated by ENTSO-E. Although initially planned for 2023, the integration was fast-tracked as a direct response to Russia's full-scale military action. This strategic move allowed both Ukraine and Moldova to disconnect from the Soviet system, historically linked to Russia and Belarus, and connect with the European energy infrastructure, thereby enhancing grid stability and strengthening energy sovereignty.

Ukraine's integration into the ENTSO-E system is a critical inflection point in national energy policy. It reflects a broader strategic shift toward energy independence from Russia and alignment with core European energy principles, such as transparency, decarbonization and sustainability, mirroring developments in the abovementioned countries like Poland, the Czech Republic, France, Germany and Slovakia. This step lays the groundwork for Ukraine's full integration into the EU internal energy market with far-reaching consequences for national economic resilience and deeper geopolitical alignment with the European Union.

In 2023-2024 the European Union in a response to the 2021-2022 energy crisis launched a tactical reform in order to strengthen the resilience, affordability and sustainability of the European electricity market within several main directions. Originally such a need arose from the electricity price volatility for consumers leading to economic difficulties and demand shift. By means of better protection mechanisms, including regulated retail prices in emergencies and expanded access to fixed-price contracts it is easier to control market conjuncture and prevent drastic changes. It is also crucial to extensively promote long-term contracts such as Power Purchase Agreements and Contracts for Difference. These mechanisms provide coherent policy on price stability for both consumers and investors, enabling the financial support for capital-intensive renewable energy projects.

International governors are to enhance demand-side flexibility and energy storage to give consumers an opportunity to play pro-active role in grid balancing. Flexible consumption together with innovative storage solutions will reduce peak prices and reliance on fossil-based backup generation. Market integration, constant investment flow as well as accelerating deployment of renewables and grid infrastructure with streamlined permitting processes will provide sufficient basis for comprehensive development. The abovementioned reform aligns with the EU Green Deal targets and supports the shift to a decarbonized, interconnected energy system. Overall, the reform aims to modernize electricity markets, make energy more affordable and secure as well as support the EU climate neutrality goals by 2050.

2. AIM AND OBJECTIVES OF THE THESIS

The **main aim** of the dissertation is to establish innovative policy for sustainable development and long-lasting efficient performance of energy market in Ukraine taking into account modern geopolitical challenges and opportunities. The absence of practical implications on how to solve energy crisis in Ukraine taking into account the long-term prospects following global sustainability vision as well as geopolitical constraints raised the following major **research question** this dissertation is intended to answer:

➤ *How can Ukraine establish and implement long-term innovative policy of energy industry sustainability under modern national challenges as well as geopolitical constraints?*

To answer the research question the thesis was divided into several objectives:

Objective 1: to analyze and understand sustainability concept in scope of modern geopolitical trends

Objective 2: to determine the theoretical foundations of innovative policy formation within the framework of national economy

Objective 3: to analyze Ukraine's energy system development milestones from the historical perspective

Objective 4: to substantiate the possibility of adapting foreign experience in regulating the energy sector activities in terms of strategic policy formation for the development of this industry in Ukraine, taking into account domestic socio-economic features

Objective 5: to provide probable scenarios (coal, gas, oil) and potential development areas in Ukraine in the context of their impact on state economic security;

Objective 6: to determine the feasibility of the state innovative policy for the energy industry development in Ukraine based on modern geopolitical challenges;

Objective 7: to develop strategic proposals and recommendations for regulatory framework improvement in the energy sector.

The dissertation is aimed at providing crucial innovative solutions to modern energy industry development Ukraine in the international scope.

3. RESEARCH METHODOLOGY

The issue of the international relations in the energy field between Ukraine on the one side and world community on another is based on the theory of **neoliberalism**. Neoliberalism itself appeared as a continuation of more classical foundations of liberalism advocated mainly by Adam Smith (2012). As Nofal (2023) states, the neoliberal thought emerged as a response to the conditions that dominated the inter-war period. Those conditions that prompted a different line of debates among liberals centered on the consequences of the war, the Great Depression, the emergence of Fascism and Nazism and other challenges that confronted the classical liberal approach. This context is considerably applicable to modern geopolitical challenges due to the economic complexity within various markets. Moreover, great scientific burden by both guru and opponents forced the conceptualists to develop some principles following more grounded economic notions. Thus, Harvey (2007) declares that neoliberals adopted neoclassical principles of competitive market and individual rationality and thus accepting the general equilibrium model developed by Walras (1954). Despite this, they did not reject several principles of classical theories, most notable their adoption of Smith's notion of the 'invisible hand' keeping the neoliberal doctrine in opposing governmental intervention theories. Neoliberals, unlike neoclassicals, are not concerned with monopoly power, setting an issue for those countries where energy sector is under complete state control.

In general, this new economic paradigm following the policy-making initiatives is an ideology standing behind the recent stage of the capitalist society development. Munck (2005) presupposes that efficient allocation of resources is the most crucial goal of any economic system and constitutes itself the most effective way to allocate resources – through market mechanisms.

Recent historical studies (Ariely, Bartels, Freeman, Venugopal, Whyte) present neoliberalism as a distinct political theory. It promotes political and economic systems that are strongly liberal and capitalist, supported by a democracy limited through constitutional checks and a restrained welfare state. Neoliberals champion liberal rights and free markets as tools to protect individual freedom and stimulate

economic growth. Although they value democracy, they place significant emphasis on its boundaries as well as its virtues. They also acknowledge the governmental role in providing social insurance and public goods but are wary of excessive regulation, high public spending and active state intervention in order to manage economic cycles.

The neoliberal paradigm declares the prioritization of financial capital over social security, thereby consolidating the process of reorientation of free society with rational citizens to the one of dependent consumers. The gradual financialization of the economy contributes to a shift in the focus of development from innovation in production to capital accumulation as well as corresponding cycle change. Within the framework of neoliberalism theory, an active role is assigned primarily to non-state stakeholders, whose activities are aimed at strengthening multi-polar management of strategic processes of a sustainable economy formation at both local and international levels.

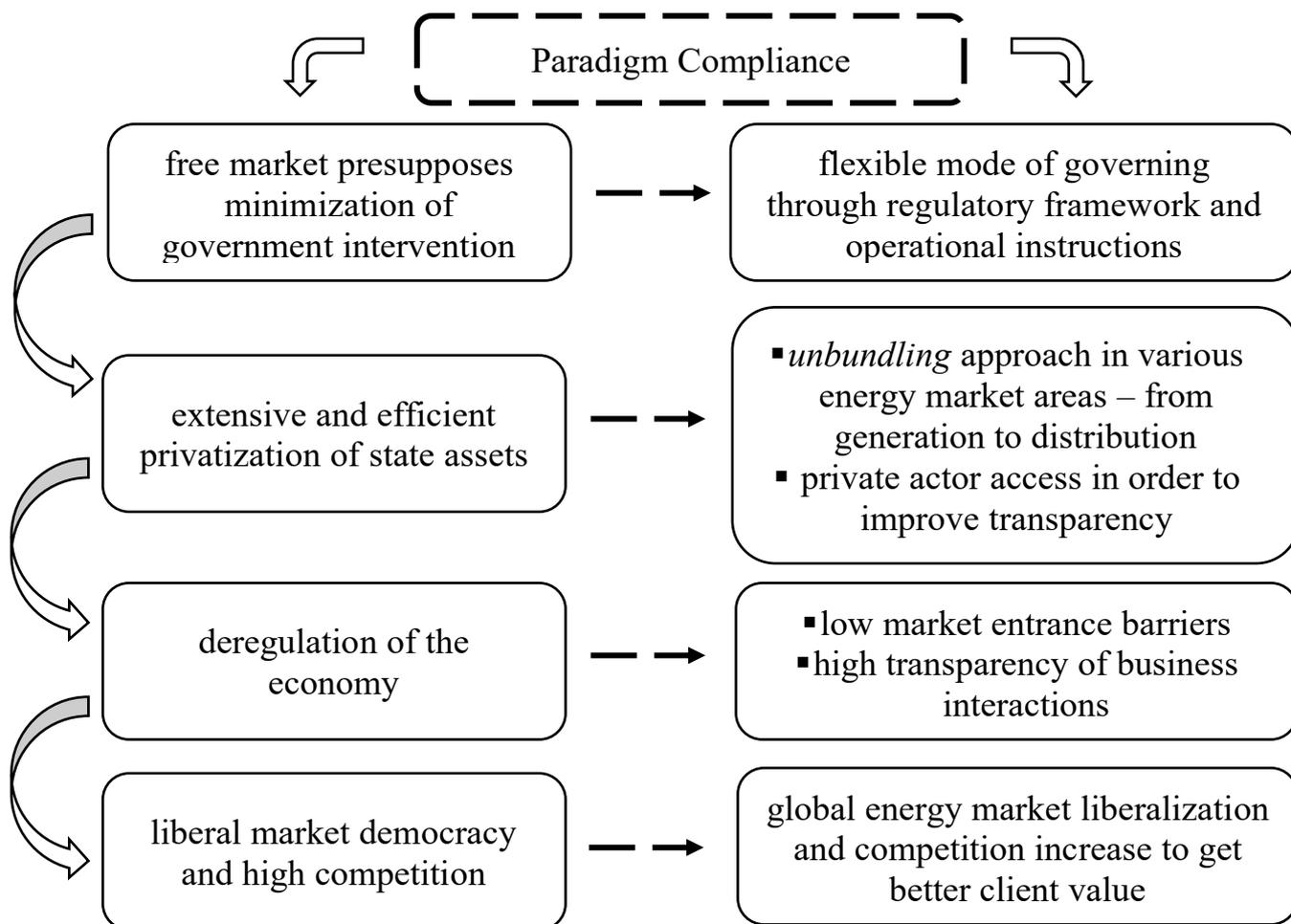
Markets enable individuals with differing values to mutually benefit from exchanges, fostering cooperation despite disagreements. In contrast, socialism relies on a central plan, necessitating the imposition of specific and often divisive values and goals on the entire population. To address these conflicts and enforce a unified plan, socialist governments must centralize political power.

Neoliberalism is mostly an economic paradigm, however, with the prerequisites of political ideology due to the historical preconditions widespread since the 1970s. The scope of theoretical compliance related to both neoliberal principles and energy market functioning peculiarities are presented in Figure 6.

In many countries since the 1980s privatization was considered to be the most important driver of efficient changes, especially regarding state energy companies (electricity grids, oil and gas corporations). Grounded programs were established in Great Britain, for example, with the British privatization program Thatcher for British Gas, British Petroleum. As a result, there was a huge formation of private energy giants operating according to market laws. Neoliberal globalization has significantly increased the influence of large energy corporations, especially in the

oil and gas sector. Nowadays, capital is concentrated in the hands of global players – Shell, ExxonMobil, TotalEnergies etc. There are increased investments in resource extraction and transportation, however, decreased control by states.

Figure 6. Theoretical compliance between neoliberal principles and energy market functioning peculiarities



Source: own compilation.

Neoliberal approach places the focus on market mechanism to climate regulation instead of direct policy regulations (e.g. trading in CO₂ emission quotas). It declares support for the development of renewable energy sources (wind, sun) through private investment rather than public funding. Rapid growth of renewable energy sources is present, but there may be regulatory issues with uneven access and dependence on subsidies.

Neoliberalism also presupposes moving away from fixed tariffs and quotas to liberalized electricity and gas markets. The procedural emergence of energy

exchanges, where prices are determined by supply and demand, undermined the understanding of competitive energy market. Despite obvious benefits, such processes may also provoke price instability, speculation and increasing vulnerability to global shocks (like 2021-22 energy crisis).

One more paradigm issue – the rejection of long-term contracts and transition to spot prices (especially in Europe). The importance of strategies for supplier diversification instead of state control over resources is hugely promoted. The market is more flexible, but also demonstrates greater vulnerability (like European gas crisis due to the reduction of supplies from Russia).

Similar to Keynesians, neoliberal theorists endorsed state intervention – but primarily to safeguard market competition, which they viewed as essential to a functioning liberal democracy (Lemke, 2001). This reimagined form of liberalism was seen as the pathway to a stable international economic system after the war. In principle, it acknowledged the role of the state while aiming to protect individual freedoms (Slobodian, 2018).

It is evident that anthropologists have interpreted neoliberalism through multiple lenses. Its analytical richness has made it a highly debated concept. Underlying the various approaches mentioned earlier are often deeper theoretical beliefs about how political power operates and what social analysis is meant to achieve.

Neoliberalism is often criticized for increasing energy inequality, overall dependence on market conditions, slow transition to sustainable energy in the absence of comprehensive government initiatives, shift from energy as a public good to energy as a profit object.

Neoliberalism is frequently discussed for organizing society around market principles, commodifying relationships and subtly steering individuals toward serving the interests of commerce and economic productivity. In doing so, it is said to construct society around a *cash nexus*. Unlike overt capitalism, neoliberalism operates in a more concealed manner, requiring significant scholarly effort to uncover its mechanisms. While neoliberalism is not inherently an ethos, it may be

perceived as fostering overly capitalist or transactional interactions between individuals.

All things considered, neoliberalism has had a huge impact on the development of the modern energy market, transforming it from a centralized, controlled sphere into a decentralized, competitive and globalized system. This has brought both positive and negative consequences – from technological innovations and geopolitical independence to social and environmental challenges.

To maximize the disclosure of the topical issues, the following explicative research methods are used:

- *method of complex textual analysis* – while thoroughly analyzing sectoral legislation as well as general regulations, including the Energy Packages and field laws of Ukraine;
- *method of comparative analysis* – in order to identify common and distinctive features of the existing energy strategy of Ukraine as well as in other countries;
- *historical method* – while summarizing the foundations as well as the influence of international imperatives on policy formation in the energy industry of Ukraine.

To fulfill practical research objectives the following methods are considered to be comprehensively used:

- *scientific abstraction and generalization, semantic and critical analysis* – in the study of the *sustainable development* and *innovation* concepts;
- *structural analysis* – when systematizing approaches to assessing the level of strategic policy effectiveness in the energy industry;
- *retrospective analysis* – while considering the development peculiarities of energy industry in Ukraine;
- *forecast methods* – to make forecasts for the energy industry development in Ukraine within the global context;
- *tabular and graphical methods* – for visual representation of analytical results and calculations.

The main research method used within the thesis will be *secondary data analysis*, based on thorough evaluation of world energy data. *Systemic* approach was comprehensively applied to multiple energy security procedural issues, simultaneously focusing on sectoral and source complexity. It is particularly relevant in order to achieve economically, environmentally and socially sustainable results. It provides practical implications on how energy data evaluation results can continue to grow and deepen beyond the energy market development and security maintenance. Strategic approach allows to reconsider energy policies and analyze future forecasts.

While conducting the research for the thesis *extrapolation* to a trend is used as one of the main methods for forecasting energy market dynamics. The essence of the method lies on the basis of a dynamic series of statistical data, the main trend of change is highly determined and thereby expands on the next period. In general, it is important to take into account that the foreseen period should not exceed a third of the forecast basis. Following the peculiarities of changes in dynamics, extrapolation methods can be simple or complex. Simple methods of extrapolation (from time to time, according to the average level of the dynamics series and the average growth rate of the series) are based on the assumed consistency in the upcoming characteristics.

The used in dissertation *forecasting* method with optimistic, pessimistic and normal (most likely) estimates is often referred to as Three-Point Estimation and commonly used in project management and business forecasting. There are three estimates within the investigating and envisaging energy market development trends in Ukraine: optimistic (best-case scenario), most likely or normal (most probable outcome) and pessimistic (worst-case scenario). A detailed forecast of the development of domestic economy or particular market is the most complex and multiple stage of comprehensive analysis. At the same time the importance of enhancement prospects of the situation is the most essential from a practical point of view as a part of market research.

Moreover, in the dissertation a *confidence interval function* is used in order to estimate potential development scenarios – normal, optimistic, pessimistic. This function or statistical method calculates a confidence interval around a sample estimate, such as a mean or proportion, to indicate the range in which the true parameter likely falls with a specified confidence level (95%).

The energy market situation can be defined as the complex of inner forces and outward impacts at any given time. This system is characterized by strong correlations with basic economic indicators, among which there is a demand to reinforce the potential. The forecast will serve as the basis for the development of innovative energy policies and strategies on the market for various products in the long term, or the development of tactical approaches to a given specific point of timeline, which will contribute to the market development.

The information base for the research is made up of international agreements and regulatory documents in the field of sustainable development of the energy industry as well as innovative provision of energy security in Ukraine and other countries of the world, regulatory and legal acts on the activities of energy companies, international statistical materials (World Bank, World Energy Council, International Energy Agency, International Renewable Energy Agency, British Petroleum) and domestic reporting data (State Statistics Service of Ukraine, National Commission for State Regulation of Energy and Public Utilities, NEC Ukrenergo), materials and analytical publications from international consulting agencies, data from integrated reporting of companies and organizations, scientific studies as well as the results of the author's own research.

4. PRESENTATION OF FINDINGS

Energy consumption is a critical and urgent issue that the global community must address. The high levels of carbon dioxide emissions contribute to worsening ecological conditions worldwide, putting human rights, social security and well-being at risk. This issue serves as a key measure of the effectiveness of global policies aimed at achieving sustainability. The future of our planet is uncertain, influenced by risks such as natural disasters and human-induced hazards. Additionally, the rapid pace of global development makes it vital to not only avoid accelerating it but also manage and balance the resources consumed with the benefits gained, leveraging technological advancements and innovative business models.

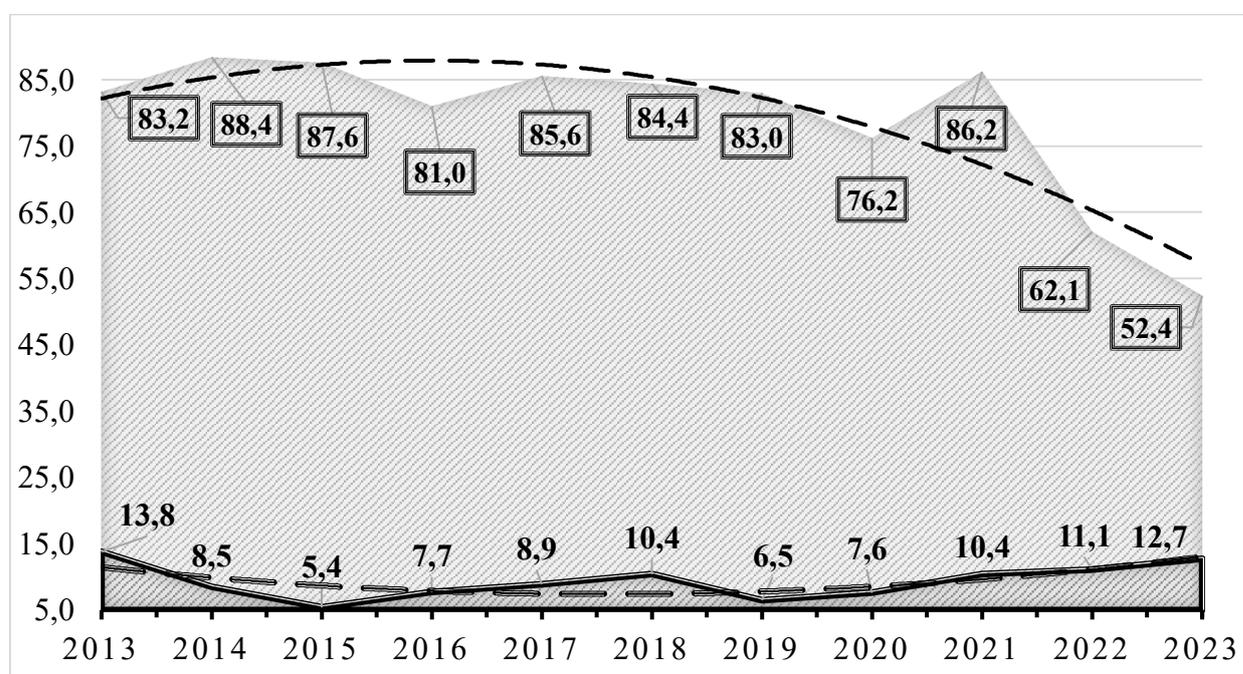
In line with the modern global perspective, energy consumption is particularly emphasized in Goal 7 – Affordable and Clean Energy – within the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development. Sustainable energy is seen as a transformative opportunity, capable of improving lives, economies and the planet as a whole. This underscores the importance of establishing global, regional and local policies to ensure access to affordable, reliable and modern energy services. These policies should focus on improving energy efficiency, expanding infrastructure and upgrading technology to deliver sustainable and modern energy solutions.

4.1 Sustainable development of energy sector in Ukraine: long-term prospects and geopolitical challenges

The energy market of Ukraine is a fundamental sector of the national economy with a rich historical background. Generation capacities are primarily concentrated in nuclear sources (Gardus, 2015), complemented by various production processes based on oil, coal, biofuel, and natural gas. Additionally, renewable sources such as solar energy, wind turbines and hydroelectric stations are already being utilized in Ukraine. Given its strategic importance, the energy sector remains a top priority for the state, constituting a significant share of the country's economic foundation.

The electricity generation sector has historically been one of Ukraine’s key contributors to GDP. It includes a diverse mix of energy sources – ranging from coal and renewables to nuclear power. Prior to the 2022 invasion, energy industry was robust and multi-faceted, allowing flexibility in managing its generation capacity. According to NPC UKRENERGO official data from January 2022, Ukraine’s installed capacities included 2 GW from wind, 6 GW from solar, 5 GW from hydroelectric power, 1 GW from pumped-storage hydro, 6 GW from combined heat and power and biofuel plants and 14 GW from nuclear power – totaling 34 GW.

Figure 7 . Dynamics of hydro and nuclear electricity production in Ukraine for 2013-2023, TW.



Source: own compilation.

Based on these figures, most electricity is generated by large thermal and nuclear power plants, accounting for over 70% of production. Power is delivered to end users through main transmission lines and distribution networks with nearly all plants connected by at least two transmission routes. Because electricity must be generated and consumed in real time, the system requires constant balancing. This is typically managed by adjusting the output of flexible plants, particularly hydroelectric facilities. When local capacity is insufficient or the infrastructure is unable to deliver

electricity from distant sources, including European imports, some regions may face complete disconnection to maintain overall system stability (Figure 7).

The abovementioned dynamics demonstrate fluctuations in electricity production over 2013-2023, however, with some stable future trend as for hydro energy. Nuclear potential is under threat due to military circumstances and is to be controlled in geopolitical context. In general, the situation is quite unstable which makes it difficult to predict with high probability the development prospects.

Electricity from centralized power systems is usually more affordable than power from standalone or autonomous sources. However, daily and seasonal demand fluctuations present challenges. For example, electricity usage during nighttime can be less than half of peak morning or evening consumption. In winter, overall demand increases due to extended lighting needs and heating requirements, making morning and evening hours particularly critical for system stability.

The solar energy sector in Ukraine is relatively nascent compared to abovementioned generation options. Solar energy is harnessed through photovoltaic technology, which involves the use of solar panels embedded with photovoltaic cells capable of capturing light photons and converting them into electrical energy via the photoelectric effect. Typically, solar panels are mounted on rooftops, repurposed land such as landfills or organized in large-scale solar farms. A key advantage of solar power lies in its sustainability and low carbon emissions, given the inexhaustible nature of solar radiation.

A significant driver of this growth has been the state-supported feed-in tariff scheme, commonly referred to as green tariff, which has been utilized by 97% of solar electricity producers. This policy allows individual homeowners or legal entities to enter into formal agreements with the state under the Guaranteed Buyer program, whereby surplus electricity generated from privately owned solar installations can be sold back to the grid. The advancements in solar panel technology have enabled electricity generation even under suboptimal conditions, such as overcast weather. According to recent energy forecasts, the green tariff is expected to reach parity with conventional electricity tariffs by 2030, at which point the financial rationale for

maintaining it may diminish. Nevertheless, generating electricity for personal use remains economically advantageous for both individuals and businesses. In this decentralized model the primary investment cost lies in the acquisition and installation of the solar system itself with no ongoing fuel or production costs. This enables significant cost savings, as owners may substantially reduce or completely eliminate reliance on centralized electricity supply. The final cost of solar installations varies depending on the manufacturer, model, power output, technical specifications and additional functionalities. Thus, a wide range of options is available to meet diverse consumer needs and budgets, further enhancing the attractiveness and accessibility of solar energy solutions.

As for the industrial scale, several critical factors have shaped the trajectory of solar energy development in Ukraine. Firstly, the Ukrainian government has played an active role in promoting renewable energy through legislative and financial incentives, particularly feed-in tariffs, to attract domestic and foreign investment. Secondly, numerous international corporations and financial institutions have already entered the Ukrainian market, recognizing both its untapped solar potential and favorable regulatory environment. Thirdly, the environmental implications of solar energy expansion are substantial. Scaling up photovoltaic capacity contributes to reducing greenhouse gas emissions and lessens Ukraine's dependence on fossil fuels, particularly coal and natural gas, thereby advancing both energy security and sustainability objectives.

Historically, Ukraine's engagement with solar power dates back to the Soviet era, when the first solar power station was established in Crimea. At the time of its commissioning, the plant had a capacity of 5 MW, a slightly low figure as regards today's standards, but it represented approximately 25% of global solar capacity at the time, highlighting its technological significance. Although the initial output of individual stations was limited, their cumulative generation capacity in the early 2010s provided a substantial energy contribution, which shaped the strategic direction of solar development in Ukraine.

Starting from 2014, coinciding with the onset of the Anti-Terrorist Operation, and up to 2017 the sector experienced marked growth driven by private initiatives. Investments exceeding 52 million hryvnias were directed toward decentralized solar installations. These small-scale, privately operated stations typically had individual capacities averaging 30 kW and could collectively reach a total capacity of 50 MW, which is comparable to the output of a mid-sized industrial solar plant.

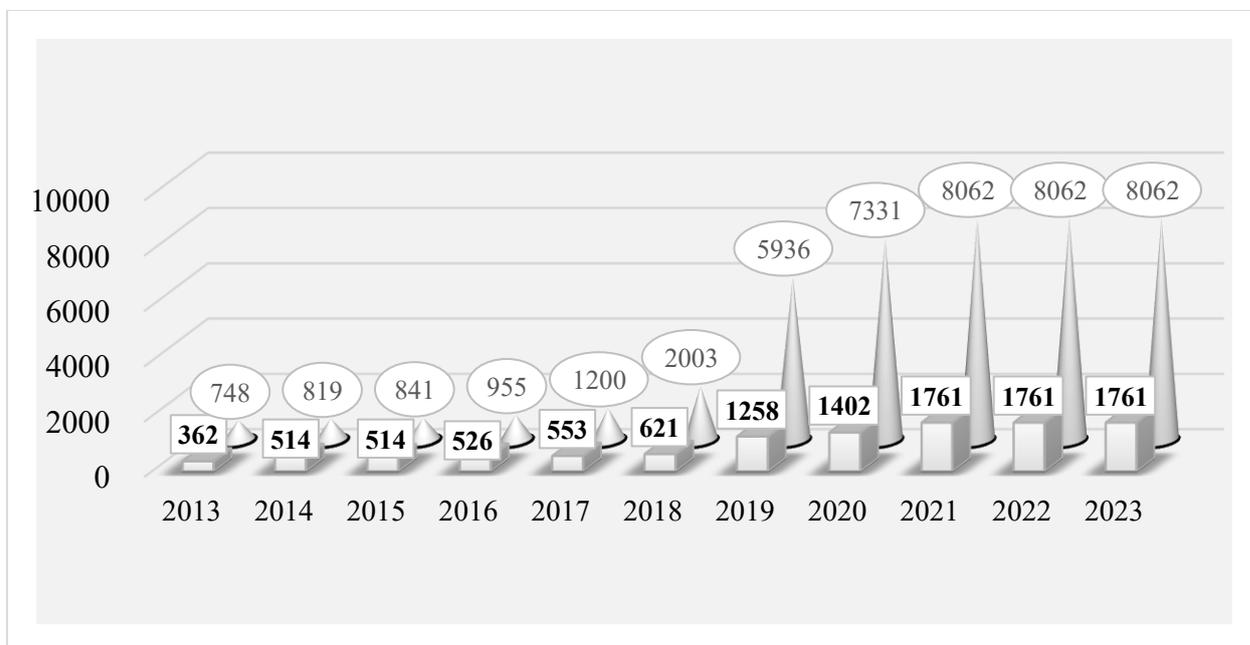
In general, Ukraine possesses favorable geographic and climate conditions for the deployment of solar power infrastructure across its entire territory. However, optimal conditions are found in the southern regions – specifically Odesa, Mykolaiv, Kherson, Zaporizhzhia parts of Donetsk and the Autonomous Republic of Crimea. Prior to the onset of large-scale invasion, these areas collectively accounted for over 60% of the country’s industrial solar power plant capacity. By the end of 2021 Ukraine’s total installed solar capacity stood at approximately 6,320 MW, excluding facilities located in territories under temporary occupation.

Before the escalation of military aggression, Ukraine was among the leading European countries in terms of the pace and effectiveness of solar energy development. However, the full-scale invasion significantly disrupted the sector, resulting in substantial losses to its infrastructure. Given that two-thirds of Ukraine’s solar facilities are situated in the southern regions, where ongoing hostilities are most intense, a considerable portion of the capacity has been rendered inoperable. Expert assessments indicate that over 30% of solar power installations, approximately 1,120-1,500 MW, are located in currently occupied territories and have been entirely destroyed. More than 25% of non-industrial (primarily residential or small-scale) solar systems have also suffered irreversible damage, further exacerbating the crisis in the renewable energy sector.

A recent trend is the growing use of solar energy, although most solar plants lack storage capacity and are heavily influenced by weather (Figure 8). Their generation peaks during daytime in summer, a period of lower electricity demand. While solar power currently contributes only around 5% of Ukraine’s energy mix, European

trends suggest this share may rise and future power system planning must take this into account.

Figure 8. Dynamics of solar and wind electricity production in Ukraine for 2013-2023, MW.



Source: own compilation.

Currently there is one innovative approach extensively applied in Ukraine – biomethane production. The industry is characterized by feedstock diversity and participation across multiple sectors, highlighting its flexibility and growth potential. This green area may constitute a significant part of EU future market. Over the medium term, Ukraine could potentially supply up to 20% of the EU biomethane demand by 2050 contributing significantly to Europe energy transition and decarbonization goals.

There are some already operating facilities and several in progress of construction demonstrating high likelihood of potential market coverage in Ukraine and abroad. Such a galloping trend can be explained by several preconditions. Firstly, Ukraine possesses the largest expanse of agricultural land in Europe, offering one of the continent strongest biomass feedstock bases for biomethane generation. Due to the low cost of agricultural raw materials, Ukraine is well-positioned to become a highly competitive player in the global biomethane market. Moreover, the country also benefits from a well-established natural gas infrastructure, including both

transmission and distribution systems, which can support biomethane injection and transport. In addition, the structure of Ukrainian agricultural sector with a high concentration of large and medium-sized enterprises is particularly suited to scaling up biomethane production efficiently.

Biomethane projects in Ukraine have been implemented at various scales, with capacities ranging from 125 kW to 26 MW. The first biomethane production plant in Ukraine was commissioned in April 2023, based on the infrastructure of a preexisting biogas facility. In February 2025 Ukraine successfully exported biomethane to the European Union for the first time, marking a significant step in energy cooperation. Thus, Ukraine has a unique opportunity to export biomethane to the EU market, especially in the light of REPowerEU strategy, which targets 35 billion cubic meters of biomethane production annually by 2030.

In terms of overall electricity generation in Ukraine the trend was very optimistic before the military actions taking place from 2022. The last years have demonstrated the same official data due to the fact that a lot of capacities were destroyed and occupied without any possibility to estimate damage. Unfortunately, the full-scale invasion led to very significant destruction and weakening, first of all, of Ukrainian generation capacities. There are a lot of irreversible changes with uncompromising consequences for the whole generation system in Ukraine as well as in the global arena. In particular:

- March 2022 *Zaporizhia* NPP, the largest in Europe, was seized, resulting in minus 6 GW or 42% of the country's entire nuclear generation;
- after the attack on April 11, 2024, the *Trypil* TPP, the largest one in Kyiv region, was completely destroyed with a minus of 3.2 GW in the system (*Centerenergo* lost 100% of its power generation capacity);
- March 2024 *Zmiivska* TPP (2.175 GW) was destroyed by a Russian strike in the Kharkiv region;
- July 2022 *Vuglehirska* TPP (3.6 GW) in the Donetsk region has been occupied by Russian troops;

- March 2024 *Kharkiv* TPP-5 (0.54 GW), one of the largest in Ukraine, was completely destroyed after the Russian attack, thus a big city Kharkiv lost its main thermal and electrical energy generation capacities;
- March 2024 missile strikes at the *Ladyzhynskaya* TPP (1.8 GW) and the *Burshtyn* TPP (2.3 GW) damaged all power units;
- April 2024 Russia attacked the *Sumy* TPP with guided aerial bombs;
- March 2024 the Kremlin struck Ukraine's largest *Dnipro* HPP (Zaporizhia) with the complete stop of operations at HPP-1 and HPP-2 (1.5 GW);
- June 2023 the *Kakhovskaya* HPP (0.35 GW) was blown up by the Russians, which caused, among other things, the largest environmental disaster;
- the *Dniester* HPP (0.7 GW) and the *Kaniv* HPP (0.4 GW) were also attacked and partially destroyed.

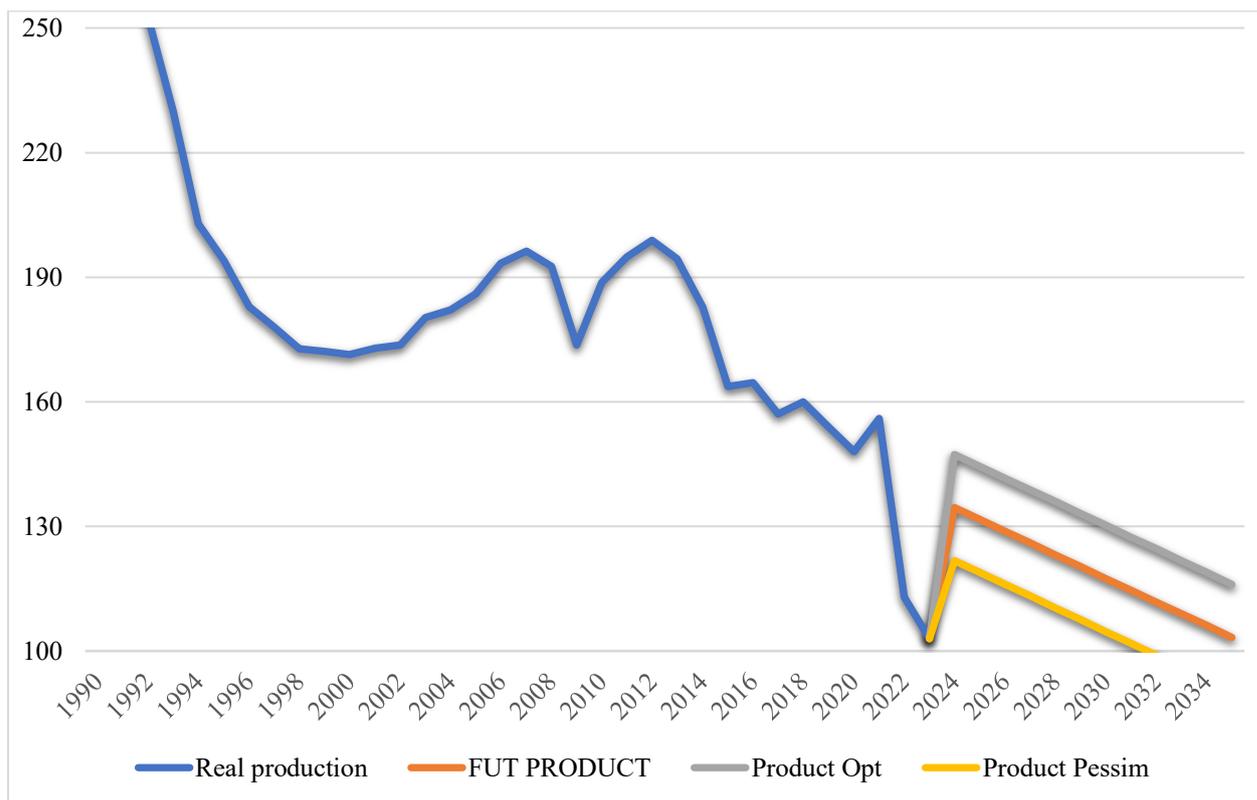
In historical retrospective, during the period of Ukraine's independence it is worth highlighting two crisis years, 2007 and 2012, respectively, which showed a tendency to a decline in the production and consumption of electricity. The first crisis was caused by a decline in the pace of industrial production and global ones. The second was associated with rapid recession processes in the Ukrainian economy due to a decline in industrial production, the lack of foreign sources of comprehensive financing from the International Monetary Fund, a decrease in external demand for products and domestic investment demand as well as general economic stagnation. In 2012 an active course was also taken towards energy independence, especially in the general structure of primary energy supply from the Russian Federation to fulfill agreements with the European Union. However, this issue was not resolved effectively and qualitatively due to pressure on the Ukrainian government from both parties to international relations, the existing significant cross-subsidization within the framework of that market model, differentiated retail tariffs and the fact that SCM Holding violated its obligations to the Energy Community in terms of ensuring non-discriminatory auction conditions.

As of June 30, 2024, due to military actions the total losses of electricity generation are approximately 22,565 GW (State Energy Efficiency of Ukraine). Only about

11,435 GW of theoretically surviving capacities remain, of which a significant part are solar power plants, which will not provide such amount of electricity in winter. This leads to a significant shortage of electricity and mass blackouts.

This dissertation aims to consider a range of potential development scenarios in order to find an appropriate solution for further market changes. While several existing forecasts have been referenced, we also present an original forecast for Ukraine’s electricity generation in the nearest future. Using the EXCEL Extra application, a comprehensive analysis of secondary data on electricity generation in Ukraine from 1990 to 2023 is given. After that different calculations are made to create a matrix of potential scenarios for the period 2024 to 2035.

Figure 9. Electricity generation forecast for 2024-2035 in Ukraine (normal, optimistic, pessimistic)



Source: own calculation and compilation.

The FORECAST function, which applies linear regression to predict future values, was employed. Additionally, the function – *like confidence interval function* – incorporates elements such as the confidence interval, which determines the range within which future values are likely to fall. This is essential for conducting a reliable

analysis and producing a realistic forecast – not only for the indicator of total electricity generation but also under optimistic and pessimistic scenarios (Figure 9). In general, a negative trend in electricity production will gradually decrease, albeit at a small pace, since the relative growth rate of generation volumes for 2006-2024 has a negative direction. It is predictable that the downward trend in generation and consumption volumes will constitute undisputable feature up to 2035 with further stabilization, but the generation structure is to qualitatively change and develop to ensure flexibility and competitiveness in accordance with the global trend of increasing the total volume of electricity generation and the prevalence of green energy and reducing harmful emissions into the atmosphere.

The electricity generation market in Ukraine demonstrates the structure with prevalence of nuclear and thermal generation with minor fluctuations in the respective values. A significant decrease in the volume of electricity production by thermal power plants in 2014 is due to the disruption of the station regular operation as for the difficult political situation in Eastern Ukraine. The full-scale war only worsened the situation as the majority of coal-powered plants have been destroyed. In general, the level of raw material supply for generation has also sharply deteriorated since 2014. A significant shortage of fuel and hydro resources affected the production and consumption of electricity, which also caused frequent imbalances in the system. A significant reduction in consumption occurred across all categories of consumers, specifically in the Luhansk and Donetsk regions. This situation caused significant changes not only in the volumes of production and consumption, but also led to a decrease in the shares of key participants in the electricity generation market.

In general, the study of the prospects for the application of established practices of electricity production is extremely relevant, since the impact of economic diversification trend of is also significantly obvious in the global energy sector. High energy prices cause structural changes in many markets and the displacement of generation centers to other regions or countries. A wide range of investment opportunities and practices of developed countries is a confirmation of the successful

implementation of specific cases of restructuring energy markets and laying new development vectors for other participants. However, innovative technologies, uncertainty in demand for oil and gas, the growing role of renewable sources and shale – these factors are becoming challenges for modern electricity production not only in the world, but also in Ukraine. In order to build a forecast for the future prospects of electricity generation from various sources in Ukraine a method of extrapolation was used (Table 6).

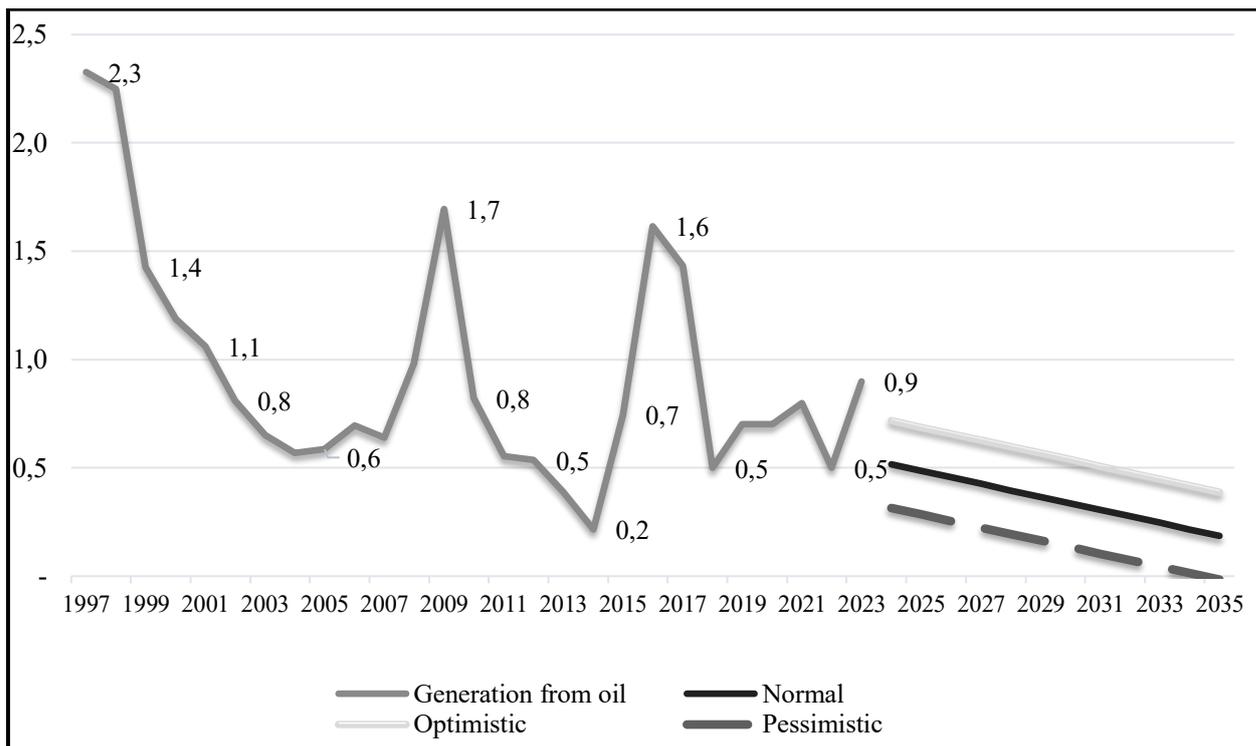
Table 6. Forecast matrix for electricity generation by the type of raw material until 2035

Raw Material	Forecast	Year 2024-2035											
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
oil	Opt	0,72	0,69	0,7	0,63	0,6	0,57	0,54	0,51	0,48	0,45	0,42	0,39
	Pes	0,3	0,28	0,25	0,22	0,19	0,2	0,13	0,1	0,07	0,04	0,01	-0,02
	Norm	0,52	0,5	0,46	0,43	0,4	0,37	0,3	0,31	0,28	0,25	0,22	0,19
gas	Opt	8,68	7,92	7,15	6,39	5,63	4,86	4,1	3,34	2,57	1,81	1,05	0,28
	Pes	4,14	3,38	2,62	1,85	1,09	0,33	-0,44	-1,2	-1,96	-2,73	-3,49	-4,25
	Norm	6,41	5,65	4,88	4,12	3,36	2,59	1,83	1,07	0,3	-0,46	-1,22	-1,99
coal	Opt	52,97	52,42	51,87	51,31	50,7	50,2	49,65	49,09	48,54	47,98	47,43	46,88
	Pes	41,93	41,38	40,82	40,27	39,7	39,16	38,6	38,05	37,5	36,94	36,39	35,83
	Norm	47,45	46,9	46,34	45,79	45,2	44,68	44,13	43,57	43,02	42,46	41,91	41,35

Source: own calculation.

The forecast for oil, gas and coal were built by extrapolating data from 1996 to avoid significant errors caused by sharp fluctuations in values due to historical aspects of the development of generation in Ukraine. All three forecasts – pessimistic, optimistic and normal in the matrix of data and calculations – testify to the unpromising use of oil as a raw material for electricity production, which is confirmed by the tendency of calculated values to 0 (Figure 10).

Figure 10. Forecast of electricity production from oil until 2035, TWh.

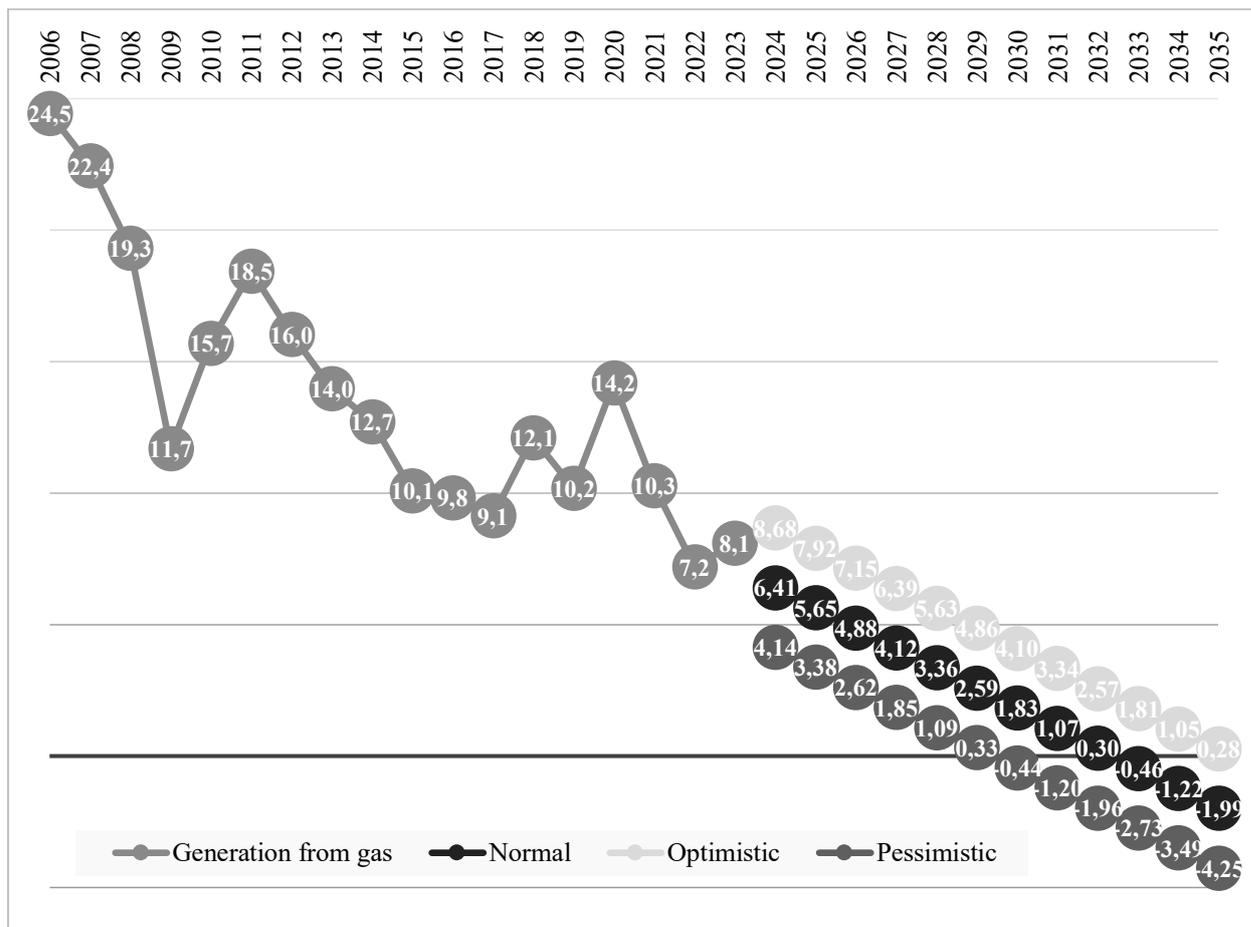


Source: own calculation.

At the onset of the military conflict, Ukraine’s domestic oil production covered only around 30% of its needs, with the majority of oil products being imported from Russia and Belarus. In June 2022, the state-owned energy company NNEGC Energoatom signed agreements with the American firm Westinghouse Electric Company to secure a stable supply of nuclear fuel. In the weeks that followed, Ukraine and Moldova successfully synchronized their power systems with the European electricity grid, ENTSO-E. This milestone enabled Ukraine to begin commercial electricity trade with the European Union starting in June 2022.

The built forecast for natural gas also indicates the invalidity of the development of this direction of generation, since all three trends have a downward direction of movement. The year 2006 was chosen as the starting point, which formed the current dynamics of changes in values, not taking into account the sharp drop compared to the 1990s. Although the obtained values are higher than those for oil, a decrease in production volumes is also inevitable (Figure 11).

Figure 11. Forecast of electricity production from natural gas until 2035, TWh.



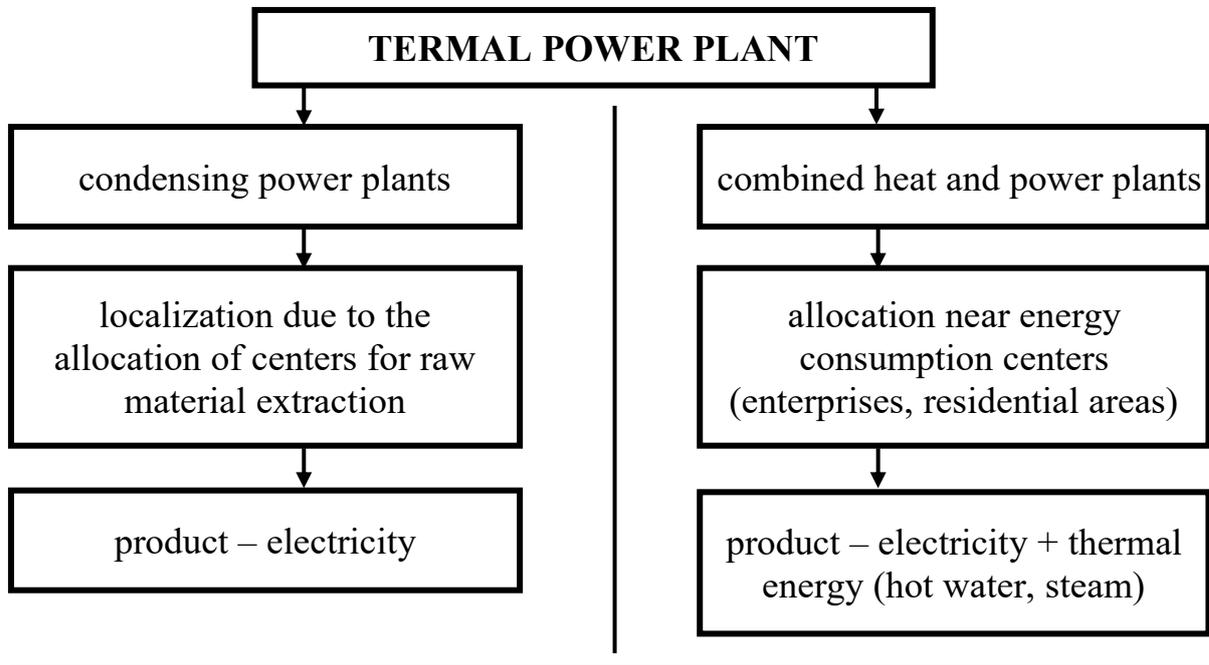
Source: own compilation.

Since 2014, Ukraine has steadily reduced its reliance on Russian natural gas. However, it remained partly or fully dependent on imported fuels. Prior to Russia’s full-scale invasion in February 2022, Ukraine was able to meet approximately 75% of its coal demand through domestic production. When shortages occurred, Ukraine integrated a variety of competitive international suppliers into its import strategies to ensure stable supply chains.

Thermal power plants constitute one of the biggest shares in the electricity production. The operation of these plants is generally based on the law of energy conservation. Electricity is generated through the sequential conversion of thermal energy obtained from various natural sources (coal, natural gas, fuel oil etc.), first into mechanical energy and then into electrical energy. The operational principle of a thermal power plant is to burn the energy resource in a special boiler in which

water is heated and converted into steam. This steam is fed to turbines that rotate a generator, producing electrical energy.

Figure 12. Key characteristics of the main types of thermal power plants



Source: own compilation.

The specific operating mode of a thermal power plant determines the production composition and type of equipment. Units (boilers and turbines) standardized in terms of power, voltage and current strength with generators and condensers are integral elements of electricity production, which make it possible to assess the efficiency of the plant as a whole, based on two key parameters:

- operating conditions of the thermal power plant;
- nature of the course of thermal processes (costs – heat and energy losses).

The practice of operating thermal power plants demonstrates a significant increase in the thermal efficiency due to the integrated production of electricity and heat, since heat losses in turbines are reduced, which affects the reduction of the final cost of electricity and heat produced. Thermal power plants have significant generation capacity. They are also competitive and reliable given the national experience of electricity production. However, these plants have a sufficient number of advantages and disadvantages in comparison with other generation options (Table 7).

Table 7. Advantages and disadvantages of thermal power plants

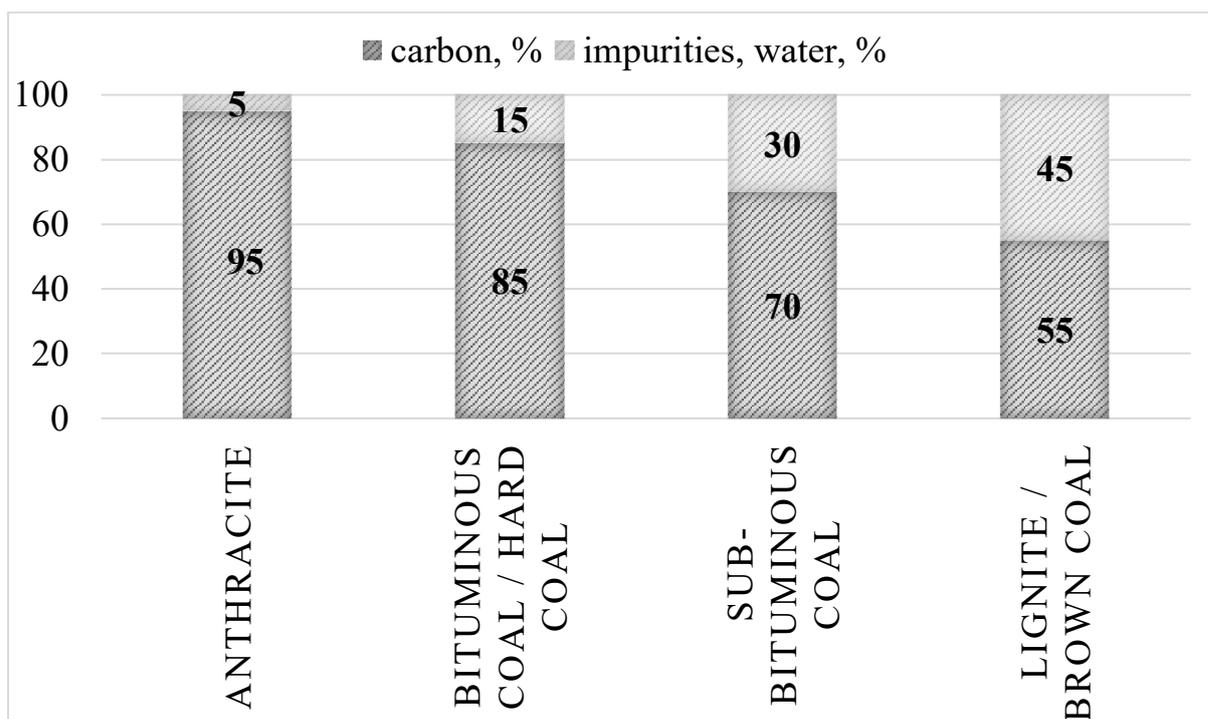
TERMAL POWER PLANT	
ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"> ▪ <u>reliability</u> - generation does not depend on seasonality; - ability to meet peak or base load needs; - support of network systems 	<ul style="list-style-type: none"> ▪ <u>raw material dependence</u> ensure constant supply of raw materials in order to minimize operational disruptions and provide production flow
<ul style="list-style-type: none"> ▪ <u>availability</u> - relative fuel availability; - low cost per kW of energy 	<ul style="list-style-type: none"> ▪ <u>low efficiency</u> – coefficient of performance (COP)
<ul style="list-style-type: none"> ▪ <u>technological capability</u> <p>technological development to reduce the harmfulness of electricity generation contributes to the electricity production process improvement with constant renewal of physically and morally obsolete capacities</p>	<ul style="list-style-type: none"> ▪ <u>high electricity generation harmfulness</u> - generation causes large emissions of harmful substances and compounds into the atmosphere exacerbating the risks of global warming; - significant proportion of production waste, most of which cannot be reused or recycled; - coal (high-ash) plants are the most harmful, gas-fired – the least
<ul style="list-style-type: none"> ▪ <u>safety</u> - the risk of a man-made disaster is much lower compared to a nuclear power plant; - working conditions are constantly improving towards the accident rate reduction 	<ul style="list-style-type: none"> ▪ <u>variability of operating modes</u> possibility of changing the operating mode of such station with periodic shutdowns causes significant fuel overconsumption, faster equipment depreciation and production interruptions
<ul style="list-style-type: none"> ▪ <u>independence and flexibility</u> - station construction does not significantly depend on territorial features, but is determined by raw material availability; - no need for a large territory for station construction; - high speed of construction and commissioning of generating capacities compared to nuclear and hydroelectric power plants 	<ul style="list-style-type: none"> ▪ <u>ecological factor – ecosystem change</u> significant emissions of mercury compounds, sulfur dioxide, nitrogen oxides, carbon dioxide and dust into the atmosphere affect the climate and ecosystem conditions as well as Significant emissions into the atmosphere of mercury compounds, sulfur dioxide, nitrogen oxides, carbon dioxide, and dust affect the climatic and ecosystem conditions of human and organism life, and reduce biodiversity. reduce biodiversity.

Source: own compilation.

Given the distinctive functioning features of various thermal power plants, the resource base for generation is also different. Thus, the parameters of the raw materials determine the different heat output of the plant and the corresponding mode of its operation. As a comprehensive indicator in international practice, the ratio of available reserves to the level of consumption of a given country is used,

which shows the possibility of raw material supply provided that the existing rates of industrial production are prolonged. Accordingly, Ukraine's potential is the largest among European countries, and the corresponding level of potential coal reserves (more than 500 years) is possessed by various countries of South America (Brazil, Venezuela), the countries of the Middle East, Pakistan and New Zealand.

Figure 13. Qualitative heat parameters of different coal types



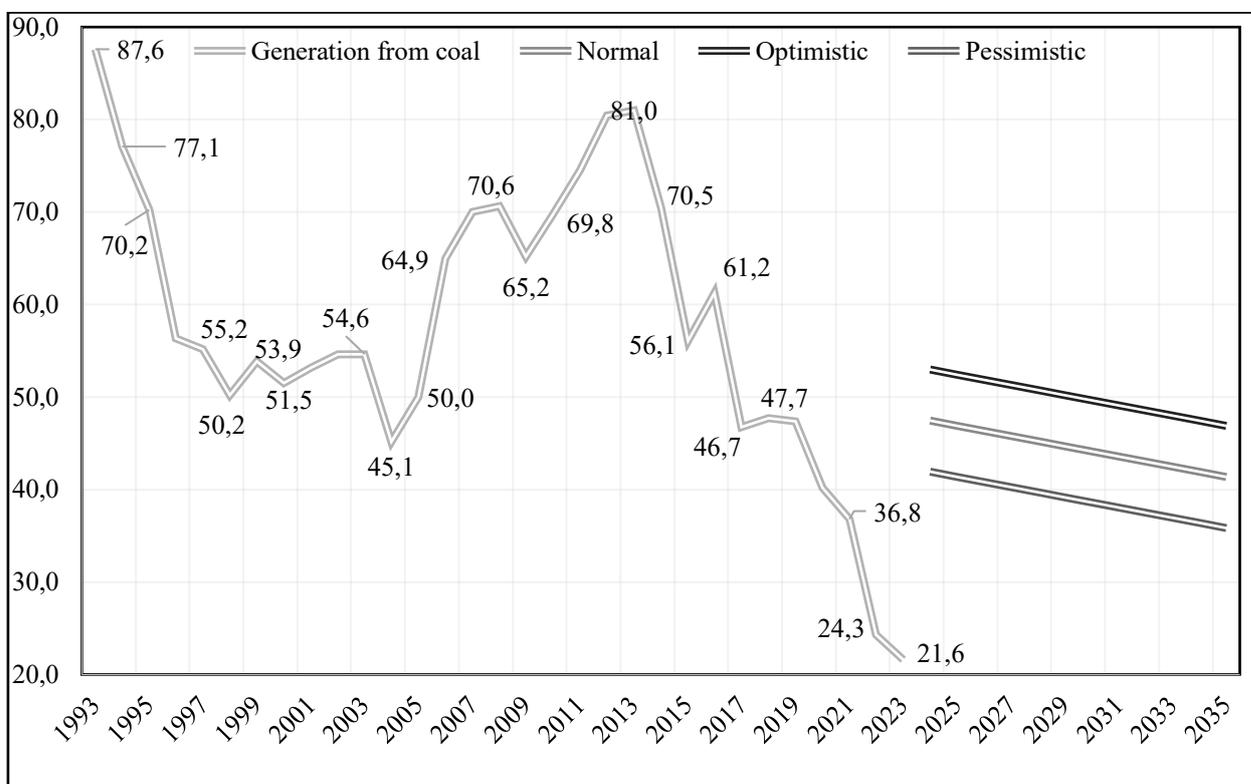
Source: own compilation.

Complicated situation with coal supplies in Ukraine is due to the geopolitical conflict in Eastern Ukraine. Since significant reserves of coal, in particular, high-quality anthracite, are concentrated in the Luhansk and Donetsk regions, which are no longer under the control of the Ukrainian authorities, generating companies were forced to import scarce anthracite. The quality of power plant work was declining, since production capacities could not be fully loaded.

Another functioning feature of thermal power generation sector in Ukraine is the constant complication of pricing policy. Due to the constant need to regulate the volume of raw material imports and the production impossibility in the occupied territories, the price of kW regularly changes to bring it into line with current international rates and tariffs in terms of production costs. Moreover, the issue of the solvency of the Ukrainian population directly affects the profitability of electricity

generation enterprises, since the constant increase in electricity prices leads to an increase in the share of the consumer's budget spent on utility payments leading to a decrease in active consumer demand and deepening of the socio-economic crisis. The volume forecast of electricity production from coal in Ukraine starting from 1993, unlike oil and gas, shows an upward direction of change until 2013. However, coal generation plants are largely destroyed due to military activities and in all three options for the development of the industry until 2035 there is an obvious downward trend which confirms previous primacy of this energy source in the domestic electricity generation, but irreversible destruction impact (Figure 14).

Figure 14. Forecast of electricity production from coal until 2035, TWh.



Source: own compilation.

There used to be a constant trend of thermal power prevalence in electricity balance in Ukraine before war. Modern policymakers consider various probable directions for new mix design. Assessing the 'before-and-after' dynamics presents a complex challenge in identifying the most advantageous scenarios. As of February 2022, prior to the full-scale invasion, Ukrainian energy market held significant influence within Europe, largely due to its strategic geographic location and extensive territorial

coverage. The country was home to one of the largest electricity generation capacities on the continent and possessed the largest underground gas storage facilities in Europe. Over half of Ukraine's electricity was produced from low-carbon sources such as nuclear, hydro, and renewables – positioning the nation on a path toward carbon neutrality and reduced CO₂ emissions. Additionally, Ukraine had a well-developed infrastructure for the transit of fuels like natural gas, oil and petroleum, supporting dependable and enduring energy cooperation with neighboring European nations.

It's worth mentioning that Ukraine has a strong potential in the production of renewable energy – according to various estimates it is about 70 million tons of oil equivalent per year. It has one of the fastest growing RES markets in Europe. The preliminary amount of foreign investment in renewable energy projects in Ukraine over the past two years amounted to about 1.15 billion USD.

Despite the challenges facing Ukraine's energy sector, its development prospects include a transition to clean and sustainable energy sources, the integration of new technologies and a broad diversification of its energy mix. The success of these efforts will depend largely on sustained international support and effective management of domestic resources.

Following the results of the abovementioned forecasts, nuclear energy will remain a key part of the Ukraine's power system. Natural gas, which currently provides under 10% of electricity generation, will play an important role in heating systems and consequently its share may increase after 2030 to replace coal-fired generation due to net-zero initiatives.

The renewable sector is also promising. However, the high level of the green tariff in Ukraine creates an excessive price burden for consumers. In addition, the operation of large renewable energy power plants, especially those that produce electricity from solar energy, wind, is characterized by sharply changing modes of operation within the United Energy System of Ukraine. This leads to additional costs for the scheduling of power plants and the maintenance of reserve capacity to regulate the modes of operation of power plants that use solar energy, wind. And the

availability of sufficient reserves of energy generating capacity to maintain the balance between supply and demand in the electricity market is an important factor in the reliable and safe operation of the United Energy System.

The auction model replaced the form of support for producers at the green tariff. The new approaches should balance the interests of electricity consumers and other market participants, ensuring the further development of renewable energy and reducing the growing financial burden on the final price of electricity.

Unfortunately, the war significantly affected the volume of electricity production by renewable energy power plants. Today, almost half of all renewable energy facilities are in the war zone or in the temporarily occupied territories. A significant number of such facilities are located in the occupied territories and have virtually ceased operations due to damage to transformer substations and power lines, danger to personnel and inability to access the facilities. The destruction of generating equipment due to shelling by Russian troops was recorded, in particular, several wind turbines burned due to shelling. The occupiers also stole equipment from captured renewable energy power plants.

Moreover, Ukraine is a transit country through which Russia transported gas to European countries. Accordingly, Ukraine's gas transportation system is connected to the systems of Russia, Belarus, Hungary, Poland, Slovakia, Romania and Moldova. The introduction of European rules in the gas market allows Ukraine to import gas both by physical (separate GTS route) and virtual (offset) reverse. And some of Europe's largest underground gas storage facilities allow them to be filled not only with Ukrainian but also with European gas.

Before the war Ukraine employed hundreds of gas traders, including European companies, dozens of companies extracting gas, earning an energy exchange, introducing daily balancing, importing gas from Europe and creating the preconditions for the formation of a gas hub. Due to war issues the Ukrainian transit status in geopolitics is also under threat.

Under normal circumstances, this results in the generation of additional revenues whenever the power system approaches a deficit situation and sends market signals

that stimulate investment in generating capacity. Deficit pricing is aimed at significantly increasing prices in the face of a shortage of generating capacity, thus providing better incentives for new investments in the flexibility of the energy system and its stable operation.

However, under the martial law reality in Ukraine investments in the construction of new capacities are rather risky. Sufficient volumes of highly maneuverable capacities are of high demand though. At the same time, a possible price leap after the revision or cancellation of restrictions on the organized segments of the electricity market will greatly affect economic processes in the country. It is also important to fully implement the provisions and mechanisms of REMIT to avoid market manipulation and prevent the formation of price collusion.

Modern development of the state is impossible without a clear awareness of the need to ensure an effective balance between the three main components of the concept of sustainable development: economic, environmental and social. The high level of uncertainty in the processes of interaction between stakeholders as well as the diversity of risks and influences from both the macro and microenvironment, indicate the limited effectiveness of a passive, declarative approach to the formation of strategic guidelines. This situation necessitates the development of comprehensive programs and the implementation of practical mechanisms to achieve specific results, in particular in the context of the implementation of international climate agreements and initiatives.

The need to update environmental policy in the field of operation of industrial enterprises and production facilities in Ukraine is due to its international obligations as a state party to a number of multilateral climate agreements. The main goal of these initiatives is to ensure the reduction of greenhouse gas emissions and slow down the pace of anthropogenic climate change. In accordance with the requirements of key documents, in particular the Paris Climate Agreement (the UN Framework Convention on Climate Change) and the European Green Deal, Ukraine must gradually transition to a circular economy model that involves the rational use

of resources in a closed cycle, as well as develop and implement comprehensive decarbonization programs.

According to the declared goals, Ukraine is obliged to achieve climate neutrality by 2050, which implies zero net greenhouse gas emissions with an intermediate goal of reducing their volumes by at least 40% by 2030. An important element of these measures is to keep the global average temperature increase within 1.5-2°C, which is considered a critical threshold for avoiding irreversible climate change.

The energy sector is one of the key links in the system of global transformations, because the expansion of its capacities, based on outdated technological solutions and physically worn-out production assets, causes an increase in environmental burden at the regional and national levels. In this context, the structural modernization of the energy industry is a long-term and capital-intensive process. Therefore, the gradual implementation of the decarbonization policy of energy enterprises in Ukraine will contribute to the activation of the responsible participation of stakeholders in the processes of sustainable production and consumption, which, in turn, will create the basis for the formation of a circular economy and ensure inclusive socio-economic development.

The operating practice of energy companies testifies to their unwillingness to spend additional investment resources on the modernization of assets in the absence of directive recommendations at the state or international level. Sustainable development of both enterprise and industry cannot be ensured in conditions of curbing evolutionary technological transformations and achieving climate goals. In the process of carrying out a comprehensive analysis the following features of the energy industry functioning in Ukraine should be taken into account:

- tremendous destruction of various generation capacities throughout the state territory;
- presence of significant differences in the natural and climatic conditions for doing business in different regions of the country;
- lack of proven mechanisms for substantiation and implementation of scientific developments and improved technologies;

- isolation and asynchronous development of research centers and electricity producers;
- significant difference between international and domestic practices for the development of various types of generation.

Among all the entities of the energy sector that generate electricity, thermal power plants have the most significant negative impact on the state of the environment. This is due to the high level of harmful emissions generated as a result of their operational activities. An analysis of current trends in the development of both global and national electric power allows us to outline the main vectors of the transformation of the industry in Ukraine in the long term:

- nuclear and thermal power plants will retain the leading role in the structure of electricity production because of military actions;
- in the context of the intensification of the green transition the functional tasks of thermal power plants will be transformed towards performing reserve and maneuvering functions;
- the expansion of the use of renewable energy sources will contribute to the structural modernization of the energy market and the launch of its decentralization processes.

The implementation of the above-mentioned measures will take place gradually under the influence of internal economic factors as well as conditions of leading international practice integration into the activities of generating enterprises. At the same time, the current state of functioning of domestic thermal power plants significantly differs from the requirements set forth by modern environmental regulations and operational standards. In particular, there is a systematic failure to comply with even basic standards for cleaning and filtering emissions, which creates additional threats to the environment and reinforces the need for urgent measures to modernize equipment and technological processes.

The current state of extremely high concentration of players in the electricity market allows the latter to manipulate the cost of generation and artificially inflate prices for consumers. Taking into account the transformational features of the market

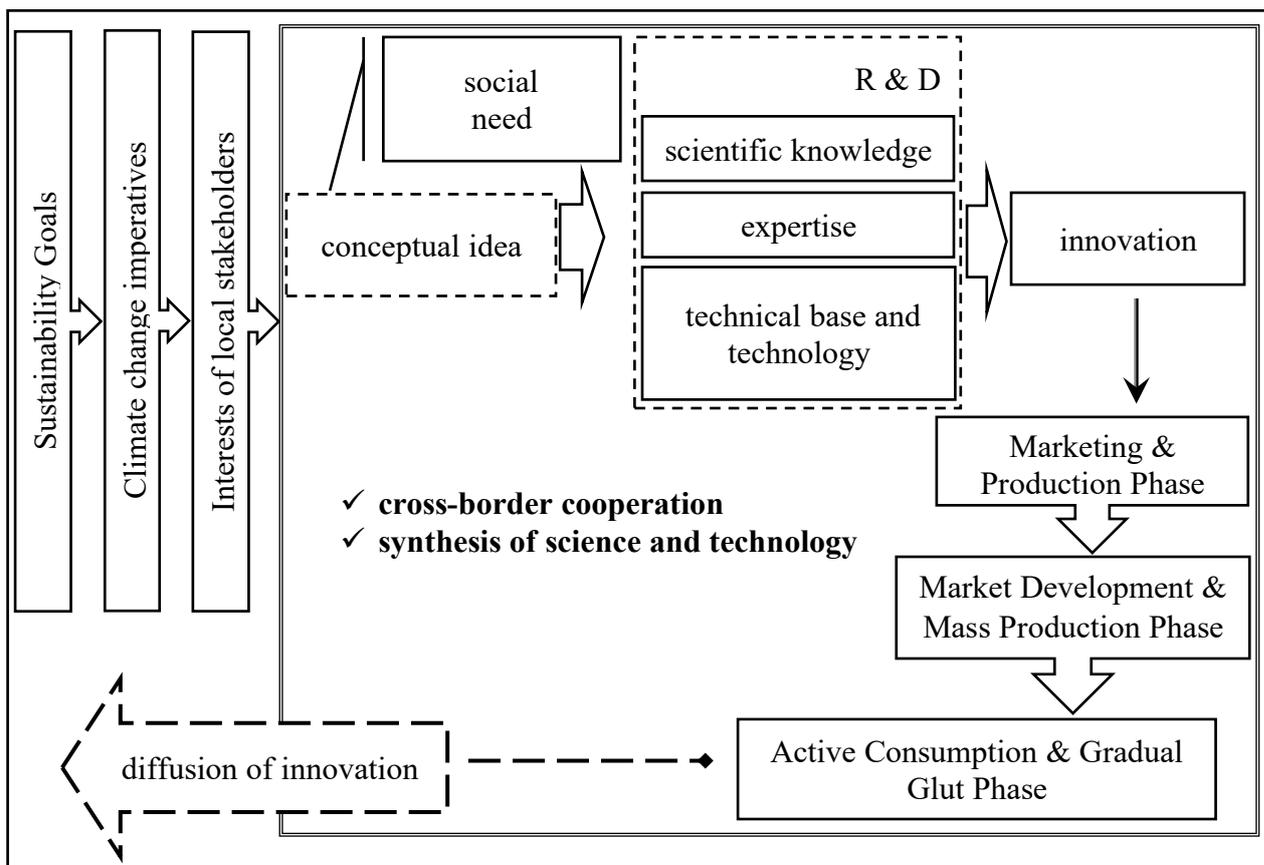
functioning under the conditions of its transition to a new model, it is advisable to note that prices will only increase in the future, since the uneven scope of electricity consumption by the relevant groups of consumers, in particular small and medium-sized businesses, involves its purchase at an extremely high exchange price. That is why reducing prices as a factor in increasing the efficiency of the functioning of electricity generation enterprises and ensuring their sustainable development in terms of its components – economic, social and environmental – is especially impossible without technical and technological modernization through the introduction of innovations that will contribute to reducing the cost of production.

4.2 Model of the innovative policy for energy industry sustainable development in Ukraine

The innovation policy is formed in connection with the applied need to find and implement ways to achieve the goals of sustainable energy development using the more effective technologies and approaches than those that are already known in science and practice. It is not so much an economic category as a semantic combination of two key blocks for the effective functioning of enterprises in modern conditions of uncertainty and market turbulence – the attraction to innovations as well as investments in digitalization and the possibilities of their further implementation.

Within the dissertation it is considered relevant to present own interpretation of the innovative policy of sustainable development as a set of measures aimed at qualitatively improving the processes of functioning of an enterprise in any industry by initiating and introducing new or improving existing sustainable innovations in order to increase production efficiency, create sustainable way of thinking and environmental awareness as well as ensure effective interaction with stakeholders for the implementation of corporate social responsibility and building up reputation capital in the framework of international relations (Figure 15).

Figure 15. Innovative policy model for energy industry sustainable development in Ukraine



Source: own compilation.

It should be emphasized that there is no unified approach to the development of a strategy or policy for innovative development of the industry. The high level of influence of risk factors restrains a significant number of possible qualitative transformations and directs the efforts of companies to solve short-term tasks. The lack of established criteria for balancing urgent and long-term goals further distorts the positive dynamics of sustainable development of the energy industry. That is why it is important to adhere to a general strategy, avoiding the substitution of some approaches for others.

Every corporate strategy for sustainable development must be amenable to constant adjustments and go through the implementation procedure with changes caused by the influence of external environment. The industry standards and international imperatives are the basis for the formation of development targets. They lay the field for interaction between state, business and consumers. The energy sector of Ukraine

is not exceptional. The development and mastering of new generation technologies and business practices is an unconditional prerequisite for the formation of a powerful innovative development of both specialized enterprises and related business processes of business entities. The proposed conceptual framework for electricity market is given in Figure 16.

The model for the formation of an innovative policy for sustainable development of the energy industry in Ukraine is multi-element, since it takes into account the global factors of the industrial development, sectoral features of compliance with the procedure for fulfilling certain imperatives and the factor of the need to activate cross-border cooperation in order to achieve an effective result from the synthesis of science and technology. It should be noted that, in contrast to the standard innovation process, which aims at creating a new product and accumulating financial benefits from its implementation and gradual withdrawal, the goal of achieving a high level of sustainable development transforms the ordinary value proposition into a value choice and the mass type of consumer behavior into a conscious one, based on sustainable thinking.

On business level the implementation of innovative development concept involves solving various large blocks of issues. First of all, priority is given to aspects of improving labor safety, greening the main production and ancillary processes of the enterprise, stabilizing the economic component of business processes. Second-level innovative solutions are to be focused on developing new areas of business in the energy industry for their further monetization and international collaboration.

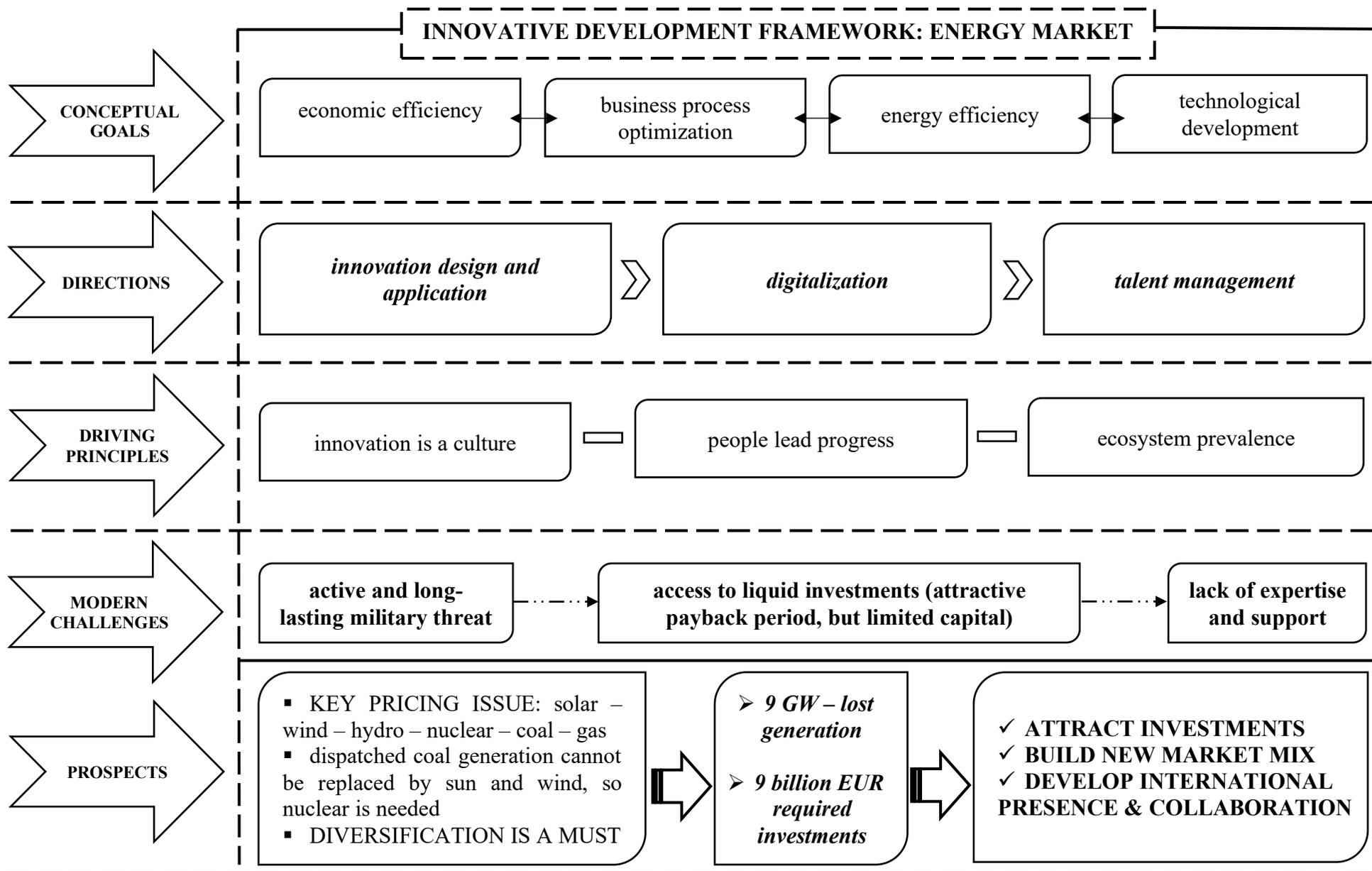


Figure 16. Innovative development framework for electricity generation market in Ukraine

Source: own compilation.

4.3 Innovative development framework implementation – from national transformation to business sustainability

The global energy crisis and the problem of climate change are precisely projected onto the situation in Ukraine. On the one hand, in order to increase energy security and implement a green transformation, it is necessary to actively develop distributed generation based on renewable energy sources. More and more of the world industrial actors are committing themselves to transforming their economies so that they become carbon-neutral in the next 10-30 years. But while CO₂ emissions are stabilizing in Europe and North America, they continue to rise in Asia and Africa. The state economic power and CO₂ emissions are closely linked, so it is not surprising that particularly the industrial sector is responsible for the largest share of total greenhouse gases.

Along with the introduction of sustainable development principles into business practice, the relevance of issues related to global warming and the reduction of harmful emissions into the atmosphere has also increased. In 2015 in Paris within the framework of the 21st UN Climate Conference, it was proposed to strengthen the Kyoto Protocol by extending obligations on emissions into the atmosphere to all states, regardless of their level of economic development, by concluding the Paris Agreement to reduce harmful carbon dioxide emissions from 2020.

This agreement is aimed at strengthening the global response to the threat of climate change in context of sustainable development and efforts to eradicate poverty by:

- holding the increase in global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;
- increasing the ability to adapt to the adverse effects of climate change, as well as promoting climate resilience and low-carbon development in a way that does not jeopardize food production;

- ensuring the consistency of financial flows with the direction of low-carbon and climate resilient development.

The international community has developed three scenarios for the development of the energy use and electricity generation sectors in order to ensure targeted regulation of individual imbalances and adjustment measures. These forecasts are created based on the current state of the world’s energy sector and taking into account the risk factor of climate change, which is recognized as the greatest threat of the 21st century due to the high degree of uncertainty (Table 8).

Table 8. Features of global energy sector development until 2040: three-scenario plan with a risk-factor input of climate change

ENERGY BASE	ENERGY BLUE	ENERGY GREEN
<i>Climate and energy policy</i>		
<ul style="list-style-type: none"> • 2030 goals not achieved • lack of effective measures to reduce harmful emissions • increase in temperature by 5-6 °C 	<ul style="list-style-type: none"> • 2030 goals achieved • slowing the growth rate of harmful emissions • increasing temperature by 3-4 °C 	<ul style="list-style-type: none"> • strengthening the trend of sustainable development • development of regional climate policies • increase in temperature by 1.5-2 °C
<i>Energy: supply and demand</i>		
<ul style="list-style-type: none"> • fossil fuels remain dominant • rising fuel prices driven by increased resource demand in geopolitical context • moderate development of renewables 	<ul style="list-style-type: none"> • resource shortage • rising energy prices • diversification towards renewables 	<ul style="list-style-type: none"> • progressive energy efficiency policy • gradual phasing out of fossil fuel subsidies • price increases are a lever for influencing existing policies, incl. CO₂ reduction • development of renewable energy sources
CLIMATE CHANGE AS A RISK FACTOR FOR GENERATION		
<p>* temperature increases, droughts and decreased precipitation reduce the efficiency of thermal, nuclear and hydropower generation due to limited water access</p> <p>* cyclones, storms or floods lead to operational risks on the ground associated with the shutdown of individual units or stations</p> <p>* increased risk of fires – significantly impairs the development of biomass electricity generation sector due to the crop loss threat</p>		

Source: own compilation based on Enerdata; Ubran & Mitchell.

The demonstrated scenarios indicate an undeniable increase in temperature and significant global climate change that awaits humanity in the next half century. The weather factor is especially difficult in terms of predicting the expected impact, as possible cataclysms and natural disasters will lead to the loss of various generation capacity types as well as the inability to control emissions of harmful substances and use the potential of renewable energy.

Carbon dioxide may become the key global warming driver, but methane is also a powerful greenhouse gas and its level in the atmosphere has risen significantly over the past decade. Therefore, the commitment of an alliance of more than 90 countries representing two-thirds of the world economy to reduce methane emissions by at least 30% from current levels by 2030 is considered an important step forward, albeit belated. It's worth underlying that methane is released from gas and oil wells, pipelines and municipal landfills. However, Russia, China and India have not pledged to reduce methane emissions.

Moreover, the energy security is an important condition for every country, including Ukraine, in close connection with sustainable development. Energy consumption of the economy, inefficient use of energy resources, market monopolization and total dependence on energy imports (oil, gas, fuel for nuclear power plants and even coal) make the domestic energy sector vulnerable to sustainable operation and rapid response to technological, economic and social challenges, both external and internal. Solving these problems will require a new level of technological development of the energy sector and thereby increase its competitiveness and make the sector transparent for both service providers and consumers, which in general will enhance the energy security level in Ukraine.

The importance of the innovative component was outlined (Khalatov, 2016) starting from the pre-reform times taking into account the following prerequisites:

- lack of modern equipment and closed-cycle installations, which would increase the role of the innovative component of the technological re-equipment of the industry;

- low efficiency leads to an increase in tariffs for consumers, which does not contribute to increasing the competitiveness of enterprises;
- imbalance of income and expenses of companies as well as the high share of irretrievable losses of energy itself do not create opportunities for investment and replacement of worn-out polluting installations.

Due to present military circumstances the main purpose of the ongoing reform is to increase Ukraine's energy security in the following key areas (Government portal of Ukraine, 2022):

- security of electricity and natural gas supply to consumers;
- integration of energy markets into European markets;
- reliability and efficiency increase in the Unified Energy System of Ukraine;
- diversification of sources and routes of energy supply;
- increase in the domestic energy production taking into account economic feasibility;
- development of renewable and low-carbon energy sources, alternative fuels;
- energy efficiency in the chain from production to energy consumption;
- coal industry reform in Ukraine.

Current reforms in the energy sector are aimed at boosting the energy sector development and integration with European complexes, bringing it in line with EU norms and standards and creating fully functioning competitive natural gas and electricity markets with transparent pricing and adequate protection of consumers. Thus, the Ukrainian Government has been supporting the implementation of the EU Green Deal since its introduction, also having climate obligations under Paris Agreement. As an EU candidate country, Ukraine will also have to adjust its long-term energy and climate targets to meet EU climate ambitions. Clear climate goals will be necessary for attracting needed investment into Ukraine's energy sector. Moreover, an EU-aligned energy and climate policy plan makes it easier to receive support from the EU, prevent carbon tariffs and participate in burden-sharing (allocation of allowances).

Regardless of the importance and relevance of developing national potential in the field of electricity generation, the benchmark for ensuring the competitiveness of power generation enterprises is set on a global level. The following key features can be identified in the development of the world power generation market.

Firstly, generation from coal is dominant, although it shows certain fluctuations associated with the economic downturns of the leading producing countries, in particular the prevailing share of the region of Asia (>60%) and Africa (>30%), contrastingly at a consistently high energy consumption level.

Secondly, the role of oil as a raw material for the production of electricity began to decrease since the crisis of the 1970s, although it remains a key source of energy in some countries of the world, such as Iraq, Lebanon.

Thirdly, nuclear generation grew during the 1970s and 1980s and at the beginning of the new millennium, it took a completely opposite trend due to changes in the generation structure of the world's leading countries. Today, the USA, France, China and the Russian Federation are the leaders in the world market.

Fourthly, gas as a raw material for power generation is actively used by the USA, the Russian Federation, Qatar and Iran, thus forming a powerful potential with an ever-increasing development trend.

Fifthly, the development of renewable energy market is due to the importance of achieving the goals of sustainable development, low-carbon production and environmental security on a global scale, with the initial dominance of hydropower and today's active development of solar, wind, biofuels.

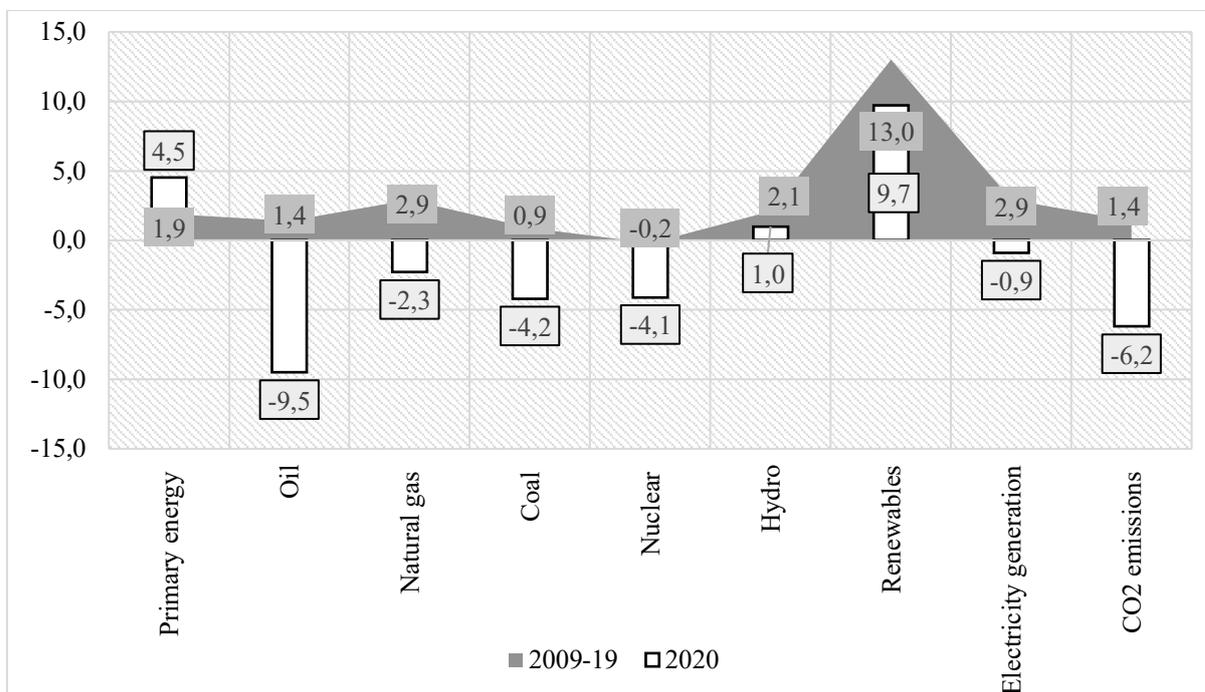
Sixthly, the key consumers of electricity are industry, transport and household sector without significant structural changes over the past 50 years.

World energy consumption and production shifts are also crucial to analyze in terms of potential input. World trends in energy field were quite promising as for the end of 2021. Ongoing economic growth, together with cold winters and warm summers, enabled the global electricity demand to rise in 2021 by more than 6% – the largest increase since the recovery from the financial crisis in 2010. Significant changes in supply chains for coal and natural gas caused wholesale electricity prices to change

taking into account market shifts. In spite of the gradual increase in renewable power, electricity power generation from coal and gas reached its peak levels.

Following the international energy data analysis (Figure 17) some crucial trends are visible as for the period of 2009-2020. Firstly, primary energy consumption fell by 4.5% in 2020 with oil demand accounting for 72% of the decrease. Secondly, renewables power grew by a record 358 TWh and increased its share of total generation to 12%. Thirdly, carbon emissions fell by 6.2% and the carbon intensity of the energy mix declined by 1.8%.

Figure 17. Growth rate of global energy market indicators in 2009-2020, %



Source: own compilation based on British Petroleum data.

In general, as a result of slowing electricity demand growth and sufficient additions of renewable power capacity, fossil fuel-based generation is foreseen quite stable in the nearest future. The expected fall is to be fixed in coalfired generation following the decline in competitiveness relative to natural gas in markets like the United States and Europe are offset by growth in China and India. Gas-fired is considered to grow annually by around 1%. The pandemic provokes price changes and generation shifts on various markets. However, during 2022-2024 an average annual electricity demand growth of 2.7% is expected to be stated with growing renewables adequately matching moderate demand growth (INTERNATIONAL ENERGY

AGENCY, 2022). Electricity production based on solar energy in Europe is considered to increase by approximately 50 TWh in 2024. Production at wind power stations will inevitably rise by 38 TWh, nuclear progress will constitute the amount of 20 TWh, hydropower stations – by 5 TWh. Meanwhile, electricity generation from traditional fossil fuels and other sources will decrease by 60 TWh (RYSTAD ENERGY INSTITUTE, 2024).

Despite the required significant reductions in carbon emissions, all energy transition scenarios remain above the 1.5 °C pathway and result in global warming of between 1.6 °C and 2.9 °C (McKinsey & Company, 2023). Moreover, rising emissions would lead to global temperature increases above 1.5 °C by 2050, from around 1.8 °C in the Sustainable Transformation scenario, through around 2.2 °C in Continued Momentum, to around 2.6 °C in Slow Evolution (McKinsey & Company, 2024). That's why major investments are needed to make a smooth transition happen under these circumstances. Annual investment in the energy sector is expected to grow by 2-4% per year in line with global GDP growth, reaching 2-3.2 trillion USD by 2040. Along with sustainability and affordability, secure supply of energy is a key pillar of the energy trilemma. In 2023, the total international trade of oil, gas and coal was 53% higher than it was in 2000. Collectively, North America, Europe and Asia Pacific regions consumed 78% of the world's total energy in 2023.

Year 2023 saw a second consecutive record year for global primary energy consumption as it grew by 2%, reaching 620 EJ. Its growth rate was 0.6% above its ten-year average and over 5% above its 2019 pre-COVID level. Whilst a new record in the consumption of fossil fuels (in absolute terms) was recorded. In 2023, it fell to 81.5% compared to almost 81.9% in 2022. With demand for natural gas, a relatively low carbon-intensive fossil fuel, remaining flat, the increased use of more carbon-intensive oil and coal meant that energy-related greenhouse gas emissions also reached a record high, exceeding 40 GtCO_{2e} for the very first time (Energy Institute, p. 10-12).

Table 9. Recent developments and emerging trends on global energy market

MODERN TRANSITION – E N E R G Y T R I L E M M A	
<i>sustainable</i>	<i>Affordable</i>
<i>Secure</i>	
TREND 1	Over 2019-23 carbon emissions continued to increase with an average rate of 0.8% per year
TREND 2	Investment in low carbon energy have grown around 50% since 2019 at approximately 1.9 trillion USD in 2023 with high concentration in developed economies and China.
TREND 3	Much of investment has been deployed in renewable power with doubling wind and solar power generation over 2019-23. This trend has been driven by solar due to continuing falls in solar modules cost (by around 60%).
TREND 4	Growing role of green industrial policies within governments, increasing attention on the security of energy supply chains and utilization of local fossil fuel resources.
TREND 5	The war in Ukraine as well as recent disruptions in the Middle East have reinforced the importance of energy security.
TREND 6	Global energy demand has continued to grow at around 1% per year over 2019-23 driven by increasing prosperity and growth in emerging economies.
TREND 7	Fossil fuel consumption reached a new high in 2023 driven primarily by rising oil consumption – oil and gas upstream investment totaled 550 billion USD.
TREND 8	Strong growth in natural gas demand in emerging Asian economies, combined with disruptions to Russian pipeline exports to Europe, has increased the importance of liquified natural gas within global gas markets.
TREND 9	Downward energy efficiency improvement trend. The amount of energy used per unit of economic activity has fallen by a little over 1% per year – slower than the previous 10 years and weaker than 4% annual rate targeted in COP28 energy efficiency pledge.
TREND 10	Growth in electricity has continued to outpace total energy demand growth in recent years as the energy system has increasingly electrified. Additionally, growth in less mature, higher cost, low carbon energy vectors and technologies – including low carbon hydrogen, synthetic biofuels and carbon capture and storage – remains at a very early stage.

Source: own compilation based on KPMG and British Petroleum reports.

Following the disruptions caused by the COVID-19 pandemic and the ensuing global economic rebound, global growth trends showed signs of further deceleration in 2024. The world economy grew by an average of 3.2%, aligning closely with the pre-pandemic average of 3.4% recorded between 2010 and 2019. Inflation continued its downward trajectory in 2024, easing from the sharp surges that followed the pandemic and the onset of the war in Ukraine. Energy prices, particularly oil, also declined after peaking in 2022. However, geopolitical tensions remained, and some markets continued to experience instability. Notably, the TTF – Europe’s key natural

gas price benchmark – had doubled by December 2024 compared to its February 2024 low, highlighting ongoing market volatility.

The global energy transition is accelerating. However, the path forward remains uncertain due to a variety of factors, including evolving technologies, geopolitical risks and unpredictable consumer behavior. This uncertainty complicates the development of resilient investment strategies capable of succeeding across diverse future scenarios. As a result, decision-makers increasingly face the challenge of balancing long-term decarbonization goals with the need to deliver short-term economic returns.

In 2023 the energy sector set new records for total fossil fuel consumption, resulting in significant shifts in emissions as well as in renewable energy production, particularly driven by the expansion of wind and solar power. Global geopolitical instability continued to influence the energy market, with regional events leaving a notable imprint on supply and demand dynamics. For instance, the war in Ukraine has contributed to a major redistribution of gas resources across Europe: overall demand for gas has substantially declined, setting a new consumption paradigm, while Russia's share in total gas imports to the EU has significantly decreased.

In Ukraine the energy market has also undergone notable transformations in response to emerging geopolitical challenges. Strategic efforts are increasingly focused on developing distributed generation to ensure greater stability and flexibility of the national energy system. Among innovative steps is the expansion of gas generation capacities through the construction of mini-thermal power plants and combined heat and power plants. Several state-owned companies have already announced the launch of new production facilities to support this transition.

Ukraine's robust energy base was largely developed during the Soviet era. Major developments began in the 1970s with the construction of 750-kV transmission lines, designed to carry substantial electricity flows westward, including into Eastern Europe. Despite the severe crisis of the 1990s, this 750-kV network played a critical role in maintaining Ukraine's energy security under unforeseen conditions and extreme operational regimes.

Historically, the primary consumers of electricity were industrial enterprises. However, following the collapse of the USSR between 1991 and 1996, Ukraine experienced a deep economic crisis that led to a sharp decline in electricity demand. This downturn resulted in a significant reduction in both electricity production and domestic consumption, as well as exports. The steepest decline in electricity production was observed at thermal power plants, primarily due to a decrease in organic fuel extraction and deterioration in fuel quality. Nevertheless, the existing generation capacity remained sufficient to meet the system's total demand.

Electricity consumption in Ukraine fell to 166.9 billion kWh in 2000 and 169.2 billion kWh in 2001, amounting to only 63% of the 1990 consumption levels. Since gaining independence, the Ukrainian energy sector has undergone significant transformations. Technological processes and equipment have been modernized, business operations at enterprises have been enhanced, and numerous reforms have been implemented, including changes to legislation and regulatory frameworks.

Technological difficulties in Ukraine's energy sector were compounded in the 1990s by a fundamental reorganization of the administrative and economic management of energy facilities, which shifted from state ownership to corporate and private forms. During this period, a new electricity market was established, comprising key market elements such as generation, transmission, and supply. Despite these challenges, the Ukrainian energy industry managed to stabilize operations and began to recover after 2000, showing a positive trend in technical and economic performance indicators.

Today, approximately 3% of the Ukrainian population is employed in the energy sector. It remains one of the country's leading taxpayers, contributing nearly a quarter of national budget revenues and accounting for up to 8% of GDP. Moreover, Ukrainian energy companies actively participate in export activities.

Ukraine has also made notable progress in reforming its energy sector to align with the legislative requirements of the European Union. Between 2019 and 2021 the Ukrainian government successfully designed and implemented the unbundling of gas and electricity transmission system operators, a process confirmed by unified certification in accordance with principles of full independence and transparency.

Both the gas and electricity markets have undergone major structural changes as part of these reforms.

Ukrainian energy system is structured into several branches without a single centralized controller. Generating enterprises supply the necessary resources to the network, which are then transmitted to final consumers. Local networks are interconnected through specialized substations, ensuring system-wide distribution. From the perspective of management and ownership, the Ukrainian energy system is composed of main transmission lines and generation capacities. The transmission lines are state-owned and not subject to privatization. Generation assets are also predominantly state-owned, including hydroelectric and nuclear power plants, as well as a significant share of thermal power plants and combined heat and power plants. Nevertheless, a substantial number of TPPs, CHPs, and renewable energy facilities – such as wind and solar power plants – are privately owned, and several CHPs are under communal ownership.

The main governing body of the electricity sector is NPC Ukrenergo, which operates as a private joint-stock company with 100% of its shares held by the state. Ukrenergo is managed by the Ministry of Energy of Ukraine and is responsible for transporting electricity to distribution companies.

An ongoing corporate governance reform further strengthens the sector. Since 2017, NPC Ukrenergo, as Ukraine's Transmission System Operator for electricity, has been preparing the country's power system for synchronization with ENTSO-E, following the signing of the Agreement on the Conditions for Future Interconnection. Preparations included testing the power units of Ukrainian nuclear, thermal, combined heat and power, and hydroelectric plants, and developing a mathematical model of the Ukrainian and Moldovan power systems. This model enabled ENTSO-E to conduct studies on the static and dynamic stability of Ukraine's and Moldova's energy systems when operating synchronously with the Continental European network. As a result of these efforts, Ukraine joined the ENTSO-E Continental Europe Synchronous Area a year earlier than planned.

Today, the energy systems of Ukraine and Moldova are fully synchronized with the ENTSO-E network, marking a major milestone in the region's energy integration. As of 2024, the global energy industry stands at a crossroads, facing significant changes and unforeseen challenges. On one hand, there is a rapid surge in interest and investment in renewable energy sources. On the other hand, debates continue regarding the future role of traditional energy carriers such as oil and natural gas. Leading organizations highlight the growing investment in clean energy, the active digitalization of the energy sector, and the profound influence of geopolitical and economic factors on the global energy market. In particular, key drivers shaping future energy strategies include global economic conditions, the accelerating increase in electricity production from renewable sources, and the critical need to reduce dependence on fossil fuels.

The largest share in the structure of electricity production in Ukraine is occupied by nuclear and coal-based generation, however, the real capacity utilization in various types of generation ranges from 11% to 73%. The average capacity utilization factor in the industry is about 38%. The highest capacity utilization factor was at the NPP (over 70%), it is much lower at other producers. Therefore, the amount of installed capacity is almost twice as high as the peak electric load in the UES of Ukraine, which in recent years has fluctuated in the range of 23-27 GW before war.

Military challenges have already worsened the situation. Commercial electricity flows are a powerful market tool for balancing supply and demand. The summer heat, which coincides with the time of repairs on the main generating equipment, leads to an increase in demand. In summer 2024 the Ukrainian operator of the transmission system – Ukrenergo – was repeatedly forced to call in emergency assistance to cover the difference between production and consumption. Increasing commercial imports during peak hours are to help meet demand and avoid the need for emergency assistance from adjacent grid operators.

Growing imports can meet demand and avoid emergency assistance from neighboring grid operators. However, the current price restrictions will make it difficult to attract electricity imports from EU countries in the peak hours of the

winter 2023/2024. Further liberalization of prices on the Ukrainian electricity market can only lead to their increase and not provide the required result in investments in new generating capacities, that's why such steps are to be taken with thorough consideration.

Renewable energy continues to maintain its relevance in Ukraine. Collaborative projects with the European Bank for Reconstruction and Development and the involvement of major international companies such as Vestas, Notus Energy, and Goldbeck Solar underline the growing interest and investment in Ukraine's renewable energy sector.

It is worth highlighting that in 2024, the European Union added approximately 60 GW of new solar PV capacity, maintaining the same level as in 2023. This figure was more than twice the annual additions seen in 2021, prior to the energy crisis triggered by Russia's full-scale invasion of Ukraine in 2022. However, outside of the three major markets – Germany, Italy, and Spain – over 15 EU member states experienced a year-on-year decline in newly installed PV capacity. The surge in solar PV deployment during 2022 and 2023 was driven by high electricity prices and enhanced incentives that made residential and commercial systems more economically viable. In contrast, the decline in energy prices and reduced policy support in 2024 led to a slowdown in growth across many markets.

Given the global complexity of achieving energy sustainability and the urgent demand for long-term solutions, renewable energy sources are projected to account for up to 50% of global electricity generation by 2030, and up to 85% by 2050, with solar and wind power being the primary drivers of this growth. Additionally, the deployment of modern technologies for carbon capture, utilization, and storage has the potential to significantly mitigate reliance on renewables alone. However, the widespread adoption of CCUS will largely depend on political support and further reductions in implementation costs. Nuclear energy is also increasingly recognized as a potential solution for addressing energy crises and ensuring long-term energy security. Meanwhile, coal without the integration of CCUS technologies is expected to gradually phase out of the global energy sector. To maintain grid stability,

electricity generation is anticipated to rise through gas-fired plants, which will be increasingly adapted to operate on hydrogen.

Despite the ongoing war and active military operations causing widespread destruction and disruption, Ukraine's energy sector continues to adapt and evolve. In the Sustainability Plan of Ukraine, presented by the President at the end of 2024, energy – particularly sustainable and secure energy – was highlighted as a core priority. A major focus is placed on the expansion of nuclear power, which is viewed as the cornerstone of the country's energy security.

By the end of 2024 Ukraine is to introduce regional sustainability passports to evaluate local energy profiles, followed by the creation of generation passports in 2025 to enhance the strategic management of energy resources.

These national-level efforts are mirrored in the corporate sector. To drive meaningful and structured reform, the Cabinet of Ministers adopted the Strategy for the Implementation of Sustainability Reporting by Enterprises. This initiative underlines the importance of aligning with European Sustainability Reporting Standards (ESRS), mandating that Ukrainian companies prepare, publish, and disclose sustainability reports. Additionally, the strategy introduces measures for auditing these reports and ensuring the quality of audit services through proper regulatory mechanisms.

The war has profoundly impacted Ukraine's energy sector – not only by destroying infrastructure such as power plants, transmission networks and gas pipelines, but also by reshaping energy policies and priorities (Verkhovna Rada of Ukraine, 2024). Rebuilding these critical assets demands substantial time and financial investment, while simultaneously reducing the country's capacity for energy production. Continued support from European partners is essential. Any delays, cutbacks or increasing debt in the energy market could compel the government to scale back subsidies for vulnerable groups, potentially driving up electricity tariffs and overall energy costs.

Looking ahead, the Ukrainian government is expected to prioritize green energy initiatives and the development of energy storage systems to enhance supply

resilience in the post-war era. The private sector is also stepping up, exemplified by DTEK Tyligulska Wind Farm, which is set to produce 1.7 TWh annually from 2025, marking the largest wind power facility constructed in Eastern Europe in a decade. Going from the top to the bottom level of energy system, it is worth outlining that historical preconditions for extensive depletion of existing energy potential, formed in view of the irrational use of domestic natural resources with both scientific and technical base of the past, do not lay the foundation for creating competitive advantages for progressive market development, but deepen the crisis. Among the negative operational aspects of energy companies in Ukraine are the following (Figure 18):

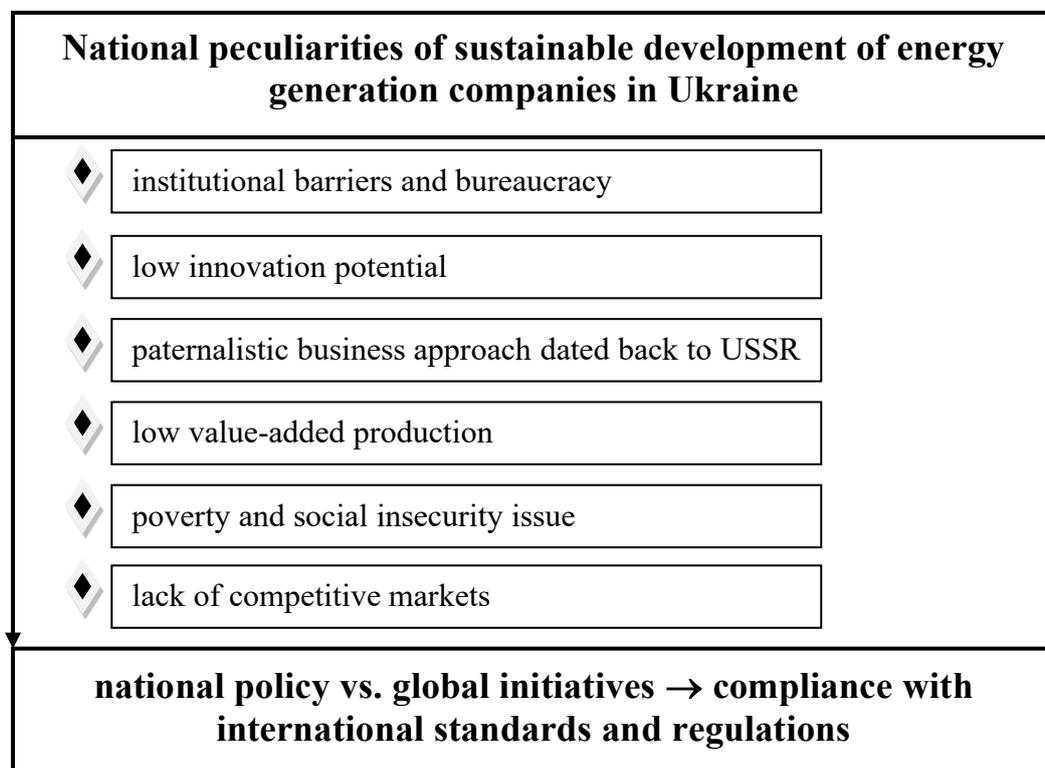
- gradual destructions of generation facilities, especially in the south and east;
- insufficiently flexible generation structure slows down the development of alternative energy sources and determines the primacy of only two types – thermal and nuclear;
- lack of mechanisms for attracting and using reserve and maneuvering capacities;
- high level of depreciation of fixed assets makes it impossible to carry out comprehensive modernization without significant investment resources;
- short-term nature of policies in the field of environmental protection and production greening;
- superficial implementation of international norms and standards in compliance with acceptable levels of emissions of harmful substances and decarbonization of the economy as a whole.

Key topics currently being discussed by both businesses and governments across many countries include:

- human rights: establishing corporate standards to uphold human dignity and eliminate discrimination;
- labor relations: promoting voluntary employment and ensuring decent working conditions;

- environmental initiatives: implementing local policies with significant global impacts, including ecological monitoring, protection and prevention efforts;
- access to justice and fair treatment: strengthening the rule of law, improving access to legal aid and ensuring legislation is clear and accessible;
- social dialogue and minority issues: enhancing communication with socially vulnerable groups and developing solutions to achieve greater equality and awareness;
- anti-corruption measures: implementing strategies to prevent and combat corruption.

Figure 18. National peculiarities of sustainable development of electricity generation companies in Ukraine



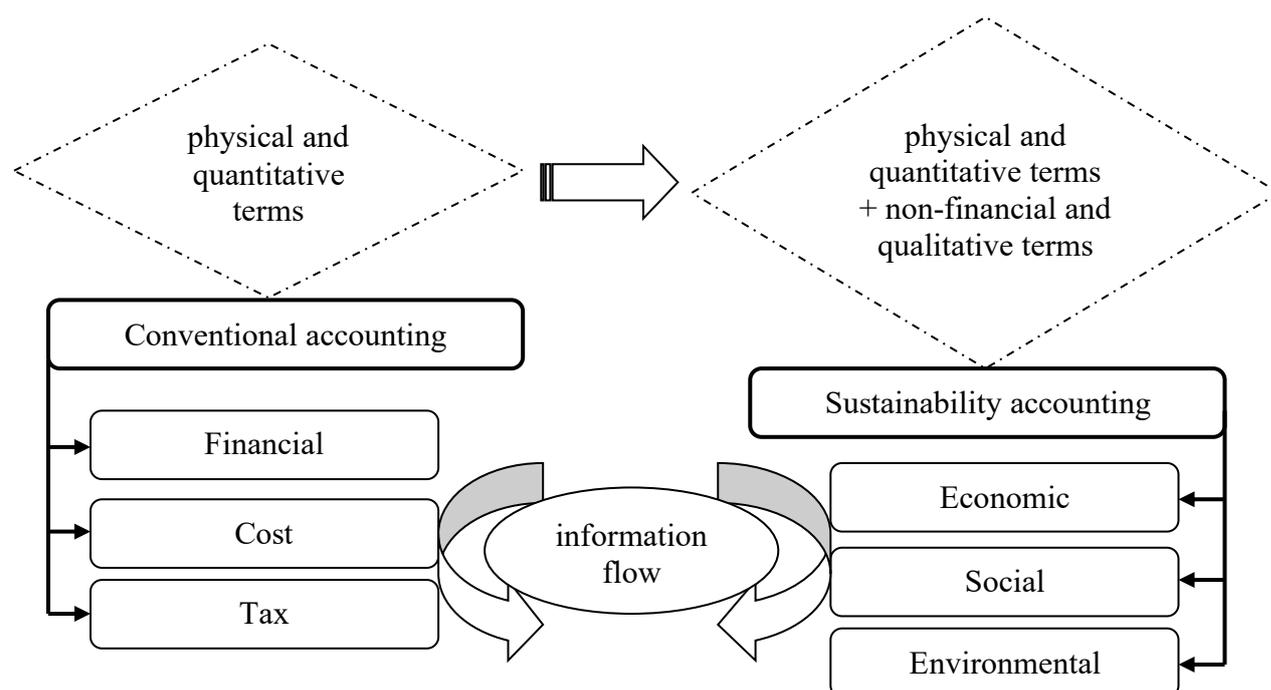
Source: own compilation.

All things considered, future development trends indicate growing pressure on corporations to operate in a conscious, transparent and responsible manner, adhering to international guidelines and reporting standards (Vasylchuk, p. 213). Sustainable development policies and corporate social responsibility practices have already become essential components of major companies across different economic sectors,

including electricity generation. In response to irreversible climate change and significant operational risks, there is a pressing need for targeted programs and comprehensive policies to meet social expectations, address global demands and develop new practical tools for covering non-financial aspects and enhancing the overall effectiveness of reporting.

In the area of information disclosure, special attention must be given to sustainability accounting. Introduced as a new concept, sustainability accounting was designed to meet the needs of both management and external stakeholders (Figure 19). Accountants still face the significant challenge of addressing not only the physical aspects of a company's operations but also the broader environmental impacts across ecosystems.

Figure 19. Conceptual transition from conventional accounting theory to modern sustainability accounting



Source: own compilation.

Nowadays sustainability accounting is understood as a system of methods used to document corporate activities related to sustainability, covering economic performance, environmental concerns, and social impacts. Although securing long-term profit growth remains the top priority for most companies, there is a rising focus on recognizing and addressing major risks and challenges, such as regulatory

pressures, ethical considerations, and internal self-regulation. Accountants play a crucial role in supporting information disclosure and performance evaluation, while also encouraging management's active involvement in building a sustainable organization with strong internal and external communication networks.

Figure 19 shows the way of smooth conceptual transition from conventional accounting theory to modern and sustainable.

Another important aspect is the availability of practical technological support. While many companies strive to develop their own methods for reaching sustainability goals, there are also organizations specifically recognized for their ability to support the development of sustainable business strategies, sustainability accounting, reporting and assurance.

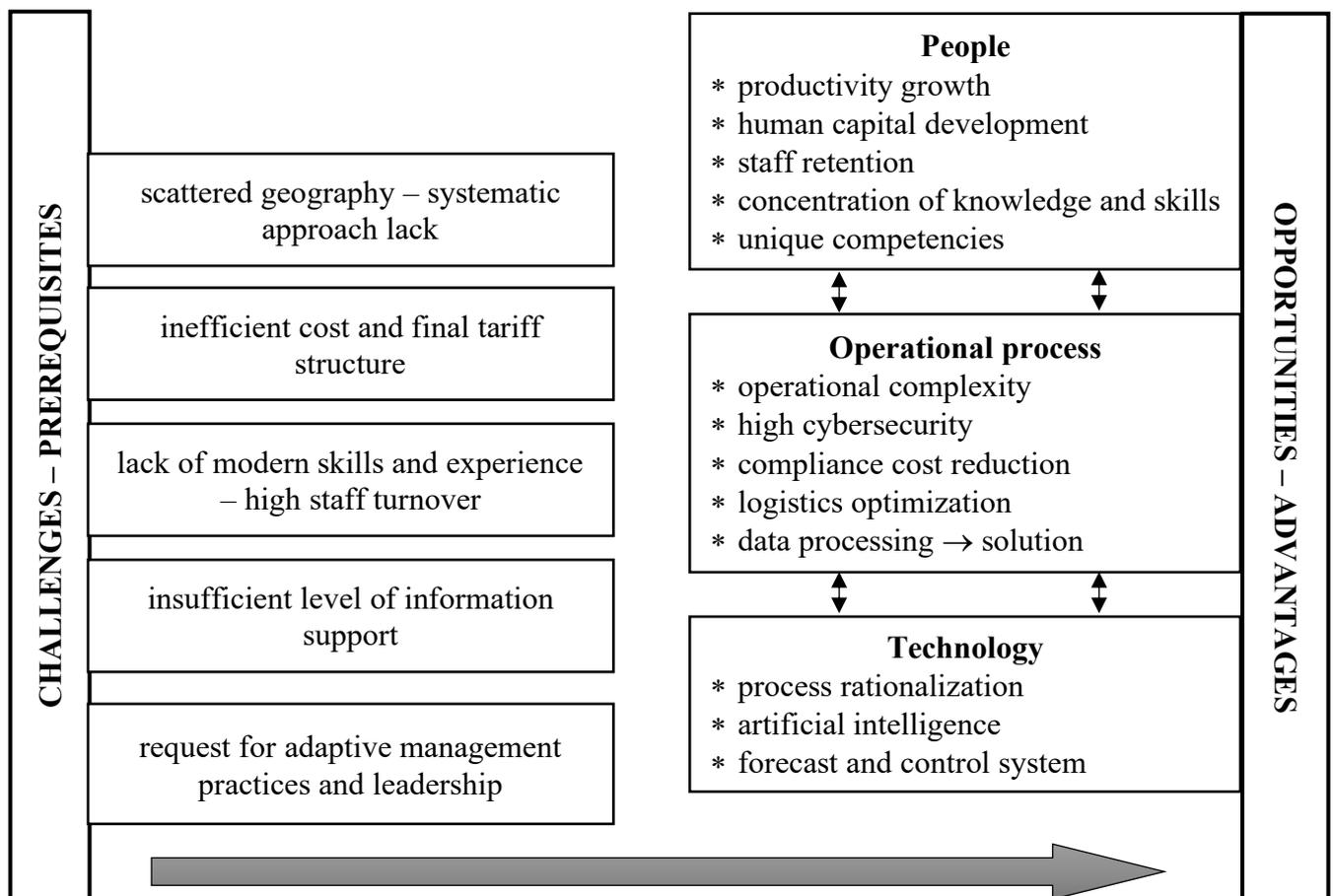
Digitization is a fundamental factor in ensuring the innovative development of any energy generation company in the long term. It is the flexibility and complexity of this system that will allow the company to gain and maintain competitive advantages in the domestic market, initiating the transition to a qualitatively new generation, and to join the international practice on a large scale. First, despite the long-term ineffective policy in the field of electricity generation in Ukraine, global trends and the Fourth Industrial Revolution force participating domestic companies to proactively respond to changes in order to create a positive image of the country as a potential investment partner and a reliable participant in the international division of labor. In the 21st century, there have been significant paradigm shifts from traditional, centralized control to a self-regulated and volatile generation environment. Secondly, the galloping development of artificial intelligence and information technologies creates prerequisites for the effective interaction of various stakeholders, contributing to the comprehensive analysis and evaluation of large data sets and the adoption of qualitatively new decisions both within a separate generation and at the sectoral, state or global levels. The positive effect is observed not only in the field of generation. Engineering and IT are powerful drivers of introducing digitization systems into the state economy. The cooperation of specialists within

the framework of innovative programs and the development of personnel potential is one of the important factors of sustainable development in the long term.

Thirdly, the nature of doing business is changing. In particular, a generating company is no longer considered as an independent economic entity, but acts as a constituent element of a more complex system, which requires the construction of nationally and globally connected interacting systems and such operating models that can quickly react to uncontrollable factors of the external environment (weather change, consumption mode) and work in real time.

To create a comprehensive program for the corporate sustainable development towards its digitalization, which will support the initiation of digital transformation of the entire industry, it is necessary to outline the existing prerequisites and assess the possibilities of using modern digital systems (Figure 20).

Figure 20. Key challenges and opportunities for implementing innovative digitalization programs in energy companies



Source: own compilation.

In the context of modern business environment transformation, electricity generation companies in particular should focus on the consistent implementation of a number of strategic steps to ensure effective digital transformation and contribute to long-term development. It is advisable to adhere to the following algorithm of actions (Littlefield, 2017):

- formulation of a business case for digital changes with clearly defined goals and expected results of the transformation;
- implementation of an adaptive, open-to-change organizational culture;
- emphasis on continuous improvement of operational processes as a means of achieving operational excellence;
- development of partnerships with technology suppliers in order to form a flexible IT architecture that supports strategic business guidelines.

Despite the obvious advantages provided by digitalization – high level of automation, acceleration of management processes, increased control accuracy – significant challenges remain on the way to its comprehensive implementation. First of all, this is the need for significant investments as well as the need for a radical transformation of the organizational structure, operational processes related to the production and economic activities.

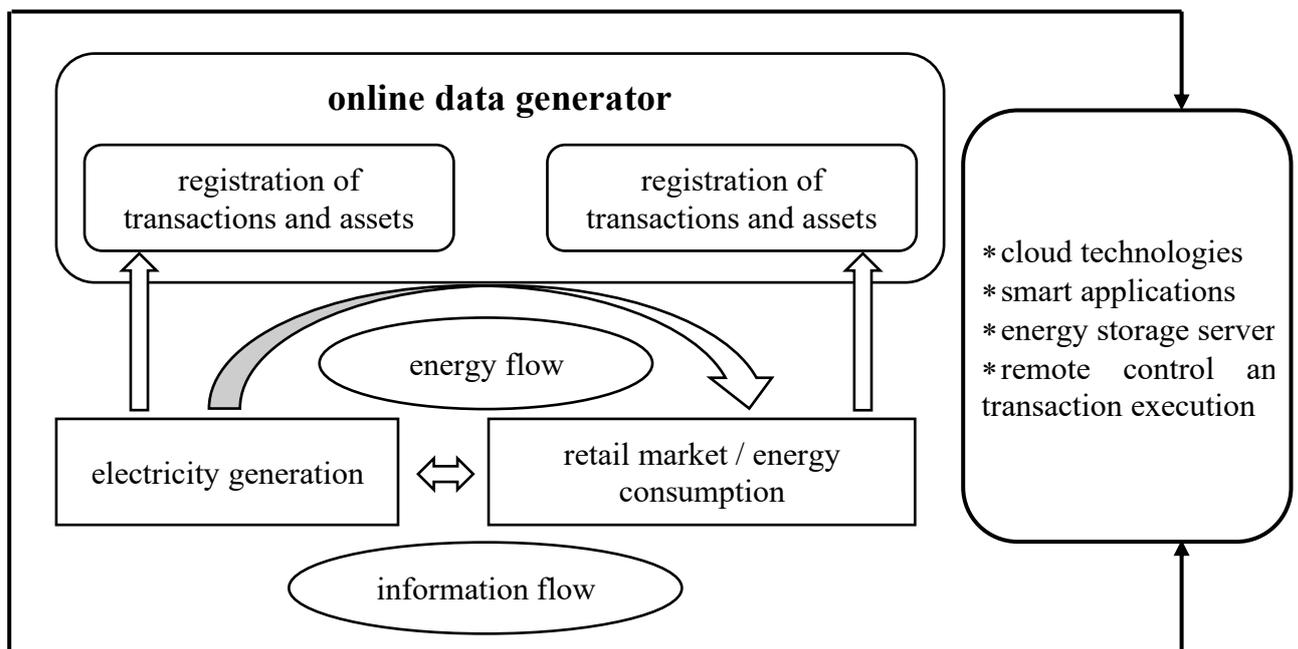
Following the preconditions of the innovative policy for energy sector sustainability, an important area of improving business processes in order to increase the efficiency and compliance of any energy enterprise is the use of blockchain technologies. Under modern conditions of active accumulation and processing of data for their further targeted use, such functional categories of systems as protection and speed become especially important. Both in the field of state regulation of the electricity market in Ukraine and within generation companies, it is advisable to use blockchain mechanisms to ensure operational efficiency and flexibility of different levels of systems in general. Among the key benefits of blockchain are the following:

- openness / transparency of the transaction;
- automation of interaction processes for market agents;
- reduction of distorted information;

- level increase of data reliability and veracity;
- high level of transaction control;
- autonomy and speed of input data processing;
- minimization of abuse and fraud;
- significant decrease of costs in supply chains.

A general scheme of energy company operating regulation process using blockchain is demonstrated below.

Figure 21. General scheme of energy company operating regulation process using blockchain technologies



Source: own compilation.

Blockchain technology can not only simplify processing transactions, but also digitalize the entire mechanism of interaction of market agents related to the generation, distribution, exchange and consumption of electricity as well as corporate systems in order to optimize operational processes. Continuous monitoring and control, cross-functional adherence to international and national imperatives for the concentration of harmful emissions at different stages of the supply chain will ensure a stable link between quality and compliance with existing requirements for sustainable development of the energy sector. Localization of the use of innovative technologies will increase corporate reputation, as it will obtain

much higher competitiveness compared to other market participants as well as create new value for both consumers and the company itself.

Despite the wide range of advantages due to the high level of automation and quick control within the digitalization system, it is worth highlighting two main problems on the way to its comprehensive implementation. The first is related to the need to attract significant investments and restructure the process of organization and implementation of production and economic activities. On the practical level, for instance, the possibilities of reducing emissions depend on the volume of generation, but digitalization will contribute to effective monitoring of emissions and control both of the entire generating system of the enterprise and of individual installations. The strategic imperatives of the company development in the context of digital transformation are determined by the management, taking into account the opportunities for business design and the existing potential. The introduction of the Internet of Things (processes) using elements of artificial intelligence will allow describing the current state of generation, analyzing data sets and predicting future trends for the production of effective business solutions. A comprehensive system of monitoring and control will allow to optimize the logistics chain, reduce production costs and maintain a high level of return on investment. As a result, the interaction of all stakeholders within the framework of public-private incorporation will improve the value of business for society and the added value of the generation product will increase.

Modern companies of the energy sector of Ukraine should not only ensure the efficiency of internal business processes to maintain competitiveness, but also adjust their own corporate strategies in connection with the need to achieve long-lasting sustainable development.

Taking into account the cost, implementation time and overall system efficiency, energy management emerges as the most effective option – though it often falls short on its own. The financing challenge adds another layer of complexity. With heightened risks due to an unpredictable environment affecting conventional investment sources, it's essential to strengthen capital markets and develop

innovative financial instruments that mitigate uncertainty and attract private sector investment.

One more crucial point constitutes in human capital. In the current climate of war and economic instability, companies have focused on retaining their workforce, acknowledging the value of preserving and enhancing this sort of capital. To boost enterprise productivity and competitiveness, it is vital to increase investments in human capital, especially in developing employees' technical, digital and soft skills. Ukrainian micro, small and medium-sized enterprises (MSMEs) face limited international exposure, which must be addressed through robust policy frameworks and business support mechanisms. These should help integrate MSMEs into global supply and value chains and facilitate their entry into the EU single market.

In the long run developing a strategic plan to expand electricity generation capacity is crucial. This involves building a more decentralized energy system – less predictable and thus harder for Russia to target – through the gradual deployment of energy assets like gas turbines across multiple, unexpected locations. Such a distributed network would be more flexible and easier to protect.

A key objective for the Ukrainian energy sector within the broader European energy system is achieving climate neutrality by 2050. This goal demands a shift to clean, low-carbon energy sources, including renewables and advanced nuclear technologies, both of which are essential for system stability and the phasing out of outdated fossil fuel infrastructure.

Access to affordable capital is a major factor influencing energy costs. Investors could obtain competitively priced debt if supported by the state through balanced annual quotas for the development of renewables, flexible generation, and energy storage. However, investment decisions are hindered not just by war-related risks – which some governments already account for – but also by uncertain regulatory conditions. Furthermore, Ukraine must develop a sound economic framework to address carbon pricing in anticipation of the full implementation of the Carbon Border Adjustment Mechanism in 2026.

5. DISCUSSION

The biggest motivational factor for choosing this dissertation topic is my own national identity and Ukrainian origins. Despite my experience as for living in various countries and working in different fields, the issue of making a good contribution to my homeland development has been always present. My first grounded expertise on energy sustainability I received in Norway and since then I have been trying to deliver conceptual alterations to the Ukrainian business as well as establish social responsibility initiatives within various companies. In particular, I am focused on energy sector which encompasses both historical industrial burden and huge development potential.

To add more credence to my assertion, I would mention the remarkable scope of natural fund in Ukraine due to its genuine unique geographical features. According to the rough estimation of resource asset value, it is clear that this amount is more than 15 trillion dollars. Experts suggest that coal accounts for up to 65% of the total value of mineral resources, iron – for 15% and other assets – for less than 5%. The total volume of mineral resources is stated to be more than 110 billion tons. The war for rare resources and unique products is considered to be present nowadays and well-recognized among geopolitical experts. Due to the overwhelming historical context, Ukraine hasn't had an opportunity to diminish previous Soviet approach to undervaluing production development while extensively using a given of nature.

One more driver lies in the prism of technological advancement. The development of modern business sector in Ukraine and all around the world, determined by conditions of the Fourth Industrial Revolution course, declares the primacy of technological transformations and innovative developments in the context of achieving not only financial goals, but also social and environmental benchmarks within the framework of both global and national policies. The rapid development of information technology and industrial innovation requires proactive business approaches from enterprises to set the vector of future growth and increase competitiveness in the global market. That is why the issue of developing an innovative policy in the energy industry of Ukraine to ensure the sustainable

development of companies with the gradual implementation of corporate social responsibility principles remains relevant.

Geopolitical re-focus drives concern stating unprecedented challenges on the global arena. Taking into account irreversible military changes on the world map as well as modern economic paradigm, new normal is to be established in order to mitigate potential threats. Ukraine has already faced enormous impact of the abovementioned processes with yet no practical guidelines for the recovery. Energy system is partly destroyed under military aggression and such condition set new challenges for the European Union as for the major partner. After-war recovery is a crucial goal as well as undeniable imperative, following the demand to maintain energy system viability in the long term.

The **main aim** of the dissertation is to establish innovative policy for sustainable development and long-lasting efficient performance of energy market in Ukraine taking into account modern geopolitical challenges and opportunities.

The lack of precise solutions to address Ukraine's energy crisis – while considering long-term goals aligned with global sustainability efforts and current geopolitical challenges – has led to the central **research question** that this dissertation seeks to comprehensively explore:

➤ *How can Ukraine establish and implement long-term innovative policy of energy industry sustainability under modern national challenges as well as geopolitical constraints?*

The conducted research showed that conceptually sustainable development is to declare inclusivity and equality in order to ensure that marginalized and vulnerable populations benefit from progress. Furthermore, the development of alternative economic models that prioritize long-term sustainability over short-term growth is vital. Such models are to balance profitability of energy companies with environmental and social goals, making this area critical for high performance.

Understanding the interconnections between abovementioned domains is essential for designing holistic and effective solutions. Further research is to focus on innovative policy integration, as effective sustainable development approaches

require compliance at local, national and global levels like in scope of energy market. The complexity of these interactions underscores the need for systemic thinking in addressing sustainability challenges.

Applied within the study neoliberal approach emphasizes reliance on market mechanisms rather than direct regulatory interventions to address climate challenges – for instance, through carbon trading systems such as CO₂ emission quotas. This framework advocates for the expansion of renewable energy sources, particularly wind and solar, primarily via private investment rather than through state funding. Although the renewable energy sector has experienced significant growth, challenges persist in the form of regulatory disparities, unequal access and ongoing dependence on subsidies. Furthermore, neoliberalism promotes the transition from administratively set tariffs and quotas toward liberalized electricity and gas markets. The gradual establishment of energy exchanges, where prices are determined by market dynamics of supply and demand, has complicated traditional conceptions of what constitutes a competitive energy market.

Within this dissertation there are several **objectives** stated in order to provide extensive background and generate solutions as for the main aim.

Objective 1 is aimed to analyze and understand sustainability concept in scope of modern geopolitical trends. The primary objective of comprehensive implementation of sustainable development concept is to ensure long-term economic stability and environmental safety by critically identifying and deliberately addressing key economic, ecological and social challenges. Such an approach emphasizes targeted solutions considering available natural resources and current technological advancements. Initially sustainable development was considered primarily as a forward-looking strategy focused on guiding future global progress. Nowadays the concept is significantly transforming due to uncompromising shifts in geopolitics connected with military risks, non-compliance and reluctance to collaborate voluntarily on strategic international issues. It is worth mentioning that in order to contribute to global efforts focused on environmental protection and climate change mitigation enterprises, regardless of their industry or ownership

structure, are to establish a systematic policy that prioritizes the implementation of feasible sustainability goals at their current stage of development, while setting a forward-looking direction towards eventual alignment with all Sustainable Development Goals in order to ensure a holistic positive impact. The innovation process in this context represents a multi-complex system of interrelated components that collectively generate a qualitatively new outcome in both social production and consumption.

Objective 2 places emphasis on determining the theoretical foundations of innovative policy formation in the framework of national economy. Within the scope of this dissertation it is considered appropriate to offer an original interpretation of innovative sustainable development policy. This concept is defined as a set of strategic measures aimed at enhancing the qualitative functioning of enterprises across various sectors through the initiation and implementation of new or improvement of existing sustainable innovations. The final goal is to increase production efficiency, foster sustainability culture and environmental consciousness as well as ensure effective stakeholder engagement. Such an approach supports the implementation of corporate social responsibility initiatives and contributes to the accumulation of reputational capital within the context of international cooperation. The model for shaping an innovative policy for the sustainable development of Ukraine's energy sector is inherently multifaceted, as it incorporates global industrial development trends, sector-specific requirements for meeting regulatory imperatives and the drive to strengthen cross-border cooperation to optimize the integration of scientific and technological advancements. Unlike the conventional innovation process, which typically focuses on developing a new product and generating financial returns through its commercialization and eventual market exit, sustainable development shifts this dynamic. It transforms the traditional value proposition into a deliberate value-based choice and encourages a transition from mass consumerism to conscious consumption rooted in groundbreaking sustainable thinking.

It is proved that in light of current geopolitical dynamics, the pursuit of innovative and sustainable business development has become essential across all industries, with the energy sector being particularly critical given prevailing trends in global consumerism. The ongoing transformation of global energy markets, especially in electricity generation, is largely driven by shifts in the global energy consumption landscape, necessitating a reconfiguration of national and international energy balances. This transformation is further accelerated by rapid technological advancement and the emergence of numerous innovations, which collectively support the transition from conventional, fossil fuel-based production methods toward cleaner and more responsible energy generation practices. This transition is intrinsically tied to the broader goals of sustainability.

Objective 3 is aimed to analyze Ukraine's energy system development milestones from the historical perspective. Before the reform Ukraine's electricity market operated under the Single Buyer model, which was based on the wholesale procurement of electricity from various producers for subsequent resale at prices regulated by the National Commission for State Regulation of Energy and Public Utilities. Under this system wholesale electricity market functioned as a sole trading platform facilitating various interactions among all market participants with its operations managed by a dedicated entity – Energorynok.

Due to the lack of genuine market liberalization in terms of governing interactions among market participants, there were no effective incentives to foster competition or enhance service quality. To address the shortcomings of this inefficient framework a new electricity market model was implemented in July 2019. This reform introduced the operation of six distinct market segments designed to facilitate efficient interaction between diverse types of suppliers and consumers.

The new electricity market model is founded on the principle of ownership unbundling with key structural reforms mandated by the Third Energy Package. As part of Ukraine's commitments under its energy sector agreements with the European Union, the activities of electricity generation are to be legally and operationally separated from those of transmission. Taking into account corporate

unbundling, the Ukrainian reform ensures a clear division among the functions of electricity distribution and supply, thereby facilitating the establishment of a competitive retail electricity market. This retail market encompasses the interactions between end consumers and electricity suppliers as well as the various entities engaged in delivering related services.

A major milestone in Ukraine's energy sector was achieved in March 2022, when Ukraine's power grid was successfully synchronized with the Continental European Network managed by ENTSO-E. It was originally scheduled for 2023, but this collaborative integration was expedited in response to Russia's full-scale invasion. This step enabled Ukraine together with Moldova to decouple from the former Soviet system (connected with Russia and Belarus) and align with the European energy framework, ensuring enhanced system stability and independence.

In this research it is demonstrated that the integration of Ukraine into the ENTSO-E network marks a turning point in the Ukrainian energy policy, symbolizing both energy independence from Russia and commitment to European energy values, including market transparency, decarbonization and sustainability (like shown on the examples of Poland, the Czech Republic, France, Germany and Slovakia). It is a foundational step towards Ukrainian energy market full integration into the European internal market with long-term implications for economic resilience and full-scope geopolitical alignment.

Objective 4 is stated to substantiate the possibility of adapting foreign experience in regulating the energy sector activities in terms of strategic policy formation for the development of this industry in Ukraine, taking into account domestic socio-economic features. The extensive examination of future prospects for applying established electricity generation practices remains highly relevant, particularly in light of the noticeable influence of global economic diversification trends on the energy sector. In light of the global challenges associated with achieving energy sustainability and the pressing need for durable long-term solutions, projections indicate that renewable energy sources could contribute up to 50% of global electricity generation by 2030 and as much as 85% by 2050, with solar and wind

energy serving as the main catalysts for this transition. At the same time, the advancement and implementation of carbon capture, utilization and storage technologies offer a complementary pathway for reducing greenhouse gas emissions, thereby easing the exclusive reliance on renewables. Nonetheless, the broader deployment of utilization and storage technologies will be contingent upon sustained political commitment and further declines in technological and operational costs. Nuclear energy is also gaining renewed attention as a viable option for addressing energy crises and enhancing long-term energy security. Conversely, coal-based power generation is expected to be gradually phased out. In order to support grid stability, electricity production from gas-fired power plants is projected to increase with growing efforts to adapt such facilities for hydrogen-based operation, which is already actively developing in Ukraine.

For example, in 2023 the global energy sector witnessed record-high levels of fossil fuel consumption, which led to notable changes in both greenhouse gas emissions and renewable energy output, particularly due to the accelerated deployment of wind and solar power technologies. Ongoing geopolitical instability continued to exert considerable influence on global energy markets with several regional conflicts significantly shaping supply and demand dynamics. The war in Ukraine has triggered a substantial reallocation of natural gas flows across Europe and prompted the restructuring of regional energy strategies and infrastructure.

Moreover, elevated energy prices are driving structural shifts across various markets, often resulting in the relocation of generation hubs to different regions or countries. The broad array of investment strategies and practices adopted by developed nations illustrates the successful restructuring of energy markets and provides models for other participants to follow. Nevertheless, modern electricity generation – both globally and in Ukraine – faces significant challenges, including the rapid advancement of innovative technologies, uncertainty surrounding oil and gas demand, the expanding role of renewable energy and the impact of shale energy development (gas, oil).

The energy sector represents a critical component in the broader system of global transformations. Its expansion, when reliant on outdated technologies and deteriorating infrastructure, significantly increases the environmental burden at both regional and national levels. In this context, the structural modernization of the energy industry constitutes a long-term and capital-intensive endeavor. Consequently, the decarbonization policy implementation within Ukraine's energy enterprises will play a pivotal role in fostering responsible stakeholder engagement in sustainable production and consumption processes. This, in turn, will lay the groundwork for the development of a circular economy and promote inclusive socio-economic growth. This dissertation explores a range of potential development scenarios to identify viable solutions for future transformations of the electricity market, taking into account already existing initiatives and forecasts.

Objective 5 overtakes focus to provide probable scenarios (coal, gas, oil) and potential development areas in Ukraine in the context of their impact on state economic security. As of June 2024, military actions have resulted in total electricity generation losses up to 22,565 GW. Only around 11,435 GW of generation capacity remains theoretically operational, a substantial portion of which consists of solar power plants – resources that are insufficient to meet electricity demand during the winter months. This situation has led to a critical electricity shortage and widespread blackouts. An analysis of current global and national trends in the development of the electric power sector makes it possible to identify the key long-term directions for the transformation of Ukraine's energy industry. Firstly, nuclear and thermal power plants are expected to continue playing a dominant role in the overall electricity generation mix. Secondly, in the context of an accelerating green transition, the role of thermal power plants will gradually shift toward providing reserve and flexible (peaking) capacity. Thirdly, an increasing integration of renewable energy sources will support the structural modernization of the energy market and drive forward processes of decentralization. In this scope solar power plants contribute to reducing greenhouse gas emissions and lessen Ukraine's dependence on fossil fuels, particularly coal and natural gas, thereby advancing both

energy security and sustainability objectives. Moreover, biomethane production as an innovative approach is being extensively developed in Ukraine. The biomethane industry is marked by a diverse feedstock base and multi-sectoral participation, underscoring its adaptability and significant expansion potential. Diversity enhances the production resilience and scalability, making it a strategically important component of the broader renewable energy landscape. Ukraine is well-positioned to play a vital role in the EU green energy transition. It is shown that in the medium to long term, Ukraine could meet up to 20% of the EU biomethane demand by 2050. Such a contribution would be useful in advancing the EU decarbonization objectives and strengthening the regional energy security through increased reliance on sustainable and domestically produced alternatives to fossil fuels.

Objective 6 emphasizes the feasibility of the state innovative policy for the energy industry development in Ukraine based on modern geopolitical challenges. As of 2024 the global energy sector finds itself at a pivotal juncture, marked by profound transformations and emerging uncertainties. On the one hand, there is a substantial increase in both interest and capital investment directed toward renewable energy sources. On the other hand, ongoing debates persist concerning the long-term viability of conventional energy options such as oil and natural gas. Among crucial global trends to consider are the growing allocation of resources to clean energy initiatives, the rapid digitalization of the energy sector and the notable impact of geopolitical and macroeconomic dynamics on world energy markets. Amid the primary factors shaping future energy strategies are global economic performance, accelerating pace of renewable electricity generation and urgent imperative to reduce reliance on fossil fuels.

The necessity to revise sustainability policy concerning the operations of industrial enterprises and production facilities in Ukraine arises from the country's international commitments as a signatory to multiple multilateral climate agreements. These initiatives primarily aim to reduce greenhouse gas emissions and mitigate the progression of anthropogenic climate change. In alignment with the obligations outlined in key international frameworks – mainly the Paris Agreement

under the UN Framework Convention on Climate Change and the European Green Deal – Ukraine is required to progressively adopt a circular economy model. This model outlines the efficient use of resources within a closed-loop system and necessitates the development and implementation of comprehensive national decarbonization strategies. Ukrainian energy market has experienced significant transformations in response to ongoing geopolitical challenges. Strategic priorities have increasingly shifted toward the development of distributed generation as a means to enhance the stability and adaptability of the national energy system. Notably, one of the key innovative approaches involves expanding gas-based generation capacities through the construction of mini thermal power plants and combined heat and power plants.

The adoption of new legislative frameworks focused on green transformation, alongside the formulation of a National Energy and Climate Plan, has already reflected Ukraine’s strong commitment to align with the European Union environmental and energy policy objectives. These initiatives signal a clear strategic intent to achieve carbon neutrality by 2050 and confront broader energy and climate-related challenges. A key element of this transformation is the integration of market-based mechanisms designed to incentivize the expansion of renewable energy sources. Moreover, the decentralization of energy generation introduces new possibilities for consumer engagement, enabling end-users to contribute to balancing supply and demand. This, in turn, leads to cost reductions for consumers while enhancing their role in shaping the dynamics of the national energy market.

Overall, recent reforms in the energy sector are marked by increased transparency, enhanced opportunities for renewable energy development, and the establishment of a more sustainable and resilient energy mix. In light of the escalating attacks on Ukraine’s energy infrastructure, it has become imperative to prioritize the development of distributed, highly flexible generation capacities and battery energy storage systems. These technologies are essential for maintaining the adaptability and reliability of the national grid. Furthermore, investments in modernizing distribution networks are critical. In this context, the state assumes a pivotal role in

guaranteeing favorable conditions for both domestic and foreign investors, while simultaneously supporting initiatives that contribute to national energy security and long-term resilience.

Objective 7 is focused on developing strategic proposals and recommendations for regulatory framework improvement in the energy sector. The wartime context has reshaped perspectives on both global and national economic trajectories. The geopolitical dimension of energy policy also plays a decisive role in shaping this transition. As global carbon emissions continue to drive significant climate change, the urgent need to decarbonize energy systems places renewable sources, particularly solar power, at the forefront of global environmental agendas. Countries that remain dependent on imported energy resources face heightened vulnerabilities in terms of national security and political autonomy. Moving beyond a legacy of industrial dominance and reliance on fossil fuels, Ukraine like other countries has begun to embrace renewables not only as a domestic solution but also as a potential export opportunity. In many cases, the importation of renewable energy resources serves as a strategic tool to address critical challenges, such as enhancement of long-term ecological sustainability. Consequently, expanding domestic renewable generation capacity is increasingly viewed as a means of safeguarding energy independence and strengthening resilience.

Technological innovation is essential to the long-term transformation success. The digitalization and modernization of public energy governance have become central components of reform efforts. Investments in digital infrastructure and cybersecurity not only bolster the resilience of the energy system against external threats but also enhance its operational efficiency through improved resource management and transparent oversight. There is an imperative to develop robust mechanisms for information and analytical support systems that can monitor, evaluate and guide the implementation of both domestic and international energy policies, ensuring accountability and strategic coherence.

The formulation of a comprehensive corporate strategy for sustainable development, oriented toward digitalization, is a critical step in facilitating the digital

transformation of the energy sector as a whole. This process necessitates not only considerable financial investment and legislative ground, but also a profound restructuring of organizational frameworks and operational processes associated with both production and economic activities. In alignment with the foundational principles of innovation-driven policies aimed at ensuring energy sector sustainability, the adoption of blockchain technology emerges as a significant mechanism for optimizing business processes. Its implementation can enhance operational efficiency and strengthen compliance with regulatory standards across energy enterprises. In the dissertation it is stated that blockchain technology has the potential not only to streamline transaction processing but also to digitize the entire framework of interactions among market participants involved in electricity generation, distribution, exchange and consumption. Additionally, it can be integrated into corporate systems to enhance the efficiency of operational processes. By enabling real-time monitoring and control, blockchain facilitates cross-functional compliance with both international and national regulations concerning harmful emissions throughout energy supply chain. This ensures a strong alignment between quality standards and sustainability requirements in the energy sector. The targeted application of innovative technologies will also strengthen corporate reputation by enhancing competitiveness in the marketplace and generating additional value for both consumers and the enterprise.

All things considered, the **scientific novelty** of the research lies in the development of theoretical and methodological foundations as well as applied peculiarities of the innovative policy formation in the energy industry of Ukraine.

The study **practical relevance** lies in its exploration of potential future development policies based on innovative practices and sustainability principles as for the groundbreaking circumstances for complying with European integration and mitigating military threats. The findings and further research are expected to comprehensively yield policy-relevant recommendations for establishing innovative recovery policy in the electricity generation industry of Ukraine.

CONCLUSION

The development trajectory of Ukraine is significantly shaped by complicated and constantly evolving geopolitical dynamics, which have created substantial obstacles to achieving economic stability, energy security and institutional reform. The ongoing consequences of full-scale invasion in 2022 have not only devastated infrastructure and disrupted supply chains, but also strained public finances and reduced investor confidence. These conditions have hindered long-term strategic planning and weakened the country's capacity to implement sustainable development initiatives. Furthermore, the geopolitical context has made Ukraine highly dependent on international financial and humanitarian support, while simultaneously requiring alignment with European Union standards as part of its integration aspirations. The dual pressure of responding to immediate security threats and fulfilling structural reform commitments poses a unique challenge, particularly in sectors such as energy, public administration and environmental governance. Addressing these development challenges requires a coordinated approach that balances national resilience, institutional capacity-building and international cooperation.

Energy industry at both global and regional levels as well as within municipal and operational policies is one of the most crucial areas of security and sustainability. The existing experience has already demonstrated that without proper energy-efficient consumption or full use of available opportunities for developing and accumulating renewable energy sources, achieving necessary green effect required by the Green Deal directives becomes impossible. The strategic significance of enhancing the energy sector performance in Ukraine – and in the operations of individual enterprises – stems not only from the need to meet international standards but also from the national priority of establishing an energy-independent country with strong capabilities in electricity production, generation, and storage, including for export purposes. Continued reliance on outdated technologies, worn-out facilities and inefficient filtration systems exacerbates the socio-economic crisis within both the industry and the broader region, while also raising future operational risks for

companies. Gradual and effective implementation of sustainable development measures will create a synergistic effect across multiple areas of life thus reducing the environmental and economic burdens, increasing employment opportunities, advancing infrastructure and improving overall living standards.

At the current stage of business sector development there is a widespread belief that innovation plays a crucial role in ensuring the long-term sustainable development of any country. The growing focus on issues such as resource scarcity, environmental protection and climate change has led to a division of responsibility and influence among three key actors: government, social institutions and businesses. Companies are increasingly acknowledging that greening their operations or individual links within their supply chain creates value by enhancing resource efficiency and boosting their competitiveness in both the short and long term. In certain industries, such as information technology, the rapid qualitative advancements in specific business models also contribute to the emergence of new markets. Some companies foster innovation by developing new business models, improving resource efficiency and labor productivity by substituting traditional materials with more eco-friendly alternatives, ultimately offering improved products and services.

The innovative direction of business activity is one of the most desirable and relevant today. At the same time entrepreneurs strive to implement green technologies that create the basis for radical eco-innovations. Since a significant part of business processes is associated with the use of information technologies and the creation of electronic competencies, the traditional approach to defining innovations is gradually changing to a new one that takes into account technological, economic and environmental aspects.

Of particular importance is the establishment of a process of rapid acceptance of changes by company employees, which are necessary for its transition to sustainable development. Therefore, the effective passage of all five stages of the formation of a new culture among employees is key to overcoming resistance to change:

definition and awareness of the purpose change; overcoming the initial negative perception of culture; direction of culture; transfer of culture; involvement of culture. Therefore, the issues of sustainable development are as diverse as biodiversity in natural ecosystems and as complex as social transformations within human society. The energy sector in Ukraine is one of the most vulnerable yet crucial segments of the economy, particularly in light of current geopolitical challenges. In recent years, the Ukrainian energy industry has faced an array of unprecedented threats, including nuclear terrorism through the seizure of nuclear power plants as well as extensive damage to critical infrastructure such as electrical grids and gas networks.

Additionally, there has been a significant decline in demand for energy products due to the mass displacement of the Ukrainian population. Consequently, numerous business premises and industrial facilities have been abandoned, driven by diminished demand, workforce shortages and high operational risks stemming from ongoing attacks and regulatory uncertainty. These profound shifts have further exacerbated the financial strain within the energy system, leading to a critical reduction in payment levels across the sector. Despite the severe hostilities, fuel shortages and systemic instability, Ukraine has made the strategic decision to continue the synchronization of its energy system with that of Continental Europe. Regardless of these considerable challenges, Ukraine remains on a trajectory toward full membership in the European Union, highlighting the resilience and strategic importance of its energy sector within the broader European framework.

To address the critical challenge of the energy trilemma while ensuring future compliance with global targets and maintaining a reliable electricity supply for consumers, several practical strategies can be proposed. First, the development of additional generation capacities in targeted regions could help balance electricity demand and supply, while also minimizing internal power system flows. Distributed generation systems, being smaller and more localized, are less susceptible to enemy attacks and have a limited impact if disrupted. Among the most advantageous options is the construction of cogeneration plants at existing boiler facilities,

enabling highly efficient use of fuel for both electricity generation and heating needs, including space heating and hot water supply.

Another key priority is increasing network capacity, including the repair of damaged substations. While this approach is particularly effective during peacetime, the risk of repeated damage remains significant during military conflict. Additionally, the installation of autonomous diesel or gasoline generators is essential to ensure power availability during outages.

An equally important measure involves managing consumer electricity consumption. This would help balance the load across the power grid, reduce internal power flows and decrease the overall strain on power plants. The deployment of large-scale energy storage systems would further stabilize grid operations. These storage units should be installed both at critical points within the power system and at major consumer sites.

Despite practical implications of the research topic, the conceptual development of innovative policy in disclosure of sustainability and efficiency states a huge emphasis on further scientific discussion. Innovative sustainable development is a critical area of study that requires ongoing research due to its complexity, interdisciplinary nature and the global challenges it seeks to address. As it was mentioned within this dissertation this field aims to balance economic growth, environmental protection and social equity, making it essential for researchers to explore new solutions and enhance existing frameworks.

Taking into account global geopolitical threats, one of the primary drivers for continued research is the need to mitigate and adapt to international issues such as climate change, resource scarcity and energy security. Climate change remains a significant threat, necessitating the development of innovative solutions such as renewable energy technologies and emission reduction strategies. Similarly, resource scarcity demands efficient alternatives and optimized energy management, while the ongoing loss of biodiversity calls for robust strategies to protect and restore ecosystems. Energy security is becoming a major priority in the international

relations. These challenges are interconnected, requiring a systems-thinking approach to address their multifaceted impacts on the environment and humanity. Moreover, there are no practical recommendations on establishing innovative policies for sustainable technology as this matter presupposes unique approach due to national peculiarities. In particular, technological advancements play a pivotal role in sustainable development of energy companies, offering opportunities to enhance efficiency and reduce environmental impact. However, implementation of non-standard solutions requires sensitivity to diverse cultural contexts, as sustainability strategies must be tailored to local communities and national behavioral patterns in order to ensure their effectiveness.

This dissertation showed that emerging technologies, including artificial intelligence, blockchain and biotechnology, have the potential to revolutionize sustainability practices, however, their long-term implications remain underexplored. For instance, the transition to a circular economy, which involves recycling, reusing and reducing waste, requires further study of industrial processes and material sciences. While renewable energy sources such as solar and wind power are becoming more prevalent, continuous research is essential to improve energy storage, grid integration and overall efficiency in the energy transition.

On the other hand, developing robust sustainability metrics is the same way crucial for evaluating the effectiveness of implemented policies and innovations. Comprehensive understanding the long-term impacts of proposed solutions is essential to avoid unintended consequences. For example, while biofuels may reduce emissions, their production can lead to deforestation and food insecurity.

Conceptually sustainable development must prioritize inclusivity and equity to ensure that marginalized and vulnerable populations benefit from progress. Furthermore, the development of alternative economic models that prioritize long-term sustainability over short-term growth is vital. Such models are to balance profitability of energy companies with environmental and social goals, making this a critical area for high performance. Understanding the interconnections between the abovementioned domains is essential for designing holistic and effective solutions.

Further research is to focus on innovative policy integration, as effective sustainable development approaches require alignment at local, national and global levels like in scope of energy market. The complexity of these interactions underscores the need for systemic thinking in addressing sustainability challenges.

All things considered, the loss of control over key industrial assets and ongoing attacks on critical energy infrastructure pose severe threats to Ukraine's economic recovery and national security. Under these circumstances, reindustrialization founded on advanced technologies and renewable energy sources is of strategic importance. A technologically modernized industrial base is essential not only for ensuring economic resilience but also for reinforcing national defense capabilities. Positioning Ukraine within the framework of a sustainable European future necessitates comprehensive investment aimed at achieving energy independence and enhancing competitiveness within the EU internal market. This, in turn, calls for the development and execution of a targeted reindustrialization strategy. Such a strategy should prioritize attracting capital to the manufacturing sector, upgrading industrial capacities and fostering the emergence of innovative, high-tech industries. These measures are crucial for both the wartime stabilization of the economy and its long-term post-war recovery and growth.

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RESUMÉ

Pretrvávajúca geopolitická nestabilita predstavuje hlavnú prekážku hospodárskeho pokroku, reformy energetického sektora a budovania inštitucionálnych kapacít na ceste Ukrajiny k udržateľnému rozvoju. Dôsledky rozsiahlej vojenskej invázie v roku 2022 boli hlboké, čo viedlo k rozsiahlemu poškodeniu infraštruktúry, narušeniu kritických dodávateľských reťazcov a zvýšenej fiškálnej zraniteľnosti. Tieto podmienky narušili dôveru investorov a obmedzili schopnosť vlády realizovať koherentné dlhodobé stratégie rozvoja. Súčasne záväzok Ukrajiny k európskej integrácii zahŕňa prísne reformné programy a dodržiavanie regulačných rámcov EÚ, čo zvyšuje tlak na už aj tak napätý vnútroštátny systém. Súlad naliehavých bezpečnostných požiadaviek a nevyhnutnosti systémovej transformácie, najmä v oblasti správy vecí verejných, environmentálnej udržateľnosti a energetiky, predstavuje jedinečne zložitú výzvu. Riešenie týchto rozvojových obmedzení si vyžaduje komplexnú, viacúrovňovú reakciu, ktorá integruje vnútroštátne stratégie budovania odolnosti s medzinárodnou koordináciou.

Súčasný rozvoj každého národa je neoddeliteľne spojený s jeho schopnosťou udržať dobre nastavenú rovnováhu medzi tromi základnými piliermi trvalo udržateľného rozvoja: hospodárskym rastom, ochranou životného prostredia a sociálnou spravodlivosťou. Prevládajúca vysoká miera neistoty vo vzájomných vzťahoch zainteresovaných strán – znásobená rôznymi rizikami pochádzajúcimi z makroekonomického aj mikroekonomického prostredia - poukazuje na obmedzenú účinnosť pasívnych alebo len deklaratívnych stratégií pri formulovaní dlhodobej politiky. Táto skutočnosť si vyžaduje vytvorenie integrovaných strategických programov a zavedenie pragmatických mechanizmov na zabezpečenie konkrétnych výsledkov, najmä v rámci medzinárodných dohôd o klíme a globálnych iniciatív v oblasti udržateľnosti.

Ukrajinská environmentálna politika, najmä pokiaľ ide o činnosť priemyselných a výrobných podnikov, si vyžaduje výraznú revíziu, aby sa zosúladiť so svojimi záväzkami vyplývajúcimi z viacerých mnohostranných dohôd o klíme. Cieľom týchto záväzkov je predovšetkým znížiť emisie skleníkových plynov a zmierniť

zrýchľovanie antropogénnej zmeny klímy. V súlade s hlavnými medzinárodnými rámcami – konkrétne Parížskou dohodou v rámci Rámcového dohovoru OSN o zmene klímy a európskou Zelenou dohodou – sa od Ukrajiny očakáva, že zavedie postupný prechod na obehové hospodárstvo. Nasledujúca transformácia kladie dôraz na efektívne a cyklické využívanie zdrojov a zároveň nariaďuje vypracovanie a realizáciu komplexných národných stratégií dekarbonizácie.

V súlade so svojimi deklarovateľnými cieľmi sa Ukrajina zaviazala dosiahnuť do roku 2050 klimatickú neutralitu, ktorá je definovaná ako dosiahnutie nulových čistých emisií skleníkových plynov. Dočasný cieľ zahŕňa zníženie národných emisií o minimálne 40 % do roku 2030. Kľúčovým aspektom tejto stratégie je udržanie nárastu globálnej priemernej teploty v rámci hranice 1,5°C - 2°C, ktorá sa všeobecne považuje za nevyhnutnú na odvrátenie najzávažnejších a nezvratných dôsledkov zmeny klímy.

Energetický sektor zohráva kľúčovú úlohu v širšom kontexte globálnych transformácií. Jeho pretrvávajúca závislosť na zastaraných technológiách a zhoršujúcom sa stave infraštruktúrnych aktív však výrazne zhoršuje environmentálne tlaky na regionálnej aj národnej úrovni. V tejto súvislosti sa štrukturálna modernizácia ukrajinského energetického systému javí ako naliehavý, dlhodobý a kapitálovo náročný podnik. Postupné zavádzanie politik dekarbonizácie v tomto sektore uľahčí aktívnejšie a zodpovednejšie zapojenie zainteresovaných strán do podpory udržateľnej výroby a spotreby. Takéto zapojenie je základom rozvoja obehového hospodárstva a napredovania inkluzívneho sociálno-ekonomického pokroku.

Napriek tomu súčasné prevádzkové trendy v ukrajinských energetických podnikoch odhaľujú výraznú neochotu investovať do modernizačného úsilia bez jasných regulačných smerníc od vnútroštátnych alebo medzinárodných orgánov. Udržateľný rozvoj na úrovni podnikov aj odvetví nemôže účinne pokračovať v prostredí, kde je technologický pokrok obmedzený a klimatické ciele zostávajú nesplnené. Komplexné hodnotenie ukrajinského energetického sektora odhaľuje niekoľko kritických charakteristík, ktorými je potrebné sa zaoberať – rozsiahla deštrukcia

rôznych kapacít na výrobu energie v celej krajine, regionálne rozdiely v prírodných a klimatických podmienkach, ktoré ovplyvňujú hospodárske činnosti, absencia dobre zavedených mechanizmov na uplatňovanie vedeckého pokroku a technologických inovácií, neprepojenosť a nedostatočná synchronizácia medzi výskumnými inštitúciami a výrobcami elektrickej energie, značný rozdiel medzi domácimi a medzinárodnými normami a postupmi pri rozvoji výrobných kapacít.

V dizertačnej práci sa načrtáva, že dlhodobá prevádzková neefektívnosť sa vysvetľuje zastaraným trhovým modelom a jeho nedávnou zmenou ako reakciou na nové výzvy a predpisy. Ukrajinský trh s elektrinou dlhé roky fungoval podľa modelu jedného kupujúceho, v rámci ktorého centralizovaný subjekt nakupoval elektrinu vo veľkom od rôznych výrobcov a ďalej ju predával za regulované ceny stanovené Národnou komisiou pre štátnu reguláciu energetiky a verejných služieb. V rámci tejto štruktúry slúžil veľkoobchodný trh s elektrinou ako jediná platforma pre transakcie medzi všetkými účastníkmi trhu, pričom na jeho fungovanie dohliadal určený operátor – Energorynok.

V tomto rámci boli kľúčové parametre, ako je plán zaťaženia sústavy, prognóza energetických bilancií a dispečerské objemy, stanovené direktívnym spôsobom zhora nadol. Tento centralizovaný prístup účinne určoval celkový objem výroby elektrickej energie v celej sústave.

Pri absencii skutočnej liberalizácie trhu chýbala interakciám medzi účastníkmi trhu s elektrinou konkurenčná dynamika, čo viedlo k minimálnym stimulom na zvýšenie kvality služieb alebo efektívnosti. Na odstránenie týchto štrukturálnych nedostatkov bol v júli 2019 zavedený nový model trhu s elektrinou. Cieľom tejto reformy bolo vytvoriť konkurencieschopnejší a transparentnejší systém zavedením šiestich odlišných trhových segmentov, čo uľahčilo efektívnejšiu interakciu medzi rôznymi kategóriami dodávateľov a spotrebiteľov.

Základom nového modelu trhu s elektrinou je zásada oddelenia vlastníctva v súlade so štrukturálnymi reformami uvedenými v treťom energetickom balíku Európskej únie. V rámci záväzkov Ukrajiny vyplývajúcich z jej dohôd s EÚ v oblasti

energetiky musí byť výroba elektriny inštitucionálne a právne oddelená od jej prenosových činností.

V rámci podnikového oddelenia ukrajinská reforma energetického sektora nariaďuje jasné rozdelenie funkcií distribúcie a dodávky elektrickej energie, čo je predpokladom pre vytvorenie konkurenčného maloobchodného trhu s elektrickou energiou. Tento maloobchodný segment zahŕňa zmluvné vzťahy a vzťahy súvisiace so službami medzi koncovými spotrebiteľmi a dodávateľmi elektriny spolu s ďalšími subjektmi zapojenými do poskytovania príslušnej infraštruktúry a podporných služieb. Napriek výzvam, ktorým ukrajinský energetický sektor čelí, jeho perspektívy rozvoja zahŕňajú prechod na čisté a udržateľné zdroje energie, integráciu nových technológií a širokú diverzifikáciu energetického mixu. Úspech tohto úsilia bude do veľkej miery závisieť od súdržnej medzinárodnej podpory a účinného riadenia domácich zdrojov.

Hlavným cieľom dizertačnej práce je vytvoriť inovatívnu politiku pre udržateľný rozvoj a dlhodobu efektívne fungovanie trhu s energiou na Ukrajine s prihliadnutím na súčasné geopolitické výzvy a príležitosti.

Absencia praktických, kontextovo špecifických riešení ukrajinskej energetickej krízy – najmä takých, ktoré by boli v súlade s dlhodobými cieľmi globálnej udržateľnosti a zohľadňovali pretrvávajúce geopolitické výzvy – viedla k formulácii hlavnej výskumnej otázky, ktorú sa snaží riešiť táto dizertačná práca.

- Ako môže Ukrajina vytvoriť a realizovať dlhodobú inovatívnu politiku udržateľnosti energetického priemyslu v podmienkach moderných národných výziev, ako aj geopolitických obmedzení?

Na zodpovedanie výskumnej otázky bola dizertačná práca rozdelená do niekoľkých cieľov:

Cieľ 1: analyzovať a pochopiť koncept udržateľnosti v rozsahu moderných trendov

Cieľ 2: určiť teoretické základy tvorby inovačnej politiky v rámci národného hospodárstva

Cieľ 3: analyzovať míľniky rozvoja energetického systému Ukrajiny z historickej perspektívy

Ciel' 4: zdôvodniť možnosť adaptácie zahraničných skúseností v oblasti regulácie činností energetického sektora z hľadiska tvorby strategickej politiky rozvoja tohto odvetvia na Ukrajine s prihliadnutím na domáce sociálno-ekonomické charakteristiky

Ciel' 5: poskytnúť pravdepodobné scenáre (uhlie, plyn, ropa, jadrová energia) a potenciálne oblasti rozvoja na Ukrajine v kontexte ich vplyvu na ekonomickú bezpečnosť štátu;

Ciel' 6: určiť uskutočniteľnosť štátnej inovačnej politiky rozvoja energetického priemyslu na Ukrajine na základe súčasných geopolitických výziev;

Ciel' 7: vypracovať strategické návrhy a odporúčania na zlepšenie regulačného rámca v energetickom sektore.

V rámci tohto výskumu využívame kombináciu všeobecných vedeckých a aplikovaných metód s cieľom komplexne preskúmať transformáciu ukrajinského energetického sektora v kontexte udržateľnosti a geopolitických zmien. Komplexná textová analýza sa vykonáva s cieľom kriticky zhodnotiť sektorové právne predpisy, nadradené regulačné rámce a medzinárodné právne nástroje vrátane energetických balíkov Európskej únie a príslušných ukrajinských zákonov v tejto oblasti. Komparatívna metóda sa uplatňuje s cieľom identifikovať spoločné aj odlišné črty súčasnej ukrajinskej energetickej stratégie vo vzťahu k najlepším medzinárodným postupom.

Okrem toho sa historická metóda využíva na sledovanie vývoja ukrajinskej energetickej politiky a posúdenie vplyvu medzinárodných záväzkov na vývoj domácej regulácie. Na dosiahnutie cieľov výskumu sa používa rad analytických nástrojov. Na skúmanie konceptuálnych základov energetickej politiky založenej na inováciách sa používa vedecká abstrakcia, zovšeobecnenie a sémanticko-kritická analýza. Štruktúrna analýza pomáha pri organizovaní a hodnotení prístupov k meraniu účinnosti strategickej politiky, zatiaľ čo retrospektívna analýza pomáha skúmať historickú dynamiku ukrajinského energetického sektora. Okrem toho tabuľkové a grafické metódy podporujú vizualizáciu analytických výsledkov a zlepšujú prezentáciu empirických údajov.

Primárnym metodologickým základom práce je analýza sekundárnych údajov, ktorá sa opiera o globálne energetické štatistiky a správy s cieľom získať zmysluplné poznatky. Na riešenie energetickej bezpečnosti z viacerých hľadísk – technologického, inštitucionálneho a zdrojového – sa uplatňuje systémový prístup, ktorý umožňuje fundovanejšie pochopenie odvetvových súvislostí. Táto metodologická orientácia je obzvlášť dôležitá pre dosiahnutie ekonomicky, environmentálne a sociálne udržateľných výsledkov. Okrem toho umožňuje komplexnú interpretáciu energetických politík cez perspektívnu optiku a ponúka praktické dôsledky na zvýšenie adaptability politík, zdokonalenie strategického plánovania a informovanie o dlhodobej odolnosti energetického sektora.

Metóda prognózovania vývoja výroby elektrickej energie predstavuje analytické nástroje a techniky používané na predpovedanie budúcich trendov vo výrobe elektrickej energie, pričom sa zohľadňuje celý rad technologických, hospodárskych, environmentálnych a politických premenných. Hlavným cieľom tejto metódy v rámci tejto dizertačnej práce je podporiť strategické rozhodovanie odhadom budúceho dopytu po elektrine a určením optimálnej štruktúry výroby energie na efektívne a udržateľné uspokojenie tohto dopytu na Ukrajine. V rámci analýzy prognóz sa používa funkcia intervalu spoľahlivosti na odhad potenciálnych scenárov vývoja - konkrétne normálnej, optimistickej a pesimistickej prognózy. Táto metóda umožňuje zostaviť interval spoľahlivosti okolo odhadu vzorky, ako je priemer alebo podiel, s cieľom vymedziť rozsah, v ktorom sa očakáva, že skutočný parameter populácie spadá so stanovenou úrovňou spoľahlivosti (zvyčajne 95%). Výsledky výskumu kvantifikujú neistotu a variabilitu prognózovaných výsledkov, čím zvyšujú spoľahlivosť analýzy scenárov a podporujú informovanejšie strategické plánovanie v kontexte energetického sektora.

Táto metóda vo všeobecnosti zahŕňa vyhodnotenie historických údajov pomocou metódy extrapolácie, modelovanie budúcich scenárov a zahrnutie kľúčových ovplyvňujúcich faktorov, ako sú vzorce spotreby energie, dostupnosť zdrojov, technologické inovácie, regulačné rámce a geopolitická dynamika. Uplatňovaním kvantitatívnych a kvalitatívnych prístupov – ako je analýza časových radov,

simulačné techniky a plánovanie scenárov – umožňuje prognózovanie zainteresovaným stranám predvídať zmeny v energetických potrebách, plánovať investície do infraštruktúry, posudzovať životaschopnosť uhlia, plynu a ropy ako konvenčných zdrojov energie s cieľom zabezpečiť dlhodobú energetickú bezpečnosť a udržateľnosť. Následne je možné zosúladiť stratégiu výroby elektriny s vnútroštátnymi energetickými politikami, klimatickými záväzkami a širšími cieľmi sociálno-ekonomického rozvoja, najmä pokiaľ ide o európsku integráciu.

Na základe výsledkov prezentovaných v rámci prognóz dizertačnej práce zostane jadrová energia kľúčovou súčasťou ukrajinského energetického systému. Zemný plyn, ktorý v súčasnosti zabezpečuje menej ako 10% výroby elektriny, bude zohrávať dôležitú úlohu v systémoch vykurovania a jeho podiel sa môže po roku 2030 zvýšiť, aby nahradil výrobu elektriny z uhlia v dôsledku iniciatív zameraných na čistú nulovú spotrebu.

Sľubný je aj sektor obnoviteľných zdrojov energie. Vysoká úroveň zelenej tarify na Ukrajine však vytvára nadmerné cenové zaťaženie pre spotrebiteľov. Okrem toho sa prevádzka veľkých elektrární na výrobu energie z obnoviteľných zdrojov, najmä tých, ktoré vyrábajú elektrickú energiu zo slnečnej energie a vetra, vyznačuje prudko sa meniacimi režimami prevádzky v rámci Jednotného energetického systému Ukrajiny. To vedie k dodatočným nákladom na plánovanie elektrární a udržiavanie rezervnej kapacity na reguláciu režimov prevádzky elektrární, ktoré využívajú slnečnú energiu, vietor, biopalivo. A práve dostupnosť dostatočných rezerv výrobných kapacít na udržanie rovnováhy medzi ponukou a dopytom na trhu s elektrickou energiou je dôležitým faktorom spoľahlivej a bezpečnej prevádzky Jednotnej energetickej sústavy.

Spomedzi všetkých subjektov vyrábajúcich energiu majú tepelné elektrárne najväčší negatívny vplyv na životné prostredie, a to predovšetkým v dôsledku značných emisií škodlivých znečisťujúcich látok počas prevádzkových procesov. Z predloženej analýzy existujúceho nedostatku zdrojov, ako aj prevládajúcich globálnych a vnútroštátnych trendov v sektore elektrickej energie vyplýva niekoľko kľúčových smerov dlhodobej transformácie odvetvia na Ukrajine - tepelné

elektrárne sa budú čoraz viac rekonštruovať z dôvodu postupnej deštrukcie a využívať ako poskytovatelia záložných a vyrovnávacích kapacít, zatiaľ čo rozšírené inovatívne zavádzanie technológií obnoviteľných zdrojov energie bude hnacou silou štrukturálnej reformy a iniciuje postupnú decentralizáciu trhu s energiou.

Táto dizertačná práca tiež poukazuje na rozsah inovačného rozvoja nielen na priemyselnej úrovni, ale aj na úrovni podnikov. Galopujúci rozvoj moderného podnikateľského sektora na Ukrajine aj v globálnom meradle prebieha pod vplyvom procesov štvrtej priemyselnej revolúcie, ktorá aktualizuje prioritu technologických transformácií a inovačných prístupov. Tieto procesy vytvárajú nové podmienky na dosiahnutie nielen ekonomických, ale aj sociálnych a environmentálnych cieľov v rámci národných a globálnych rozvojových stratégií. Rýchle šírenie informačných technológií, digitálnych nástrojov a výrobných inovácií si od podnikateľských subjektov vyžaduje zavádzanie proaktívnych manažérskych prístupov zameraných na formovanie strategickej vízie, zabezpečenie udržateľného rastu a posilnenie konkurenčných pozícií na domácich a zahraničných trhoch.

V tejto súvislosti má osobitný význam tvorba inovatívnych stratégií trvalo udržateľného rozvoja podnikov s postupnou integráciou princípov spoločenskej zodpovednosti podnikov do podnikateľských procesov. Podniky sú schopné samostatne určiť prioritné ciele v závislosti od špecifik odvetvia, čo poskytuje základ pre tvorbu vhodných taktických opatrení v rámci dlhodobej stratégie.

Napriek tomu, že tieto usmernenia majú odporúčací charakter, ich zohľadnenie sa v rámci rastúcej globálnej integrácie stáva čoraz viac konkurenčnou požiadavkou. Zavedenie zásad zodpovedného využívania zdrojov, technológií šetrných k životnému prostrediu a uvedomelého riadenia podnikových procesov je nevyhnutnou podmienkou realizácie koncepcie trvalo udržateľného rozvoja. Tento prístup je založený na paradigme trojitého výsledku, ktorá vyžaduje vyvážené zohľadnenie ekonomických, sociálnych a environmentálnych faktorov efektívnosti podniku. Podniky v energetickom sektore Ukrajiny by sa teda mali zamerať nielen na zabezpečenie prevádzkovej efektívnosti ako záruky konkurencieschopnosti, ale aj na strategické prehodnotenie podnikovej politiky v súlade so zásadami trvalo

udržateľného rozvoja, čo je kľúčovou požiadavkou súčasnej etapy sociálno-ekonomickej transformácie.

Potreba zaviesť komplexné systémy interakcie so zainteresovanými stranami a efektívneho riadenia technickej zložky činností energetických podnikov vyplýva z viacerých kľúčových faktorov, ktoré sú v dizertačnej práci podrobne opísané. Po prvé, napriek dlhodobej neefektívnosti politiky v oblasti výroby elektrickej energie na Ukrajine súčasné globálne trendy, najmä výzvy štvrtej priemyselnej revolúcie, stimulujú domáce podniky aktívne reagovať na zmeny. Takáto reakcia je nevyhnutnou podmienkou na vytvorenie pozitívneho obrazu Ukrajiny ako perspektívneho investičného prostredia a spoľahlivého partnera v systéme medzinárodnej deľby práce. V 21. storočí došlo k výraznej zmene paradigiem riadenia: centralizované riadenie ustupuje flexibilným, samoregulačným a dynamickým modelom fungovania energetických systémov.

Po druhé, rýchly rozvoj umelej inteligencie a digitálnych technológií vytvára nové možnosti na budovanie efektívnej interakcie medzi zainteresovanými stranami. Tieto nástroje umožňujú komplexnú analýzu veľkých objemov údajov, čo prispieva k prijímaniu inovatívnych rozhodnutí na úrovni jednotlivých výrobných zariadení, v rámci celého energetického odvetvia, ako aj na štátnej a medzinárodnej úrovni. Digitalizácia vykazuje vysokú účinnosť nielen v oblasti výroby elektriny: IT priemysel a technické riešenia pôsobia ako silné katalyzátory transformácie celého hospodárstva. Dôležitú úlohu v tomto procese zohráva interdisciplinárna spolupráca odborníkov v rámci inovačných programov a dôsledný rozvoj ľudského kapitálu s cieľom vybudovať dlhodobú stratégiu udržateľného rozvoja.

Po tretie, mení sa samotná povaha podnikania v oblasti výroby: energetické spoločnosti už nefungujú ako autonómne podnikateľské subjekty, ale stávajú sa prvkami komplexných integrovaných systémov, ktoré si vyžadujú koordináciu na národnej a globálnej úrovni. Nové prevádzkové modely musia byť schopné prispôbiť sa veľmi nestabilnému vonkajšiemu prostrediu vrátane zmien poveternostných podmienok a správania spotrebiteľov a zabezpečiť riadenie v reálnom čase.

Okrem vonkajšieho tlaku prechádza sektor výroby elektriny, najmä jeho tepelná zložka, hlbokými vnútornými zmenami. Významné zmeny ovplyvňujú regulačný rámec činností, pričom sa zvyšujú požiadavky na kontrolu dodržiavania predpisov. Zároveň sa na úrovni podnikov preorientávajú prístupy k riadeniu – kľúčovým cieľom je vytvoriť účinný mechanizmus na analýzu trhových aj interných informácií s cieľom vytvoriť optimálne výrobné portfólio, ktoré kombinuje tradičnú (uhlíkovú) a obnoviteľnú výrobu.

Efektívne podnikanie na Ukrajine je možné len za podmienok zlepšenia hospodárskeho a právneho prostredia a vytvorenia konštruktívnej spolupráce medzi verejným a súkromným sektorom. Koncepcia trvalo udržateľného rozvoja, ktorá získala status vedúcej paradigmy 21. storočia, si vyžaduje operatívne, ciele a komplexné zmeny na rôznych úrovniach sociálno-ekonomických systémov. Existujúce inštitucionálne podmienky na Ukrajine sú však naďalej nepriaznivé pre transformáciu podnikateľských postupov, pretože neposkytujú primeranú podporu podnikateľským iniciatívam, inkluzívnosti spoločnosti a zavádzaniu zásad sociálnej a environmentálnej zodpovednosti.

Vytváranie konkurenčných výhod podnikov založených na princípoch trvalo udržateľného rozvoja je zároveň objektívne potrebnou a perspektívnou stratégiou zvyšovania ich medzinárodnej konkurencieschopnosti. To následne určuje relevantnosť zamerania úsilia manažmentu na rozvoj vnútorných jedinečných kompetencií, zavádzanie inovatívnych technológií a posilňovanie podnikového potenciálu.

Záver

Problematika inovatívneho udržateľného rozvoja energetického priemyslu si starostlivo vyžaduje inkluzívnu verejnú diskusiu, pretože zapojenie zainteresovaných strán a transparentné rozhodovanie sú nevyhnutné na zosúladenie technologického pokroku so spoločenskými potrebami a environmentálnymi cieľmi. Táto dizertačná práca sa zamerala na ukrajinský kontext v rozsahu geopolitických obmedzení, ktoré sú základom hlavného základu spolupráce z hľadiska európskej integrácie a uhlíkovej neutrality.

Ukrajinský energetický sektor v súčasnosti čelí množstvu štrukturálnych a prevádzkových výziev, ktoré výrazne bránia jeho prechodu na udržateľný rozvoj. Kľúčovým problémom je prebiehajúca deštrukcia výrobných zariadení, najmä v južných a východných regiónoch, čo ohrozuje spoľahlivosť a stabilitu energetického systému. Okrem toho, výrobný mix zostáva nedostatočne flexibilný, s nadmerným spoliehaním sa na tepelnú a jadrovú energiu, čo obmedzuje integráciu obnoviteľných zdrojov energie. Túto nepružnosť ďalej zhoršuje absencia zavedených mechanizmov na prilákanie a využívanie rezervných a vyrovnávacích kapacít, ktoré sú nevyhnutné pre udržanie flexibility siete a podporu prerušovaných obnoviteľných zdrojov. Sektor tiež trpí vysokou mierou odpisovania dlhodobého majetku, čo robí komplexnú modernizáciu neuskutočiteľnou bez značných investícií. Politiky v oblasti životného prostredia majú medzitým tendenciu byť krátkodobé a roztrieštené, chýba im kontinuita potrebná na podporu dlhodobej ekologizácie priemyselných procesov. Okrem toho, implementácia medzinárodných noriem a štandardov – najmä tých, ktoré sa týkajú kontroly emisií a dekarbonizácie – zostáva povrchná, čo bráni pokroku Ukrajiny smerom k zosúladieniu s globálnymi záväzkami v oblasti klímy a dosiahnutiu nízkouhlíkovej ekonomiky, berúc do úvahy vysokú mieru ničenia zariadení na obnoviteľné zdroje energie. Štúdia naznačuje, že súčasné energetické spoločnosti na Ukrajine by mali nielen optimalizovať interné operácie, aby zostali konkurencieschopné, ale aj prispôbiť svoje firemné stratégie tak, aby boli v súlade s nevyhnutnosťou dosiahnutia dlhodobého udržateľného rozvoja založeného na inovatívnych prístupoch, ako je umelá inteligencia, blockchain, kybernetická bezpečnosť, transparentné zverejňovanie údajov, udržanie ľudského kapitálu a prevádzková racionalita.