
CHAPTER 1

Strategic and legal aspects of digital transformation of the energy sector of Ukraine: focus on foreign economic policy

Oleksandr Trehub
Tetiana Hudima
Roman Kirin
Volodymyr Khomyn

Abstract

The aim of this study is to analyze the strategic and legal aspects of digital transformation of the energy sector of Ukraine, determine the connection and specify its impact on foreign economic policy. The study discusses the achievements and shortcomings of the national strategy for the transition to digital energy, as well as substantiates proposals for improving strategic documents. Special attention is given to the analysis of the Concept for the Implementation of Smart Grids in Ukraine until 2035. The study also examines trends in the legal framework for digitalization of the energy sector both in Ukraine and in the European Union. Based on a comparative analysis, some ways to improve national legislation are outlined. Special attention is given to the impact of digitalization of the energy sector on foreign economic policy in the context of tightening the EU climate policy. Smart grid technologies and electronic guarantees of origin of electricity produced from renewable energy sources are key digital instruments in the energy sector that influence foreign economic policy. These instruments form a single digital mechanism for adapting Ukraine to EU climate and energy policy, aimed at ensuring the most favorable conditions for the export of products and stimulating the inflow of foreign investments. Establishing this mechanism is a way to mitigate the consequences of the introduction of the Carbon Border Adjustment Mechanism (CBAM) in the EU for the export of electricity from Ukraine to EU countries (by increasing the share of electricity produced from renewable energy sources). It is shown that the deployment of digital infrastructure based on smart grid technologies and the introduction of electronic guarantees of origin of electricity produced from renewable energy sources will have a positive impact not only on the investment climate in the electricity sector, but also on the

investment climate in general (access to "green" electricity is an important condition for many international companies to enter Ukrainian markets). In addition, the twin transition to the digital and climate-neutral energy system will help reduce fossil fuel imports and strengthen Ukraine's energy independence.

Keywords

Digitalization, strategy, decarbonization, climate policy, smart grids, guarantees of origin, energy efficiency, renewable energy sources, Carbon Border Adjustment Mechanism, investments, foreign economic policy.

1.1 Introduction

In modern conditions, digitalization is becoming one of the essential factors in the transformation of foreign economic policy. The direction "International Economic Policy and Trade" of the National Economic Strategy for the period up to 2030 (the NES 2030) provides for the transformation of Ukraine into an influential participant in international economic relations and a reliable economic partner in the world. As defined in the NES 2030, strengthening Ukraine's position in international economic relations will be facilitated by ensuring mutually beneficial trade with countries of the world and achieving expanded access to foreign markets, increasing the competitiveness of Ukrainian goods and services, creating a positive image of the country and ensuring the presence of Ukrainian producers in international markets. In this context, the achievement of strategic goals in the direction "International Economic Policy and Trade" depends largely on the implementation of the goals in the direction "Digital economy".

Ukraine strives to build an intelligent and carbon-neutral energy system with a high level of resilience that is in line with the best global and European experience. This contributes not only to solving a number of pressing internal issues, but to the formation of mutually beneficial foreign economic relations in the context of an accelerated "green" transition and the growing influence of global climate policy. Naturally, like other countries, Ukraine faces difficulties and obstacles along this path, which is aggravated by the war and its consequences for the economy, environment and social sphere.

Russian full-scale invasion of Ukraine in February 2022 significantly accelerated the transition to "green" energy technologies in Europe and other regions of the world, but at the same time had catastrophic consequences for Ukraine's energy sector. On the one hand, the war against Ukraine has led to the physical destruction, damage or seizure of many energy infrastructure facilities, disruption of

energy supply chains and logistics. According to the Ministry of Energy of Ukraine, the country has lost more than 30 % of cogeneration units, 40–50 % of solar energy and 90 % of wind farms since the beginning of the war. The main share of wind generation is concentrated in the occupied territories of southern and eastern Ukraine. The Russian army has been carrying out targeted attacks on Ukrainian energy facilities since October 2022. In total, about 50 % of the energy infrastructure was damaged by shelling. On the other hand, the armed aggression provoked a deterioration in financial conditions and the investment climate in the field of renewable energy, stopped the implementation of many projects and scared away potential investors. The difficult financial situation of companies operating in the field of renewable energy is worsened by the practice of applying restrictions established by the Ministry of Energy of Ukraine on payments for the supplied electricity under martial law. In this case, the funds intended to pay for electricity purchased at the "green" tariff are redistributed to other needs. Due to attacks on Ukrainian energy facilities and other factors (e.g. inconsistency in conducting auctions for the distribution of capacity of interstate crossings), the export of Ukrainian electricity to EU countries is limited and unstable. It is also important that the war has delayed the development of many vital state planning documents for reforming the energy sector. In particular, on the eve of the war, the State Agency for Energy Efficiency and Energy Saving of Ukraine developed the draft National Renewable Energy Development Action Plan until 2030. A new version of the Plan was prepared in September 2022 in order to adapt it to the realities of wartime and the new conjuncture of the global energy market, which changed rapidly after the Russian attack on Ukraine. However, this document, which is critically important for the digital and "green" transformation of the energy sector, has not yet been adopted.

The Ukraine Recovery Plan, which was developed by the National Council for the Recovery of Ukraine from the Consequences of the War (the materials of the "Energy security" working group) in 2022, also remains in draft form. This Plan is ambitious so achieving its goals in the energy sector requires a number of prerequisites: Ukraine wins the war within the next 1–2 years, no major parts of the energy sector are lost or severely damaged; business environment and macro-financial stability allows Ukraine to attract significant investments during the next 2–4 years, which provides investors with an attractive level of profit; "red tape" and other barriers for swift realization of investment projects are removed; there is a major funding and investment flow into Ukraine, both public and private [1]. It is already clear that at least some of these prerequisites are missing or will not appear in the near future. This does not stop the digital and "green" energy transition, but requires adapting the goals and tasks in this area to the changing realities.

The aim of this study is to analyze the strategic and legal aspects of digital transformation of the energy sector of Ukraine, determine the connection and specify its impact on foreign economic policy.

1.2 Literature review

The digitalization of foreign economic policy is gaining momentum. This underscores the need for radical and swift decisions in environmental protection, particularly in decarbonizing the global economy [2]. Research shows that one-quarter of global carbon emissions are attributed to international economic relations, including producing and distributing trade goods and services [3]. Governments strive to implement measures to reduce emissions within their jurisdictions, but these efforts partially or even significantly affect trade flows and production in other jurisdictions where such measures are not implemented or implemented slowly. Therefore, countries around the world and international organizations, such as the WTO, should collaborate to promote the environmental sustainability of foreign economic relations.

In this context, the discussion goes beyond merely implementing economic (tax and pricing) measures. It also involves the digitalization of the energy sector, particularly for monitoring compliance with non-digital measures. It is important to consider that the twin transition process of decarbonization and digitalization of the economy may undergo unbalanced structural transformation. This expectation should guide policy recommendations, emphasizing the need to develop a low-carbon industry and synergize between the two sectors to avoid a new carbon-intensive industrial revolution [4].

It is worth noting that the evaluation of the potential of digitalization in the energy sector is not a new topic in both domestic and international research [5]. Scholars emphasize that the application of digital technologies in the energy sector, including artificial intelligence and blockchain [6] can not only transform our energy supply significantly, but also have a positive impact on international trade and environmentally responsible consumption [7–9]. O. A. Omिताomu and H. Niu in the article "Artificial Intelligence Techniques in Smart Grid: A Survey" state that applying artificial intelligence methods can enhance the reliability and resilience of smart grid systems [10]. Similarly, G. Dileep explores various technologies supporting smart grid [11]. S. Kucherikova and H. Matvienko emphasize the importance and necessity of implementing artificial intelligence in the energy complex. They outline the main promising directions for such implementation. The researchers note that in general artificial intelligence has the potential to save a significant amount of energy

and create more resilient energy networks, but this requires the development of appropriate government regulation and support [12].

However, the digital transformation of the energy sector also poses risks. It may perpetuate and solidify persistent inequality in households' access to adequate energy services [13–15]. The article "Using the Capability Approach as a normative perspective on energy justice: Insights from two case studies on digitalisation in the energy sector" delves into the concept of energy justice by assessing the impact of two cases of digitalization in the energy sector. The digitalization promises technical solutions to urgent energy sector issues, such as climate change and fossil fuel scarcity. In ongoing academic and popular debates regarding these solutions, a techno-utopian ideal often dominates and sometimes overshadows complex ethical and social issues. Furthermore, the assessment of technology in the energy sector often focuses on the ecological and economic aspects of sustainability, while energy justice or broader ethical issues are frequently given low priority [16].

In addition to these challenges, the institutional, political, and regulatory regimes in energy and broader digital systems are tested. It seems that none of them fully addresses the specific needs of managing digital energy at present [13].

A. Clifton and coauthors highlight that these barriers can only be overcome through large-scale strategic foreign policy efforts. This involves a combination of technical, cultural and business aspects that require collaboration between businesses, academia and government [8].

The mechanisms of EU environmental diplomacy are gaining increasing importance. They are effective for application in all priority areas of state policy. Among other things, current bilateral and multilateral negotiations on the liberalization of trade in environmentally friendly goods and services are also used by the EU to promote global efforts to mitigate climate change and create business opportunities for European companies. In this context, the EU's experience in using its additional tools of foreign economic policy (including political dialogue, international negotiations, and financial instruments) to advance the sustainable development and climate change agenda and promote its implementation in partner countries is also relevant [17].

In terms of the impact of economic measures on the greening of foreign economic relations, a single carbon price that covers all countries and sectors is recommended [18]. The CBAM, designed by the EU to equalize carbon costs between domestic production and imports and reduce the risk of carbon leakage, has significant potential in this regard [19]. This initiative has been supported in academia, but it has also sparked criticism of the methodology for determining the carbon limit [18, 20].

Despite a large volume of literature on strategic and legal aspects of digital transformation in the energy sector of Ukraine, its connection and impact on

foreign economic policy remain insufficiently studied. Therefore, this research is relevant and necessary.

1.3 Strategy for transition to digital energy

In accordance with the NES 2030, digitalization involves the transformation of resource sectors of the economy into high-performance, intelligent and competitive ones. To achieve this strategic goal, the Cabinet of Ministers of Ukraine plans to implement sectoral roadmaps for digital transformation of key industries, including the energy sector. Today there is still no reliable information about the start of work on this document. It can be assumed that other strategies and plans that affect certain aspects of digital transformation of the energy sector can compensate, to some extent, for the lack of this information. However, these documents are not sufficiently interconnected and show only a general or fragmented view of the prospects for digital development.

The task of the Energy Security Strategy is to implement a data management system based on big data, digitize processes, and create convenient services for citizens. In addition, this strategy emphasizes that the digitalization of energy use allows bringing the sources of energy production closer to consumers and balancing the modes of operation of energy systems. The scenario of "positive transformation" proposed in the strategy includes the formation of a favorable investment environment due to the availability of attractive energy markets for investment in Ukraine (technological modernization, introduction of new services).

A potentially important instrument for determining the directions of digitalization of the energy sector is an overall energy strategy designed for the long term. Nevertheless, a typical problem for Ukraine is the lack of a stable political course for the energy sector. National energy strategies are usually annulled a few years after their adoption, which does not contribute to the consistent implementation of the goals and objectives. Over the past ten years, two energy strategies have been prematurely repealed. The Cabinet of Ministers of Ukraine approved the new Energy Strategy of Ukraine until 2050 (the Energy Strategy) in April 2023, but its full text remains unavailable to the public. The Ministry of Energy of Ukraine notes on its official website that the mission of the Energy Strategy is to create conditions for the sustainable development of the national economy by ensuring access to reliable, sustainable and modern sources of energy. The energy sector should be as close as possible to climate neutrality by 2050. This means the availability of clean energy, overcoming energy poverty, the development of an innovative and decentralized

energy system, the full functioning of national energy markets and their integration into international ones. The goals of the Energy Strategy are: achieving the maximum level of climate neutrality; maximum reduction of coal use in the energy sector; renewal and modernization of energy infrastructure; increasing the efficiency of the use of resources in the energy sector; comprehensive integration with the markets of the EU and effective functioning of internal markets; providing the energy sector with its own resources based on the economic feasibility; development of alternative energy sources, new products and innovative solutions in the energy sector [21]. The Minister of Energy of Ukraine also emphasizes that the Energy Strategy provides for the restoration of the energy sector using the most modern technologies, strengthening the energy security of Ukraine and the European continent as a whole. The key objective of the strategy is to turn Ukraine into an energy hub of Europe for the complete abandonment of Russian fossil fuels thanks to "green" energy from Ukraine [22]. This information generally clarifies the foreign economic vector of state policy in the energy sector, but does not reveal specific content of the Energy Strategy, so it is still difficult to assess the extent to which it reflects issues of digital transformation of the sector.

Another important document is the draft Ukraine Recovery Plan (the materials of the "Energy security" working group). This document is aimed at "rapid electrification of the economy due to the energy transition, as well as a significant increase in energy efficiency". Although the draft Ukraine Recovery Plan contains some progressive provisions for the use of various digital instruments (smart grids, automation of substations, guarantees of origin of energy from renewable sources, electronic biofuel trading platform, etc.) [1], it does not directly consider digitalization as one of the key trends in the reconstruction of the energy industry, as well as does not cover a number of its promising areas. This issue requires more attention in the context of the transformation of Ukraine's foreign policy in the energy sector. The draft Ukraine Recovery Plan focuses on creating favorable conditions for attracting investment in the restoration and modernization of the energy sector, increasing the share of renewable energy sources in the energy mix, reducing dependence on energy imports, exporting excess electricity to the EU market, adapting to the potential consequences of implementing the CBAM [1].

A notable breakthrough in the construction of an advanced high-tech energy system is the Concept for the Implementation of Smart Grids in Ukraine until 2035 (the Concept of Smart Grids), which was approved by the government in October 2022. Unlike other strategic documents, this is the first state attempt to properly organize and accelerate the process of digital energy transformation according to the best world practices. It is noteworthy that the Concept of Smart Grids provides

a number of pilot projects related to the implementation of wide area measurement system (WAMS), advanced distribution management system (ADMS), energy storage facilities, self-healing smart grid, distributed energy resources management system (DERMS), virtual power plants (VPP), smart metering, micro grid, etc. At the same time, it also provides the establishment of cooperation with international financial organizations, foreign investment companies and donor funds to attract funding for their implementation. Moreover, the government plans to prepare separate roadmaps for the development of smart grids for electricity producers, transmission system operator and distribution system operators. This task should be consistent with the strategic task of developing the roadmap for the digital transformation of the energy sector (based on the NES 2030). In this context, it is worth considering the advantages of an integrated approach, which is associated with the creation of a single roadmap. This complex roadmap can cover different areas of smart grid development and reflect the main characteristics of the future model of digital energy in Ukraine. It will be much more difficult to build optimal model in case of unjustified disintegration of strategic planning.

A well thought out strategy (roadmap) for the development of smart grids should necessarily take into account potential challenges and problems. First of all, this means cybersecurity issues. As researchers emphasize, smart grids are extremely sensitive to cyber-attacks. The failure of some vital components can lead to cascading failure and breakdown of the whole system [23]. Operational failures, power supply interruption, synchronization loss, complete blackouts, data theft, financial and social welfare damages are possible consequences of smart grid cyber-attacks [10]. Therefore, the problem of ensuring the cybersecurity of smart grids is coming to the forefront of the digital energy development strategy, especially in the context of war. It must be admitted that the Concept of Smart Grids and the Action plan for its implementation pay special attention to measures for cybersecurity and cyber defense of the energy system. According to these documents, the adoption of national standards and methods for assessing the state of cybersecurity of power grids in Ukraine is a prerequisite for the creation of smart grids. Nevertheless, cybersecurity issues require wider and more detailed coverage in the sectoral roadmap and other key documents in the field of digitalization of the energy sector. It is known that the Ministry of Energy of Ukraine is working on building a sectoral system for cyber protection of enterprises of the fuel and energy complex of Ukraine. The system is being created by combining the efforts of two sectoral cyber centers on the basis of NJSC "Naftogaz of Ukraine" and NPC "Ukrenergo". It is envisaged that these cyber centers will become sectoral cybersecurity centers for the electric power and oil and gas complexes, as well as for the nuclear, coal and peat mining complexes [24].

It is obvious that the future of new sustainable energy is closely related to artificial intelligence technologies. These technologies are associated with big data handling, improved deep learning and machine learning, increased computational power, enhanced integration of renewable energy, cyber-attacks prevention and many other advanced approaches [25]. In the recent analytical report, the National Institute for Strategic Studies notes that artificial intelligence makes it possible to integrate the latest and promising technological innovations in the energy sector and the resulting changes in the organization of energy supply systems (e.g. decentralization of energy production and distribution, as well as electrification of various technological processes). The Institute emphasizes that artificial intelligence technologies can support the functioning of energy supply systems in several ways (in line with existing trends in technological development and transformation of energy markets), including better monitoring, operation and maintenance of energy assets, better system operations and real-time control, introduction of new models of energy markets and business models. As practice shows, implementation of the energy transition, expanding the use of renewable energy sources, increasing the flexibility of energy systems and energy demand require significant investments in the modernization of energy infrastructure. In this context, business models based on the use of digital technologies enable this modernization in cheaper and more efficient ways [26].

In December 2020, the government approved the Concept for the Development of Artificial Intelligence in Ukraine. The concept defines the ways and means for solving the problem in priority areas of public policy, particularly in the economy. However, this approach does not reflect the peculiarities of the application of artificial intelligence technologies in the energy sector and other industries. This shortcoming can be eliminated by updating the concept, but it is necessary to synchronize this work with the preparation of sectoral documents on digital transformation, notably the roadmap for the energy sector.

In this context, an important event is that Ukraine and 27 countries signed the declaration on the safe use of artificial intelligence initiated by the United Kingdom (Bletchley Declaration). The Declaration defines main objectives in establishing shared agreement and responsibility on the risks, opportunities and a forward process for international collaboration on artificial intelligence safety and research, particularly through deeper scientific collaboration. Countries affirm that artificial intelligence should be designed, developed, deployed, and used in a manner that is safe to be human-centric, trustworthy and responsible. Bletchley Declaration focuses on identifying artificial intelligence safety risks of shared concern, building a shared scientific and evidence-based understanding of these risks, building respective risk-based policies across countries to ensure safety regarding such risks,

collaborating as appropriate based on national circumstances and applicable legal frameworks [27]. It is also important that developments in frontier artificial intelligence are transforming productivity and software services, which will multiply the productivity of many industries and sectors [28]. Artificial intelligence is a priority area of energy development [26], so the points of Bletchley Declaration are of great importance both for ensuring domestic electricity consumption in Ukraine and for the export of Ukrainian electricity to EU countries.

Ukraine is a party to the Association Agreement and EU candidate country, so the EU policy regarding energy and digitalization is of great significance to it. As Article 337 of the Association Agreement establishes, the Parties agree to continue and intensify their cooperation on energy matters for the enhancement of energy security, competitiveness and sustainability, which is crucial for the promotion of economic growth and progress towards market integration, including gradual approximation in the energy sector. Mutual cooperation between Ukraine and the EU covers the following areas: implementation of energy strategies and policies, development of forecasts and scenarios; modernization of existing energy infrastructures of common interests, including energy-generating capacities and the integrity, safety and security of the energy networks, progressive integration of the Ukrainian electricity network into the European electricity network; development of competitive, transparent and non-discriminatory energy markets; progress towards an attractive and stable investment climate by addressing institutional, legal, fiscal and other conditions, encouraging mutual investments in the energy field; promotion of energy efficiency and energy savings through the establishment policies and legal frameworks, compatible with the functioning of market mechanisms; development of and support for renewable energies in an economic and environmentally sound manner (Article 338 of the Association Agreement). These areas of cooperation are related to various aspects of the development of digital technologies and foreign economic relations in the energy sphere.

In October 2022, the European Commission approved the EU action plan on digitalizing the energy system (the EU Digital Energy Plan). As the European Commission notes, digitalization plays a core role in ending the EU's dependence on Russian fossil fuels and tackling the climate crisis. Furthermore, "smart buildings, smart meters and electric vehicles, Internet of Things devices provide key information that allows to monitor energy consumption, increase renewable integration and reduce costs" [29]. Apart from promoting interoperability and seamless exchange of data, strengthening cybersecurity and resilience in the energy system, developing energy-efficient solutions for the ICT sector, the EU Digital Energy Plan highly concentrates on fostering investments in digital electricity infrastructure. This

document emphasizes that the EU's electricity network has become increasingly digitalized in the last decade, but the speed of digitalization needs to increase significantly. It admits that fostering investments in smart energy grids requires a comprehensive framework, but many Member States' regulations do neither appear to incentivize digitalization nor innovation. According to the EU Digital Energy Plan, around 170 billion EUR investments in digitalization of the distribution grid will be needed over the period 2020–2030. For Ukraine, the necessary investments in smart grids are estimated at approximately 5–10 billion USD [1]. Considering these figures, it is quite clear that comprehensive and accelerated digitalization of the Ukrainian electricity infrastructure is impossible without the large-scale support of international partners.

The EU experience also convinces that a strategically sound solution for Ukraine to accelerate and strengthen digitalization is the creation of technological platforms. European Technology Platforms (ETPs) were the first type of public-private partnership established in the research field at European level. The purpose of ETPs is to "bring together the main stakeholders – research organizations, industry, regulators, user groups, etc. – around key technologies, in order to devise and implement a common strategy for the development, the deployment and the use of these technologies in Europe" [30]. In order to create a joint vision of European networks for 2020 and onwards, the European Technology Platform for Smart Grids was founded in 2005. The platform united representatives from industry, transmission and distribution system operators, research bodies and regulators [31]. In the literature, there is a proposal to create the Technological Platform "Intelligent Energy System of Ukraine" that combines innovative, production and technological, as well as management and coordination components. The platform organizes a partnership between business, scientists and authorities on joint scientific research, technology development and implementation of technology initiatives [32]. In addition to a number of other benefits, the platform can increase the effectiveness of strategic planning in this field and contribute to the improvement of regulatory framework.

Despite the fact that Ukraine has not developed a comprehensive state policy in the field of digitalization of the energy and mining industries, there are projects of leading companies that are already showing the first achievements. In 2019, DTEK Group launched the MODUS program for the company's digital transformation. This program covers several projects, including "Digital power plant", "Digital grids" and "Digital renewables". The MODUS program made it possible to digitalize the process of analyzing the operation of power units using artificial intelligence tools and methods. The sustainable growth of renewable energy will be facilitated by the consolidation of all performance indicators of different equipment, online

monitoring of the efficiency of operation, as well as the creation of other analytical models (prevention of breakdowns, forecasting of production, etc.) [33]. It would be beneficial to analyze this experience thoroughly and utilize it on a large scale.

1.4 Legal framework for digitalization of the energy sector

The possibility of obtaining foreign economic benefits (trade, investment, etc.) from the widespread use of artificial intelligence and other digital solutions in the energy sector depends largely on the level of "digitalization" of the national legislation (in this case, digitalization means bringing legislation in line with the achieved level of development of digital technologies).

Scientific literature offers various classifications and approaches to digital instruments and technologies in the energy sector. Many recent publications are devoted to the characteristics [34], components [11] and cybersecurity [23] of smart grids as a key aspect of the energy digitalization. Other authors focus on challenges and opportunities of applying artificial intelligence in the energy industry [25]. There are generalizing papers that highlight the main directions of digitalization in the energy sector, such as blockchain technologies, smart contracts, artificial intelligence, business platform, drones and remote registration, the Internet of Things, big data and data management or digital twins [35]. In this study, it is necessary to limit ourselves to a detailed analysis of the legal framework for the operation of smart grids, as well as electronic systems and documents, since it is possible to believe that these "niches" of digitalization have a huge potential for improving the effectiveness of foreign economic policy in the energy sphere.

Currently, the development of smart grids in Ukraine is regulated mainly within the legislation on energy efficiency. Article 1 of the Law of Ukraine "On Energy Efficiency" contains the basic concept of "smart grids", as well as the related concepts of "smart metering system" and "smart meter". This law defines "smart grids" as "electrical grids that unite electricity market participants in an economically feasible way and allow managing energy transmission and consumption in order to increase the reliability of power supply and the uninterrupted operation of the energy system". "Smart metering system" is an integral component (subsystem) of smart grid technologies and understood in the legislation as "an automated system that informationally unites smart meters and ensures the reception, processing and transmission of measured and other information through communication channels for the purposes of commercial calculations, monitoring and control". The provisions of the Law of Ukraine "On Energy Efficiency" on smart grids are mainly devoted to

the structure of the Concept for the Implementation of Smart Grids in Ukraine and the medium-term Action plan.

Article 15 (4) sets out the recommended list of structural elements of this concept, namely:

- 1) assessment of the current situation in the electric power industry of Ukraine regarding the availability of smart grid elements;
- 2) overview of modern smart grid technologies in the world;
- 3) vision for the development of smart grid technologies in Ukraine;
- 4) goals for a specified period;
- 5) list of measures for the development of smart grids;
- 6) roadmap for the implementation of smart grids in Ukraine;
- 7) assessment of the need for funds, sources and amounts of funding;
- 8) proposals for improving the regulatory framework;
- 9) assessment of the impact of smart grid technologies on the indicators of quality, reliability of power supply and energy efficiency of power grids.

At the same time, the roadmap may include such directions as geographic information systems, power grid monitoring and management systems, smart electricity metering systems, integration of renewable energy facilities, integration of energy storage installations, infrastructure for electric vehicles, development of communication channels and cybersecurity. In comparison with the proposed model, the Concept of Smart Grids lacks many essential elements, such as the roadmap for the implementation of smart grids, assessment of the need for funds and amounts of funding, overview of smart grid technologies in the world, etc. In this regard, the viability and expediency of some of its approaches may be questionable and require further analysis.

Another problem is related to the subject of the Law of Ukraine "On Energy Efficiency" and the legislative definition of the key concept of "energy efficiency". According to the preamble, this law defines the legal, economic and organizational principles for ensuring energy efficiency during the production, transportation, transmission, distribution, supply and consumption of energy. In this special legal context, the concept of "energy efficiency" refers to the ratio of output of performance, service, goods or energy, to input of energy. The deployment of smart grids is definitely a factor for increasing energy efficiency. Nonetheless, this is just one significant aspect from which the characteristics and useful functions of these advanced technologies can be viewed. As recent studies show, the positive effect of the implementation of smart grids is complex and multifaceted, since these grids are a "multivalent" instrument. As the authors explain, "smart grids, together with the promotion and integration of renewable energy generation in the electricity network, bear significant

potential for achieving low-carbon energy security, protection from the vagaries of international energy markets, affordable energy costs, enhanced access to energy, existent and future climate goals, empowerment of citizens, and enhanced competitiveness for the European economy" [36]. Different countries, such as the United States, China, Great Britain and Japan, consider smart grids as an opportunity to strengthen energy security and attain environmental policy goals [34]. Researchers pay special attention to climate change, as smart grids can make a great contribution to climate change mitigation and climate change adaptation from a technological standpoint (through the integration of renewable energy sources) and taking into consideration a behavioral and institutional perspective [11]. These views coincide with the position of the European Commission formulated back in 2011. The European Commission expected that smart grids would be "the backbone of the future decarbonized power system" (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "Smart Grids: from innovation to deployment", 2011). A number of legal and other steps have been taken to create this system since then. Environmental and climate goals are constantly increasing their impact on international trade, establishing a new "green" framework for economic relations between countries. This is especially true for the complex of initiatives of the EU covered by the European Green Deal.

The core idea of the European Green Deal is to build a fair and prosperous society in the EU with a resource-efficient, climate neutral (this means that there are no net greenhouse gas emissions in 2050) and competitive economy where economic growth is decoupled from resource use. The European Green Deal prioritizes the decarbonization of the energy system as energy production and use account for more than 75 % of the EU's greenhouse gas emissions. Ideally, the development of a power sector must be based on renewable energy sources, which also implies an accelerated phase-out of coal and decarbonization of gas. Climate priorities, however, should not lead to a decrease in energy security and risks for citizens and businesses. Therefore, it appears vital to ensure that the European energy market is fully integrated, interconnected and digitalized. Within this strategy, a special role is given to smart infrastructure, such as smart grids (Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions "The European Green Deal", 2019).

As the previous paragraphs show, there is a tendency in Ukraine to regulate the development of smart grids within the legislation on energy efficiency. Unlike the Law of Ukraine "On Energy Efficiency", the Directive 2012/27/EU on energy efficiency does not cover the field of smart grids as a whole, although it is aimed at

implementing the smart metering system (intelligent metering system) and smart meters (intelligent metering is an inherent part of smart grids [11]). On July 25, 2023, the EU adopted a revised Directive on energy efficiency (not yet in force) that is better aligned with the new climate goals [37]. Apart from one general reference to smart grid deployment, the subject of this Directive also includes only smart metering system [38]. It is important that the new directive does not define the concept of "smart metering system", but refers to the Directive (EU) 2019/944 on common rules for the internal market for electricity. This directive contains three articles devoted to deployment and functionalities of smart metering systems, as well as entitlement to a smart meter. Furthermore, Article 59 of the Directive (EU) 2019/944 establishes that the regulatory authority shall carry out "monitoring and assessing the performance of transmission system operators and distribution system operators in relation to the development of a smart grid that promotes energy efficiency and the integration of energy from renewable sources". There is no similar provision in Ukrainian legislation, though according to Article 4 (6) of the Law of Ukraine "On Energy Efficiency" the National Commission, which carries out state regulation in the spheres of energy and communal services shall stimulate the implementation of smart grids by establishing a system of economic incentives for transmission system operator and distribution system operator. Approximation to European rules in this area should be facilitated by synchronization of Ukraine with ENTSO-E (the European Network of Transmission System Operators for Electricity) on March 16, 2022. The task of ENTSO-E is to promote the digitalization of transmission networks including deployment of smart grids, efficient real time data acquisition and intelligent metering systems (Regulation (EU) 2019/943 on the internal market for electricity). The operator of the energy transmission system of Ukraine NPC "Ukrenergo" has already started the automation of technological processes in order to participate fully in the electricity trading mechanisms of the EU market as a member of ENTSO-E, in particular for entering European auctions. The automated enterprise management systems are one of the necessary conditions for the activity of system operators that are members of ENTSO-E, as well as a guarantee of their transparency for partners [26].

Following legal trends in the EU, Ukraine should develop the regulatory framework for smart grids in a horizontal aspect, which means involving and combining different spheres of legal regulation. In this regard, the priority issue is the modernization of legislation in the electricity sector. The Law of Ukraine "On the Electricity Market", which is fundamental to this sector, does not contain provisions on smart grids, with the exception of energy storage. In the legal sense, energy storage is related to the selection of electricity with the purpose of postponing its final use to a time later than when it was produced, its transformation into another type of

energy in which it can be stored, storage and further transformation of such energy into electricity for the purpose of releasing it into the transmission system, distribution system, power plant grid or consumer grid. The Law of Ukraine "On the Electricity Market" contains a special section dedicated to the rights and obligations of the operator of the energy storage facility. The National Institute for Strategic Studies highlights the weak progress in approximating this law to the Directive (EU) 2019/944 and other EU legislation. This fact confirms the technological unpreparedness and social rejection of new mechanisms for the organization of the energy market proposed by the EU legislation, as well as the fear associated with the use of artificial intelligence in the energy industry [26].

Nevertheless, the need to ensure favorable legal conditions for the deployment of these technologies in the electric power industry stems from the principles of the electricity market and the goals of state policy in this sphere. Article 3 (2) of the Law of Ukraine "On the Electricity Market" refers to such principles as: ensuring Ukraine's energy security; preservation of integrity, ensuring reliable and efficient functioning of the unified energy system of Ukraine; energy efficiency and environmental protection; promoting the development of renewable energy; integration of the electricity market at the regional and pan-European levels. In accordance with Article 5 (1) of the law, state policy in the electric power industry is aimed at the development of distributed generation and energy storage equipment, creating conditions for attracting investment in the industry, simplifying access to information and administrative procedures, as well as stimulating the use of innovative technologies. Taking into account the provisions of the Directive (EU) 2019/944 on duties of the regulatory authorities, the main tasks of the National Commission, which carries out state regulation in the spheres of energy and communal services should include monitoring and assessing the performance of transmission system operators and distribution system operators in relation to the development of a smart grid (Article 6 (2) of the Law of Ukraine "On the Electricity Market").

In addition, the Action plan for the implementation of the Concept of Smart Grids provides an overview of the areas for improving the regulatory framework for smart grids. For instance, the plan mentions the preparation of draft legal acts on the elimination of legislative and institutional barriers to the development of smart grids in Ukraine, the formation of necessary conditions, incentives, motivations, demand and needs for the use of smart grid technologies by electricity companies, businesses and citizens. For the deployment of digital energy infrastructure in Ukraine, the Concept of Smart Grids also provides for the improvement of legislative terminology in the field of smart grids in accordance with European approaches; the determination of the index, indicators and methods for assessing the cybersecurity of smart grids in

Ukraine in accordance with international practices; the development of statistical monitoring methodology for obtaining statistical data on smart grids in Ukraine, taking into account international practices; the amendments to the Rules for the Arrangement of Electrical Installations, the Rules for the Technical Operation of Power Plants and Grids, the Rules for the Technical Operation of Electrical Installations of Consumers and other regulatory documents; the adoption of the international standard IEC TR 63097:2017 "Smart grid standardization roadmap" as a national standard. Following these areas, it is advisable to develop specific proposals for improving legislation in the near future.

The digital side of Ukraine's integration into the European energy market based on decarbonization and transition to renewable energy sources includes not only the development of modern digital infrastructure, but also the advantages of electronic documents and electronic systems. In this case, the guarantee of origin of electricity produced from renewable energy sources, which is formed according to information from the electronic register, has distinct advantages.

Ukraine has been trying to introduce guarantees of origin since 2013. At that time, the Cabinet of Ministers of Ukraine approved the Procedure for the Issuance, Use and Termination of the Guarantee of Origin of Electricity for Economic Entities Producing Electricity from Alternative Energy Sources. In addition, the mention of guarantees appeared in the Law of Ukraine "On Alternative Energy Sources". However, the electronic register for recording information on guarantees of origin has not been created and therefore the mechanism for issuing them has not been launched. This factor has restrained the growth of domestic renewable energy sector for ten years, particularly reduced its investment attractiveness. The long-awaited adoption of the Law of Ukraine "On Amendments to Certain Laws of Ukraine on the Restoration and Green Transformation of the Energy System of Ukraine" (the Law on Green Transformation) in June 2023 should contribute to the solution of this chronic problem. In terms of the scope and content of the amendments, this law is one of the most ambitious for the field of "green" energy in the history of independent Ukraine.

Firstly, the Law on Green Transformation contains updated terminology in the field of renewable energy. It enshrines such interrelated concepts as "guarantee of origin of electricity produced from renewable energy sources", "register of guarantees", "circulation of guarantees" and "environmental value of electricity produced from renewable energy sources". Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources defines the guarantee of origin as "an electronic document which has the sole function of providing evidence to a final customer that a given share or quantity of energy was produced from renewable sources".

The Ukrainian legislator did not limit itself to the monofunctional approach of EU law and enshrined the triple function of the relevant guarantee. This function includes: confirmation of the production of a certain amount of electricity from renewable energy sources; confirmation of the environmental value of electricity (refers to the amount of greenhouse gas emissions that has been avoided by producing 1 MWh of electricity); certification of rights related to the positive effect of electricity production from renewable energy sources (the Law of Ukraine "On Alternative Energy Sources"). It is still difficult and premature to talk about the progressiveness of this approach. The expansion of functions may create additional obstacles to the recognition of Ukrainian guarantees of origin by EU countries. There is a strict rule in the EU that prohibits member states from recognizing guarantees of origins issued by a third country. As an exception, this is allowed if the EU has concluded an agreement with a third country on mutual recognition of guarantees of origin issued in the EU and compatible guarantees of origin systems established in that third country, and only where there is direct import or export of energy (Directive (EU) 2018/2001). The subject of discussions may be the national mechanism for determining the environmental value of electricity produced from renewable sources, which should be developed by the Ministry of Energy of Ukraine. It is also significant that Article 19 (2) of the Directive (EU) 2018/2001 contains direct clause regarding the expansion of functions of the guarantees, namely "the guarantee of origin shall have no function in terms of a Member State's compliance with Article 3" (Article 3 establishes binding overall Union target for 2030 to increase the share of energy from renewable sources in gross final consumption of energy). This indicates a fully balanced position of the EU on this issue.

Secondly, the Law on Green Transformation supplemented the Law of Ukraine "On Alternative Energy Sources" with a new Article 9⁷ on guarantees of origin. This article regulates a wide range of aspects, including the ownership of the guarantee, the requirements for the procedure for issuing, circulation and repayment of guarantees of origin, the content of the guarantee, the grounds for refusal to form the guarantee, etc. The Law on Green Transformation is largely based on the provisions of the Directive (EU) 2018/2001 (sometimes with minor differences). However, there are still fundamental positions that need to be considered in the process of further approximation of Ukrainian legislation in the field of renewable energy to EU law. It is necessary to pay attention to the market value of the guarantee of origin and cases where this value should be taken into account appropriately. According to the Directive (EU) 2018/2001, there is a connection between support schemes for renewable electricity producers and the market value of the guarantee of origin.

The adoption of the basic law is only the first step towards the full implementation of the mechanism for issuing guarantees of origin. The next step is the high-

quality and rapid formation of the sub-legal regulatory framework. The backbone of this level of legislation is the procedure for issuing, circulation and repayment of guarantees of origin. The authority responsible for the development of this procedure is the National Commission, which carries out state regulation in the spheres of energy and communal services.

1.5 The impact on foreign economic policy

Digitalization, combined with the decarbonization of energy and the decentralization of energy supply, creates the prerequisites for the transition to a sustainable energy system (its properties such as resilience and carbon neutrality deserve special emphasis) that can be harmoniously integrated into the modern environmental, economic and social model of global energy policy. The fundamental position of the EU Digital Energy Plan is a so-called twin transition that in the most general sense can be characterized as a simultaneous movement towards a more intelligent and climate-neutral energy system. In this regard, it is noted that "digitalization of the energy system is a policy priority and one where the European Green Deal and the Digital Decade Policy Programme 2030 for Europe go hand-in-hand as a twin transition". This key point can be viewed from different angles related to foreign economic activity and policy.

The first angle worth paying attention to is the interconnection and interdependence of digitalization and climate policy. On the one hand, digitalization is a main enabling factor of decarbonization of electricity due to the technical and economic (cost reduction) benefits of integrating a growing share of renewable energy sources based on smart technologies [39]. On the other hand, if the new climate policy of the EU is de facto a barrier in trade relations with third countries, it is impossible to overcome this barrier without widespread application of digital solutions. It will be useful to dwell on this point in more detail.

The most pressing issue in the highlighted aspect of the problem is the upcoming introduction of CBAM. The literature presents different (sometimes sharply critical) assessments of this EU initiative, but studying them is not the aim of this publication. For this reason, it is perceived as an approaching reality to which it is necessary to adapt. As the EU declares, the CBAM is a "landmark tool to put a fair price on the carbon emitted during the production of carbon intensive goods that are entering the EU, and to encourage cleaner industrial production in non-EU countries". The European Commission explains that the CBAM will ensure the carbon price of imports is equivalent to the carbon price of domestic production, and that

the EU's climate objectives are not undermined [40]. At the same time, contrary to this explanation, many countries outside the EU predictably view the CBAM as a new trade barrier under the guise of purely climate ambitions [41]. It is also argued that certain factors increase the risk that this mechanism contravenes international trade law, particularly the principle of non-discrimination [18].

In light of such risks, countries with high carbon-intensive exports already have well-founded concerns. In this situation, the United Nations Development Programme anticipates the great risks of a decline in economic activity in Ukraine, because the use of the CBAM and similar mechanisms will lead to a significant increase in the price of export goods. As a result, these goods will automatically become uncompetitive on foreign markets, which will lead to a reduction in foreign currency receipts, an increase in the balance of payments and a worsening of the macro-financial situation in the country [42]. The first (transitional) phase of the mechanism, which began in October 2023, covers the import into the EU of cement, iron and steel, aluminum, fertilizers, electricity and hydrogen [40]. The lifeline for Ukraine is a mechanism for "green" GDP growth. The development of this mechanism will be possible in Ukraine after the war. It will help to maintain the achieved pace of climate neutrality indicators and increase national competitiveness in the context of European integration [43]. For the energy sector, this means digitalized low-carbon energy with a high share of renewables. The draft National Renewable Energy Development Action Plan until 2030 relies on the fact that increasing the share of renewable sources in the energy balance of Ukraine will contribute to alleviating the CBAM consequences. Considering this, the plan especially emphasizes the urgency of creating a system for issuing guarantees of origin of electricity for exporters (to be exempted from paying the carbon tax, it is necessary to confirm the origin of electricity) [44]. However, this document does not pay due attention to the physical (infrastructural) direction of digitalization of the renewable energy sector, which is based on smart technologies. This omission does not allow to say that the draft National Renewable Energy Development Action Plan until 2030 is fully in line with the European trend of the twin transition, which is referred to in the EU Digital Energy Plan. Ideally, smart grid technologies and guarantees of origin form a single digital mechanism for adapting Ukraine to the climate and energy policy of the EU, aimed at ensuring the most favorable conditions for the export of products for Ukraine and stimulating the inflow of foreign investments.

In context of the interconnection of digitalization and decarbonization, another significant point emerges. The United Nations Economic Commission for Europe identifies two main scenarios for the development of the Ukrainian energy system – the reference scenario and the carbon neutrality scenario.

The reference scenario involves small investment needs in power generation sector, because existing power plants (based on fossil fuel) have enough reserves to cover electricity demand in the economy (Fig. 1.1) [45].

Digital modernization of the outdated energy complex is possible and can help solve the priority problems associated with war and post-war reconstruction. An example is the digital mine projects that have already been implemented in Ukraine. Digital mines are equipped with underground Wi-Fi technology, and miners use smart lamps to monitor methane content and sensors to monitor their condition. Early disabling of existing energy infrastructure, including coal-fired power units, due to hostilities is a serious threat to energy security, at least in the short and medium term. Therefore, the primary task is to restore damaged energy facilities that can still be restored.

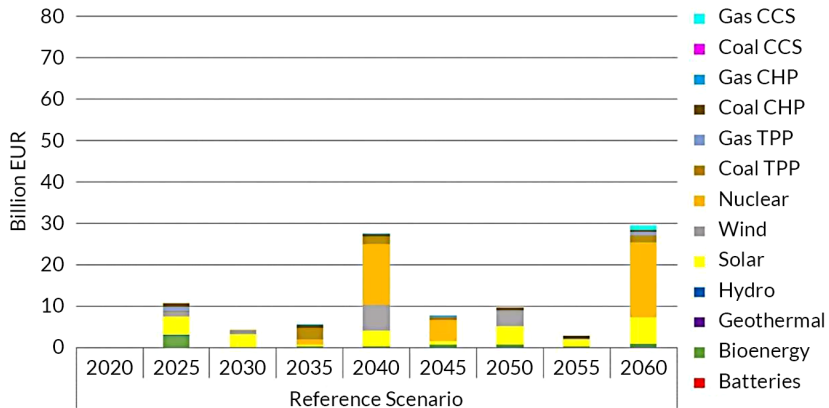


Fig. 1.1 Investment needs in power generation sector in the reference scenario

Source: [45]

On the other hand, digital modernization of outdated energy facilities is unpromising, restrictive and unprofitable from the perspective of future trade relations with the EU. The devastating consequences of the war also create prerequisites for an accelerated transition to efficient energy generation technologies that meet the long-term goals of building a low-carbon economy. This includes both the construction of new renewable energy facilities and the modernization of existing infrastructure (for example, the conversion of thermal power plants to use solid biofuels). According to the carbon neutrality scenario, much more investment is required in the clean power capacity, including wind (around 100 billion EUR)

and about the same amount of investments in total for solar, bioenergy and nuclear power plants (Fig. 1.2) [45].

Ukraine's updated Nationally Determined Contribution to the Paris Agreement also stipulates that the main share of investments in the period from 2021 to 2030 should be directed to the construction of 15 GW new wind, solar and bioenergy capacities, as well as to increase the use of biomass by boiler houses and combined heat and power plants [46]. In this case, digitalization is focused on the prospect of building mutually beneficial trade relations with the EU and increasing the competitiveness of Ukrainian exports.

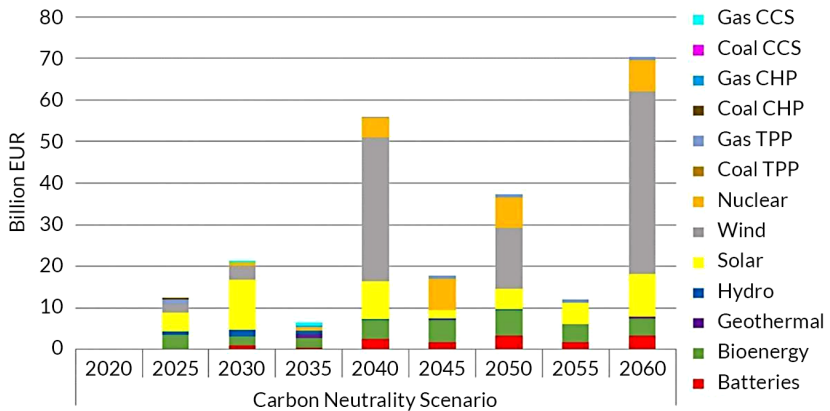


Fig. 1.2 Investment needs in power generation sector in the carbon neutrality scenario
Source: [45]

Complete ecological modernization of existing thermal power plants, which is impossible without modern digital solutions, is not the best option either. According to the model of the Finnish company Wärtsilä Energy, the scenario of ecological modernization of Ukrainian thermal power plants with the aim of achieving national goals for reducing emissions in the next 8 years (until 2031) will cost Ukraine 5.2 billion EUR more than the scenario of gradual decommissioning of thermal generation [47]. Again, this solution has no long-term prospects for increasing the competitiveness of Ukrainian electricity on the market of EU countries and essentially brings the "green" energy transition to a dead end, with all the negative consequences for international trade. Ultimately, in the context of foreign economic advantages, any "coal scenario" (low-cost scenario or high-cost scenario in the case of a complete ecological modernization) is inferior to the carbon neutrality scenario, which involves

a combination of digital solutions with the transition to renewable energy sources. This position is fully in line with the Energy Strategy's goal of maximum reduction of coal use in the energy sector.

The next angle is related to the impact of digitalization in the energy sector on the investment climate. The first and obvious outcome of the deployment of digital infrastructure and the introduction of guarantees of origin is an improvement in the sectoral investment climate. In particular, the presence of sound government policy and support for smart grids, as well as the introduction of guarantees of origin similar to European ones, is a big step towards foreign investors. It is important that Ukrainian guarantees of origin are recognized in EU countries. This will ensure real progress towards an attractive and stable investment climate in the energy sphere required by the Association Agreement. Therefore, the Ukrainian system of issuing guarantees of origin should be connected to the European hub of the Association of Issuing Bodies and to the regional register of guarantees of origin of the Energy Community (in case of its creation) [44]. In addition, the international financial system will soon move only to investing in renewable energy projects. Investors are abandoning investments in fossil fuels and redistributing them to low-carbon technologies, which increases the cost of capital for the construction of carbon-intensive facilities. Thus, investments in renewable energy in Ukraine have a more favorable cost compared to the investments required for renewal capacities on fossil energy sources [46].

Another outcome of digital transition in the energy sector is a positive impact on the investment climate in general. Actually, an increasing number of companies choose development strategies focused on social responsibility and environmental protection. As a result, these consumers are interested in buying electricity produced from renewable energy sources, with the necessary legal confirmation. It is known that most of the world's largest companies (Google LLC, Microsoft Corporation, Intel Corporation, Apple Inc., Voya Financial, Starbucks, IKEA and others) announce their goals for reducing emissions and ensuring 100 % consumption of "green" electricity. Hence, the operation of the national system of guarantees of origin is an important condition for international companies to enter Ukrainian markets [48]. In addition, the legislation needs to establish specific ways of taking into account guarantees of origin to reduce environmental taxes and sell electricity under direct power purchase agreements between producers and final consumers of energy (corporate PPAs) [44].

The last angle concerns national interests and the European integration course of Ukraine. The irreversibility of Ukraine's European course is enshrined in the preamble of the Constitution. The Law of Ukraine "On the National Security of Ukraine" stipulates that the integration of Ukraine into the European political, economic,

security, legal space, the acquisition of membership in the EU is a fundamental national interest of Ukraine. Thus, the use of digital instruments and technologies in the energy sector to ensure economic and other integration with the EU is fully in the national interests of Ukraine. However, even if to abstract from the European integration aspirations purely theoretically, the digital transformation of the energy sector remains the focus of primary national interests and foreign economic policy. The main problem is fossil fuels, the import of which costs huge sums of money and leaves the country in a dependent and vulnerable position. Before the full-scale invasion of Russia, imported gas accounted for about 30 % of total natural gas consumption in Ukraine [44]. Moreover, the high dependence of the Ukrainian energy market on the import of Russian and Belarusian oil products remained [1]. The development of renewable energy through the twin transition (digital and "green") contributes to the strengthening of the country's energy independence and sovereignty.

1.6 Conclusions

As the analysis of various national strategic documents shows, the Ukrainian strategy for digitalization of the energy sector is just beginning to take shape. At present, the only state document claiming a comprehensive vision of the digitalization of energy infrastructure is the Concept of Smart Grids. At the same time, this concept contains essential gaps and requires improvement. In particular, this concept lacks the structural elements established by the Law of Ukraine "On Energy Efficiency" (the roadmap for the implementation of smart grids, assessment of the need for funds and amounts of funding, overview of smart grid technologies in the world, etc.). Many other strategic documents provide only a general or extremely narrow view of digitization in this area and are poorly coordinated. In this regard, an integrated approach seems to be the most optimal and promising, because it implies the preparation of a single (comprehensive) roadmap for the digital transformation of the energy sector instead of several separate roadmaps.

In the context of developing new and improving existing approaches, it is important to focus on the provisions of the EU Digital Energy Plan. This plan concentrates on fostering investments in digital electricity infrastructure and admits the creation of a comprehensive regulatory framework to incentivize digitalization and attract investment.

Building a smarter energy system requires reducing the gap between the pace of progress in digital energy technologies and the improvement of energy legislation. Currently, the development of smart grid technologies is mainly limited to

the framework of legislation on energy efficiency. The Law of Ukraine "On Energy Efficiency" contains the concepts of "smart grids", "smart metering system", "smart meter", establishes a mechanism to encourage the deployment of smart grids and a recommended list of structural elements of the Concept for the Implementation of Smart Grids in Ukraine and the medium-term Action plan. Unlike this law, the Law of Ukraine "On the Electricity Market" does not contain provisions on smart grids, with the exception of energy storage. There is no reason to believe that this approach is justified, as it does not involve the instrumental opportunities of the electricity market and other important areas of legal regulation. In EU law, the focus of smart grid regulation has shifted towards electricity market legislation (the Directive (EU) 2019/944). The Directive 2012/27/EU on energy efficiency partially covers the implementation of the intelligent metering system. Based on EU law, the main tasks of the National Commission, which carries out state regulation in the spheres of energy and communal services should include monitoring and assessing the performance of transmission system operators and distribution system operators in relation to the development of a smart grid.

A reason for optimism is the positive changes emerging in the legal framework for issuing guarantees of origin of electricity produced from renewable energy sources. The Law on Green Transformation established the basic rules for issuing, circulation and repayment of guarantees of origin, but these rules need to be specified at the sub-legal level. Compared to a single function approach of the Directive (EU) 2018/2001, this law defines a triple function of the guarantee of origin (confirmation of the production of a certain amount of electricity from renewable energy sources; confirmation of the environmental value of electricity; certification of rights related to the positive effect of electricity production from renewable energy sources). The problem is that these differences can create additional obstacles to the recognition of Ukrainian guarantees of origin by EU countries.

Finally, it can be argued that foreign economic policy will be increasingly affected by the twin transition, namely the simultaneous movement towards a more intelligent and climate-neutral energy system. This question has three main facets.

Firstly, there is a complex relationship between digitalization and decarbonization, which is clearly visible in the example of the CBAM. The EU refers to the fact that the CBAM is a special tool to put a fair price on the carbon emitted during the production of carbon intensive goods that are entering the EU, and to encourage cleaner industrial production in non-EU countries. Hence, this instrument of the EU climate policy is a serious challenge for all EU trading partners with a high percentage of carbon-intensive exports. The Ukrainian electricity sector, with its still weak "green" segment and high dependence on fossil fuels, is at particular risk.

Therefore, an adequate response to this challenge is to choose the carbon neutrality scenario for the development of the energy system with a comprehensive digital transformation of the energy infrastructure.

Secondly, digitalization affects not only the sectoral (within the energy sector), but also the overall investment climate of the country. Many companies (especially global brands) are already refusing to consume electricity of unknown origin, which requires establishing the digital mechanism for issuing guarantees of its origin from renewable sources.

Thirdly, digitalization of the energy industry in parallel with its "green" transition corresponds to the national interests of Ukraine not only from the standpoint of multi-vector European integration and joining the EU climate goals. Smart renewable energy is a powerful means of reducing the country's dependence on large suppliers of traditional energy resources.

Acknowledgment

This chapter was prepared within the research project "Digital Transformation as a New Paradigm of Ukraine's Foreign Economic Policy", which is being implemented in accordance with the NAS program "Grants of the NAS of Ukraine for Research Laboratories/Groups of Young Scientists of Ukraine to Conduct Research on Priority Directions of Science and Technology Development in 2022–2023" (No. 0122U002352).

References

1. The draft Ukraine Recovery Plan (2022). The National Council for the Recovery of Ukraine from the Consequences of the War. The "Energy security" working group. Available at: <https://www.kmu.gov.ua/storage/app/sites/1/recoveryrada/eng/justice-eng.pdf>
2. Mitigation of Climate Change (2022). Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Available at: <https://www.ipcc.ch/report/ar6/wg3/>
3. Rafaël, C., Tancrede, P. (2020). CO2 Emissions Embodied in International Trade. Banque de France Bulletin, No. 228, Art. 1. Available at: <https://publications.banque-france.fr/en/co2-emissions-embodied-international-trade>
4. Fouquet, R., Hippe, R. (2022). Twin transitions of decarbonisation and digitalisation: A historical perspective on energy and information in European

- economies. *Energy Research & Social Science*, 91, 102736. <https://doi.org/10.1016/j.erss.2022.102736>
5. Hack, T., Ma, Z., Jørgensen, B. N. (2021). Digitalisation potentials in the electricity ecosystem: lesson learnt from the comparison between Germany and Denmark. *Energy Informatics*, 4 (S2). <https://doi.org/10.1186/s42162-021-00168-2>
 6. Küfeoğlu, S., Liu, G., Anaya, K., Pollitt, M. (2019). Digitalisation and new business models in energy sector. EPRG Working Paper. Available at: <https://www.econ.cam.ac.uk/research-files/repec/cam/pdf/cwpe1956.pdf>
 7. Singh, G. (2023). Artificial Intelligence in sustainable energy industry: Status quo, challenges, and opportunities. *EPRA International Journal of Multidisciplinary Research*, 9 (5), 234–237. <https://doi.org/10.36713/epra13323>
 8. Clifton, A., Barber, S., Bray, A., Enevoldsen, P., Fields, J., Sempreviva, A. M. et al. (2023). Grand challenges in the digitalisation of wind energy. *Wind Energy Science*, 8 (6), 947–974. <https://doi.org/10.5194/wes-8-947-2023>
 9. Kangas, H. L., Ollikka, K., Ahola, J., Kim, Y. (2021). Digitalisation in wind and solar power technologies. *Renewable and Sustainable Energy Reviews*, 150, 111356. <https://doi.org/10.1016/j.rser.2021.111356>
 10. Omitaomu, O. A., Niu, H. (2021). Artificial Intelligence Techniques in Smart Grid: A Survey. *Smart Cities*, 4 (2), 548–568. <https://doi.org/10.3390/smart-cities4020029>
 11. Dileep, G. (2020). A survey on smart grid technologies and applications. *Renewable Energy*, 146, 2589–2625. <https://doi.org/10.1016/j.renene.2019.08.092>
 12. Kucherkova, S., Matvienko, G. (2023). State support and regulatory measures for the development of artificial intelligence in the energy sector of Ukraine. *Acta Academiae Beregsasiensis. Economics*, 3, 215–226. <https://doi.org/10.58423/2786-6742/2023-3-215-226>
 13. Chambers, J., Robinson, C., Scott, M. (2022). Digitalisation without detriment: A research agenda for digital inclusion in the future energy system. *People, Place and Policy Online*, 16 (2), 177–192. <https://doi.org/10.3351/ppp.2022.5254227477>
 14. Sareen, S. (2021). Digitalisation and social inclusion in multi-scalar smart energy transitions. *Energy Research & Social Science*, 81, 102251. <https://doi.org/10.1016/j.erss.2021.102251>
 15. Wang, Y., Wang, Y., Shahbaz, M. (2023). How does digital economy affect energy poverty? Analysis from the global perspective. *Energy*, 282, 128692. <https://doi.org/10.1016/j.energy.2023.128692>
 16. Hillerbrand, R., Milchram, C., Schippl, J. (2021). Using the Capability Approach as a normative perspective on energy justice: Insights from two case studies on

- digitalisation in the energy sector. *Journal of Human Development and Capabilities*, 22 (2), 336–359. <https://doi.org/10.1080/19452829.2021.1901672>
17. Gabro, I. V., Shevchuk, O. V. (2022). TEU environmental diplomacy tools. *Actual problems of politics*, 69, 108–115. <https://doi.org/10.32837/app.v0i69.1310>
 18. Mehling, M. A., Ritz, R. A. (2023). From theory to practice: determining emissions in traded goods under a border carbon adjustment. *Oxford Review of Economic Policy*, 39 (1), 123–133. <https://doi.org/10.1093/oxrep/grac043>
 19. Cosbey, A., Droegge, S., Fischer, C., Munnings, C. (2019). Developing Guidance for Implementing Border Carbon Adjustments: Lessons, Cautions, and Research Needs from the Literature. *Review of Environmental Economics and Policy*, 13 (1), 3–22. <https://doi.org/10.1093/reep/reyp020>
 20. Jakob, M. (2023). The political economy of carbon border adjustment in the EU. *Oxford Review of Economic Policy*, 39 (1), 134–146. <https://doi.org/10.1093/oxrep/grac044>
 21. Energy strategy (2022). The Ministry of Energy of Ukraine. Available at: <https://www.mev.gov.ua/reforma/enerhetychna-stratehiya>
 22. Future strategy: Ukraine is an energy hub that will help Europe get rid of dependence on Russia (2023). The Ministry of Energy of Ukraine. Available at: <https://www.kmu.gov.ua/news/stratehiia-maibutnoho-ukraina-tse-enerhetychnyi-khab-iakyi-dopomozhe-ievropi-pozbutysia-zalezhnosti-vid-rosii>
 23. Nguyen, T. N., Liu, B.-H., Nguyen, N. P., Chou, J.-T. (2020). Cyber Security of Smart Grid: Attacks and Defenses. ICC 2020 – 2020 IEEE International Conference on Communications (ICC). Dublin. <https://doi.org/10.1109/icc40277.2020.9148850>
 24. Cybersecurity of the energy sector. The Ministry of Energy of Ukraine. Available at: <https://www.mev.gov.ua/storinka/kiberbezpeka-enerhetychnoyi-haluzi>
 25. Ahmad, T., Zhang, D., Huang, C., Zhang, H., Dai, N., Song, Y., Chen, H. (2021). Artificial intelligence in sustainable energy industry: Status Quo, challenges and opportunities. *Journal of Cleaner Production*, 289, 125834. <https://doi.org/10.1016/j.jclepro.2021.125834>
 26. Sukhodolia, O. M. (2022). *Shtuchnyi intelekt v enerhetytsi*. Kyiv: NISD, 49. <https://doi.org/10.53679/niss-analytrep.2022.09>
 27. The Bletchley Declaration by Countries Attending the AI Safety Summit (2023). Available at: <https://www.gov.uk/government/publications/ai-safety-summit-2023-the-bletchley-declaration/the-bletchley-declaration-by-countries-attending-the-ai-safety-summit-1-2-november-2023>
 28. Explained. What is Bletchley Declaration? Yearbook Web Desk... (2023). Available at: <https://www.onmanorama.com/news/world/2023/11/03/bletchley-declaration-explained.html>

29. Questions and Answers: EU action plan on digitalising the energy system (2022). European Commission. Available at: https://ec.europa.eu/commission/press-corner/detail/en/qanda_22_6229
30. European Technology Platforms (2017). European Parliament. Available at: [https://www.europarl.europa.eu/RegData/etudes/ATAG/2017/603935/EPRS_ATA\(2017\)603935_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/ATAG/2017/603935/EPRS_ATA(2017)603935_EN.pdf)
31. European SmartGrids Technology Platform – Vision and strategy for Europe's electricity networks of the future (2006). Publications Office. Available at: <https://op.europa.eu/en/publication-detail/-/publication/a2ea8d86-7216-444d-8ef5-2d789fa890fc/language-en>
32. Timchenko, O., Nebrat, V., Liehr, V., Bykonja, O., Dubas, Y. (2019). Organizational and economic determinants of digital energy development in Ukraine. *Ekonomika i Prognozuvannâ*, 2019 (3), 78–100. <https://doi.org/10.15407/eip2019.03.078>
33. Osyka, D. (2021). Tsyfrovizatsiia yak zaporuka staloho rozvytku enerhetychnoi haluzi. *Interfax-Ukraine*. Available at: <https://interfax.com.ua/news/blog/757318.html>
34. Majeed Butt, O., Zulqarnain, M., Majeed Butt, T. (2021). Recent advancement in smart grid technology: Future prospects in the electrical power network. *Ain Shams Engineering Journal*, 12 (1), 687–695. <https://doi.org/10.1016/j.asej.2020.05.004>
35. Hryb, O., Senderovich, G., Diachenko, O., Karpaliuk, I., Shvets, S. (2020). Analysis of digital energy development prospects in Ukraine. *Bulletin of the National Technical University "KhPI". Series: Hydraulic machines and hydraulic units*, 1, 85–90.
36. Leal-Arcas, R., Lasniewska, F., Proedrou, F. (2017). Smart grids in the European Union: Assessing energy security, regulation & social and ethical considerations. *Columbia Journal of European Law*, 24, 291. Available at: <https://heinonline.org/HOL/LandingPage?handle=hein.journals/coljeul24&div=13&id=&page>
37. European Green Deal: Energy Efficiency Directive adopted, helping make the EU 'Fit for 55' (2023). European Commission. Available at: https://energy.ec.europa.eu/news/european-green-deal-energy-efficiency-directive-adopted-helping-make-eu-fit-55-2023-07-25_en
38. Directive of the European Parliament and of the Council on energy efficiency and amending Regulation (EU) 2023/955 (recast) (2023). *EUR-Lex*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CONSIL%3APE_15_2023_INIT&qid=1691999531020
39. Rossetto, N., Reif, V. (2021). Digitalization of the electricity infrastructure: a key enabler for the decarbonization and decentralization of the power sector.

- Robert Schuman Centre for Advanced Studies Research Paper No. RSCAS 2021/47. <https://doi.org/10.2139/ssrn.3831154>
40. Carbon Border Adjustment Mechanism (EU). Taxation and Customs Union. Available at: https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en
 41. Lim, B., Hong, K., Yoon, J., Chang, J.-I., Cheong, I. (2021). Pitfalls of the EU's Carbon Border Adjustment Mechanism. *Energies*, 14 (21), 7303. <https://doi.org/10.3390/en14217303>
 42. Carbon Border Adjustment Mechanism. UNDP. Available at: https://www.undp.org/sites/g/files/zskgke326/files/2022-08/1%20FINAL%20Tree%20cbam_297x210mm_4%2B4_web_180822.pdf
 43. Maksymova, I. (2023). Digitalization-based integration of climate policies of Ukraine and the EU. *Journal of European Economy*, 22(1), 94–110. <https://doi.org/10.35774/jee2023.01.093>
 44. The draft National Renewable Energy Development Action Plan until 2030 (2022). The State Agency for Energy Efficiency and Energy Saving of Ukraine. Available at: https://sae.gov.ua/sites/default/files/DraftNPDVE_2030_SAE_21_09_2022.pdf
 45. Rebuilding Ukraine with a Resilient, Carbon-Neutral Energy System (2023). UNECE. Geneva. Available at: https://unece.org/sites/default/files/2023-07/EN_Rebuilding%20Ukraine%20with%20a%20Resilient%20Carbon-Neutral%20Energy%20System_V8.pdf
 46. Analitichnyi Ohliad Onovlenoho Natsionalno Vyznachenoho Vnesku Ukrainy do Paryzkoi Uhody (2021). The Ministry of Environmental Protection and Natural Resources of Ukraine. Available at: <https://mepr.gov.ua/wp-content/uploads/2023/07/Analitichnyj-oglyad-NVV-lypen-2021.pdf>
 47. Modernizatsiia TES koshtuvatyme Ukraini do 2031 r. na EUR5,2 mlrd dorozhche za yikh vyvedennia – Wärtsilä Energy. Interfax – Ukraine. Available at: <https://interfax.com.ua/news/greendael/750972.html>
 48. Kachan, S. (2022). Harantii pokhodzhennia elektroenerhii: Chy potribni vony v Ukraini? Available at: <https://expro.com.ua/statti/garant-pohodjennya-elektroenerg-chi-potrbn-voni-v-ukrani>