TRANSFORMATIONS OF NATIONAL ECONOMIES UNDER CONDITIONS OF INSTABILITY

Collective monograph

Edited by
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ABSTRACT

The monograph "**Transformation of National Economies in Conditions of Instability**" is dedicated to theoretical-methodological and practical approaches to addressing diverse and pressing challenges faced by key sectors of national economies under risks and threats of various scales and natures. The authors present innovative approaches and unique solutions for transforming the development of structural elements within socio-economic systems, with a particular focus on implementing advanced international experience and standards in the context of modern trends in the global economy. The book consists of nine chapters, each exploring significant aspects of current development challenges and offering forward-looking solutions of strategic importance.

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

This section of the monograph examines relevant and significant issues regarding the further development of Ukraine's energy system within the legal framework and considering long-term strategic development priorities. The authors analyze the achievements and shortcomings of the national strategy for the digital transformation of the energy sector, with particular emphasis on the Concept for the Implementation of Smart Grids until 2035. An in-depth analysis of gaps in the legislative framework is presented, and pathways to address them are proposed within the context of a unified roadmap for digital transformation. The focus is placed on the implementation of smart grid technologies and electronic guarantees of origin for electricity generated from renewable energy sources as key tools for adapting to EU policies and achieving European integration goals. The proposed solutions aim to stimulate investment inflow, improve the investment climate, and reduce Ukraine's dependence on fossil fuels.

Formation of employer's image for representatives of Generation Z in the retail sector in conditions of instability.

The study highlights the necessity of adapting employer branding strategies to the behavioral characteristics and expectations of Generation Z. On a macro level, this adaptation influences the competitiveness of the retail sector by improving workforce stability and reducing staff turnover. On a micro level, it facilitates the creation of a unique employer brand, enhances corporate culture, and increases employee satisfaction. The authors propose a systematic approach comprising three stages: analysis of the current situation, development of the desired employer brand image, and implementation of the strategy through updates to the brand book, communication tools, and value propositions. The study emphasizes the importance of

digital communication platforms (such as Instagram, TikTok, LinkedIn, etc.) and personalized offerings, which are particularly relevant for Generation Z.

Synergy of digital technologies and green development and their impact on achieving a sustainable environment in the conditions of instability.

The study focuses on an in-depth assessment of the role and significance of digital technologies in advancing the strategy of sustainable green development. Particular attention is paid to the impact of digitalization on improving energy efficiency, reducing emissions, and implementing circular economy models. The authors analyze positive international practices, including the use of sensor networks and IoT systems for resource monitoring, waste management, and energy consumption optimization. Examples of successful solutions, such as smart cities and digital carbon credit markets, are provided. The authors propose theoretical models and practical recommendations for integrating digital technologies into green management strategies, which is particularly critical in the context of instability caused by climate change and economic challenges.

Project management within the national economy in turbulent conditions.

This section of the monograph addresses the implementation of project management at the macro level, highlighting it as a key element in ensuring the resilience of Ukraine's national economy during times of crisis. Particular attention is given to the establishment of clusters, specifically "agriculture – food industry", in the context of their role and significance in stimulating effective regional development. Methodological approaches for developing project management standards and strategies, including the use of the PMBOK framework, are proposed. Practical solutions are offered to support small and medium-sized enterprises, create conditions for business clustering, and overcome economic instability through innovative state projects with practical applicability.

Universities as regional leaders for sustainable energy and climate EU-harmonized policies.

The study is dedicated to an in-depth examination of the role of universities in implementing sustainable energy and climate policies harmonized with European Union standards. Using the example of a tri-directional strategy piloted at the Ivano-Frankivsk National Technical University of Oil and Gas, the research demonstrates the integration of a demonstration solar power plant, the development of an information and measurement system for monitoring energy consumption and indoor climate, and institutional efforts embodied in the university's Sustainable Energy and Climate Action Plan. The authors emphasize the importance of integrating universities into regional projects aimed at reducing carbon footprints and improving energy efficiency, showcasing this as an example of successful harmonization of national policies with the strategic objectives of the EU.

Digital transformation of the national economy in the context of information environment development in Ukraine.

This section of the monograph examines trends in the digital transformation of economic systems in the EU and Ukraine, focusing on the evolving information environment. The "technological-singularity" development vector is identified as the conceptual foundation for digital transformation, emphasizing the increasing importance of information as a key productive resource. Digitalization is shown to be essential for global competitiveness and stability, requiring investment in ICT, infrastructure, and innovations as drivers of growth. Analysis of Ukraine's gross value-added formation highlights the growing role of digital transformation sectors, particularly information and telecommunications, while demonstrating the digital sector's role in reducing the shadow economy and corruption risks. The importance of information security in the digital economy is also emphasized. The study explores Ukraine's digital transformation prospects amid growing cyber risks. A comprehensive approach integrating economic, informational, and security elements is crucial for minimizing risks and ensuring stability. This strategy enhances economic resilience and strengthens Ukraine's global competitiveness, where adherence to high cybersecurity standards is key for integration into international digital markets.

Information and digital technology trends in the green economy.

This section explores current trends in the development of information and digital technologies within the context of the "green" economy. The authors focus on the digital transition toward a more environmentally friendly future, prioritizing sustainable development through resource optimization, waste reduction, and recycling. The practical significance of the research is demonstrated through innovative green technology clusters, trends in the development of digital technologies in the green economy, and a specific example of the impact of digital technologies on energy efficiency in Ukraine during wartime. The authors propose methodological and practical recommendations for transitioning to digital green solutions, including the identification, short-listing, and justification of trends in the development of the green economy architecture and Sustainable Development Goals (SDGs) in Ukraine.

A decision-making system for managing the remediation of water resources in the Kherson region: agent-oriented modeling in the context of post-war economic recovery.

This section focuses on innovative approaches to managing the remediation of water resources to support the rapid and effective post-war recovery of the Kherson region's economy. The authors present an agent-oriented model for managing the remediation of water resources in the Kherson region, heavily impacted by the destruction of the Kakhovka Hydroelectric Power Plant. The study highlights the

importance of integrating GIS, artificial intelligence, machine learning, and the Agile methodology to enhance the efficiency of recovery processes in war-affected areas. Innovative informational and technological solutions are proposed to minimize the time and resources required for ecological remediation, ensure access to clean water, and restore agricultural development. Particular attention is given to establishing a transparent management system that facilitates effective coordination and communication among all key stakeholders, including central government authorities, local administrations, international partners, business entities, and contractors.

Corporate governance under economy transformation and geopolitical uncertainty: case of Ukraine.

This section examines changes in corporate governance in Ukraine, both in private and state-owned enterprises. The authors focus on issues related to the reform of state-owned companies, the implementation of ESG principles, and the enhancement of transparency. The study emphasizes the adaptation of companies to crisis conditions, the integration of international standards such as OECD principles, and the introduction of ESG-oriented executive compensation. Examples of successful international practices that can be adapted for Ukraine are provided. The proposed measures aim to strengthen investor trust, improve corporate resilience, and support national recovery through transparent and responsible governance.

Keywords

Digitalization, strategy, decarbonization, climate policy, smart grids, guarantees of origin, energy efficiency, renewable energy sources, Carbon Border Adjustment Mechanism, investments, foreign economic policy, employer brand, vacancy, employees, employment, value proposition, brand positioning, Generation Z, retail, digital technologies, sustainable development, green management, international practices, environmental impact, RE100 Initiative, CO^2 emissions, project management, macro-level management, industrial districts, turbulent conditions, university leadership, energy management system, energy monitoring, climate action, digital economy, information asymmetry, information security, IT sector, shadow economy, corruption risks, green economy, trends, sustainable development goals (SDG), Agent-Oriented Modelling (AOM), remediation, water resources, Agile approach, Geographic Information Systems (GIS), Artificial Intelligence (AI), Machine Learning (ML), post-war recovery, management system, agricultural business, ecosystem, economic benefit, corporate governance, instability, geopolitics, Ukraine's economy transition, economy transformation, ESG-based remuneration, SOE governance reform, OECD principles, board independence, investor trust, capital raising, EU CSRD, sustainability metrics, executive compensation, governance structures, corporate resilience.

CIRCLE OF READERS AND SCOPE OF APPLICATION

The collective monograph "**Transformation of National Economies in Conditions of Instability**" is a valuable resource designed to engage scientists across various fields of study, specialists from key sectors of the national economy, practitioners in management, public policy, digital technologies, and sustainable development. It addresses those seeking to implement innovative approaches, advanced technologies, and original solutions to strengthen the national economy, enhance its resilience, and adapt to turbulent conditions and escalating risks and threats of various nature and scale.

Scope of application of the research findings presented in the monograph includes:

Digital transformation of the energy sector: The research findings on implementing smart grids, digital guarantees, and decarbonization technologies will be useful for policymakers, top management of energy companies, and investors. These approaches aim to enhance energy efficiency, reduce carbon emissions, and align Ukraine's energy system with EU standards.

Employer brand formation: Proposed strategies for creating an employer brand for Generation Z can be utilized by companies in the retail and other national economic sectors to attract and retain young talent. Practical recommendations include updating communication strategies, adapting working conditions, developing corporate culture, and integrating modern digital communication tools.

Synergy of digital technologies and green development: The research appeals to representatives of government agencies at all levels, relevant ministries and departments, economists, and financiers seeking optimal solutions for improving resource efficiency, reducing waste, and managing emissions using information technologies and IoT. Practical value lies in proposed solutions for smart cities, waste management, and supporting the development of strategically significant sectors of the national economy.

Macro-level project management: Proposed approaches to cluster formation and innovative macro projects, such as "agriculture – food industry," can be valuable for government bodies and businesses to stimulate regional development and economic sustainability.

Role of universities in sustainable development: Case studies demonstrate how universities can lead in implementing environmentally-oriented initiatives, including the adoption of renewable energy sources and energy management systems. This is relevant for educational and research institutions aiming to become integral elements of European integration processes.

Corporate governance and ESG: The research helps companies adapt governance models and integrate ESG principles, which are particularly important for enhancing transparency, building investor trust, and aligning with international standards. It offers practical insights for managers and top executives in increasing investment attractiveness and competitiveness on the global stage.

The monograph serves as both an intellectual inspiration and a practical tool for developing strategies aimed at long-term sustainable development under conditions of instability. It combines theoretical research with practical solutions, making it valuable for various economic sectors.

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INTRODUCTION

Focus on the transformation of economic systems in conditions of instability

Tetiana Cherniavska

The modern socio-economic system is under unprecedented pressure due to the growing number of global risks and threats of varying nature and scale, including climate change, geopolitical instability, digital transformation, and an increasing frequency of social, economic, and environmental crises. These challenges necessitate radically new approaches that enable swift responses, effective adaptation, and the optimal use of available resources and successful international practices to ensure stable and sustainable development. The monograph "**Transformation of National Economies in Conditions of Instability**" is dedicated to a comprehensive analysis of these issues and offers progressive and unconventional solutions aimed at driving structural changes and adaptation in key sectors of the socio-economic system.

The authors thoroughly examine contemporary trends in the development of strategically significant industries and activities as "growth points" and "pillars" of national economies. Special attention is devoted to the adoption of digital technologies, advanced sustainable management tools, the implementation of international principles, macro- and micro-level project management, and leveraging international experience as benchmarks to enhance the resilience of national economies. The monograph comprises nine chapters, each focused on strategically important aspects, including the digital transformation of the energy sector, employer branding strategies for Generation Z, the synergy of digital technologies and green development, remediation, and innovative approaches to resource management in post-war recovery conditions.

The transdisciplinary approach adopted in the monograph underscores the importance of international experience and standards, such as those of the OECD and ESG, which strengthen integration with the global economic framework. The role of universities as centers for generating and testing innovative solutions, along with the implementation of cluster initiatives, highlights the potential of collaboration between science, business, and government. This integration creates a platform

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for dialogue among stakeholders, laying the foundation for long-term sustainable development, improving investment attractiveness, and enhancing the competitive positioning of nations on the global stage.

The aforementioned focus not only facilitates the development of effective crisis management strategies but also ensures the long-term sustainable development of national economies, aligning them with contemporary challenges and global trends.

CHAPTER 1

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

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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

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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. Omitaomu 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. Kucherkova 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 9^7 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.

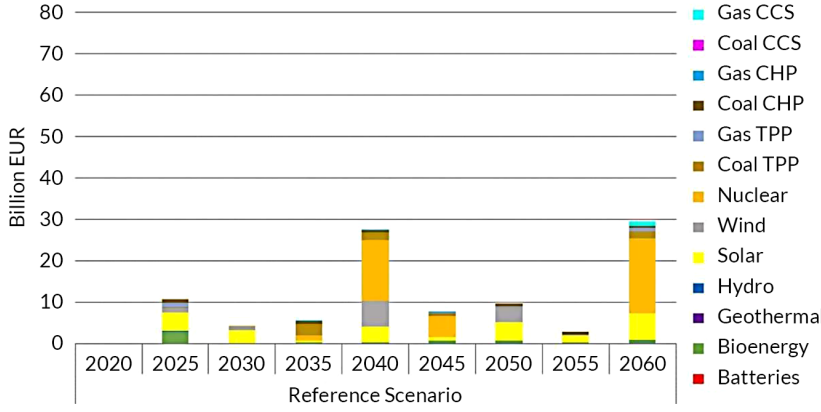

Fig. 1.1 Investment needs in power generation sector in the reference scenario
Source: [45]

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.

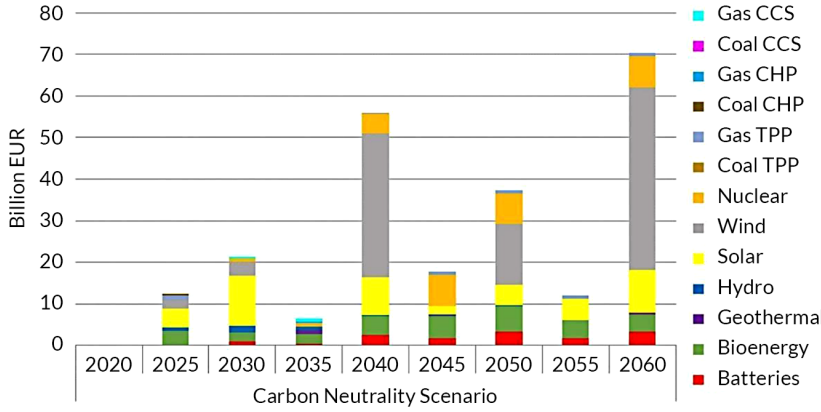

Fig. 1.2 Investment needs in power generation sector in the carbon neutrality scenario
Source: [45]

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

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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., Tancrède, 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. Küfeoglu, 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/smartcities4020029
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., Droege, 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/rey020
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/presscorner/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
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., Bykonia, O., Dubas, Y. (2019). Organizational and economic determinants of digital energy development in Ukraine. Ekonomìka ì 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://saee.gov.ua/sites/default/files/DraftNPDVE_2030_SAEE_21_09_2022.pdf
45. Rebuilding Ukraine with a Resilient, Carbon-Neutral Energy System (2023). UN-ECE. Geneva. Available at: https://unece.org/sites/default/files/2023-07/EN_Rebuilding%20Ukraine%20with%20a%20Resilient%20Carbon-Neutral%20Energy%20System_V8.pdf
46. Analitychnyi 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/Analitychnyj-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/greendeal/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

CHAPTER 2

Formation of employer's image for representatives of Generation Z in the retail sector in conditions of instability

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Abstract

Employer brand is considered as an image that a company builds to attract and retain talented staff and due to which it is known and valued in the labor market by job candidates. The employer brand is also seen as a part of the corporate brand, and together they create a synergistic effect in the company's activities. Positioning of the employer brand for Generation Z representatives is seen as a strategic process of creating and maintaining a unique and defined image of the company in the eyes of potential and current job seekers, taking into account age, behavioral, professional and economic indicators. The portrait of Generation Z representative as a target audience for the formation of employer brand is defined. A typification of the incentives of employer's value proposition for Generation Z representatives is proposed, namely: are focused on personal development, ensuring the competitiveness of the enterprise, requirements for the corporate culture of the company, the functionality of work and workplace, and material incentives. The process of forming the employer brand for companies in the retail sector which is divided into three main stages is proposed: analysis of the current situation, creation of the image of the desired employer brand, activation of steps to achieve the desired goals and their support. To assess the current state of the employer brand, it is proposed to use the metrics of reducing staff turnover in a certain period, analyzing the reasons for dismissal during the exit interview, converting the number of targeted questionnaires and the

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eNPS methodology. To analyze the eNPS, a list of questions for the survey of retail chain employees has been developed. The employer brand development strategy for Generation Z consists of updating the brand book, communication strategy, and action plan to create the desired employer image among talents. The peculiarity of this strategy is the adaptation of each component to the requirements of the generation of buzzers.

The directions of forming the employer brand development strategy are recruitment, employee experience, and company talent management. For each area, metrics are proposed, the achievement of which determines the level of attractiveness of the employer brand. Indicators of the employer brand development strategy are the increase in the number of candidates for one position, % of employed candidates, reduction in the time to close a vacancy, reduction in the % of dismissed employees, increase in the level of job satisfaction in the company and increase in the number of promoted employees during the first year.

Keywords

Brand, employer brand, vacancy, employees, employment, value proposition, brand positioning, Generation Z, employer brand development strategy, employer brand process, retail.

2.1 Introduction

The forming of employer brand is of great importance in today's market environment, as it affects the way a company attracts and retains attention and interacts with its employees. According to forecasts, by 2030, a deficit between supply and demand in the labor market of 85 million specialists is expected in the world [1]. That is why, in the context of competition for limited resources in the labor market, the issue of creating an attractive employer brand arises. A strong employer brand makes a company more attractive to talented professionals. A positive employer brand also helps to retain the current team and attract new talented professionals. If employees are convinced that they work for a company with a good reputation, they are more likely to stay and invest in their development. Companies with a strong employer brand have a competitive advantage in attracting and retaining the best talent. This is especially important in industries where competition for talented employees is intense.

Students and recent graduates, who are representatives of Generation Z, require special attention when hiring. The younger generation is prioritized for hiring for several reasons, including fresh knowledge and skills, flexibility and adaptability

to new technologies or working methods, long-term job prospects, energy, digital skills, and a high level of use of digital technologies and the Internet. However, young people prioritize their own interests and goals over work, and pay great attention to mental health and financial well-being. As a result, there is the need to develop theoretical and methodological provisions for creating the employer brand that is attractive to young people.

2.2 The essence of the employer brand

The theoretical provisions related to the content of the employer brand, the relationship between the corporate brand and the employer brand, and the general principles of employer brand management have been studied by many scholars, including S. Tsymbaliuk [2], S. Mokina [3], T. Bilorus, S. Firsova [4], L. Stepanova, O. Tuzhylkina [5], O. Khytra [6], T. Vonberg, S. Dmitruk, Y. Zubova [7], O. Dragan, O. Solomka, L. Maznyk [8], C. J. Halvorsen, E. Emmanuel [9], J. Macalik, A. Sulich [10], K. Tanwar, A. Prasad [11] and others. In the conducted studies, almost no attention was paid to the employer brand for students and graduates of educational institutions. The scientific works of L. Löffler, C. Giebe [12], K. Gomez, T. Mawhinney, K. Betts [13], E. Jones [14], E. Seemiler, M. Grace [15] considered the importance of studying Generation Z as a target audience in the labor market. These scientific papers considered the current achievements of Zoomers, their characteristics and role in the future development of companies, taking into account technological innovation changes. However, there is the need in studying approaches to create attractive employer brand for young people, which is the basis for the company's development and increase its competitiveness.

S. Tsymbaliuk [2] considers the employer brand as an emotionally entertaining image of the enterprise that arises in the process of interaction of people with the enterprise and is determined by a set of unique characteristics that distinguish the company from others in the labor market. S. Mokina [3] considers the employer brand as a purposeful set of company qualities that determine the benefits of the company's employment conditions for the target audience. T. Belorus and S. Firsova [4] consider the employer brand as a reputation or image of the company aimed at attracting and retaining qualified employees. L. Stepanova and O. Tuzhylkina [5] define the employer brand as a set of economic, professional and psychological benefits that the employee receives by joining to the enterprise, as well as a way for management to define the identity of its business and communicate it to stakeholders. O. Khytra [6] considers two levels of the employer brand:

the first level, at which the employer brand interacts with the staff brand, and the second level of the set of HR brands of enterprises that have common industry specifics, are united by intra-industry ties and are dependent on the situation in the industry labor market. T. Vonberg, S. Dmytruk and Y. Zubova [7] consider the employer brand to be a reflection of the corporate brand, but in the labor market. They believe that marketing tools and communication policy for brand formation when working with the target audience are similar for the formation of the company's corporate brand and the employer brand. O. Dragan, O. Solomka and L. Maznyk [8], consider the employer brand of food industry enterprises, determine its relationship with corporate social responsibility, financial stability of the company and the company's stability in the market. C. J. Halvorsen and E. Emmanuel [9] consider the employer brand as a level of company reputation that determines the candidate's intention to be employed. J. Macalik and A. Sulich [10] note that the employer brand demonstrates the employee's loyalty to the company, and this is determined, among other things, by the company's involvement in sustainable development, its principles of corporate social responsibility and the level of development of corporate culture. L. Löffler and C. Giebe [12] consider the employer brand as a set of components of its value proposition, corporate culture and the level of competitiveness of the company.

L. Stepanova and O. Tuzhylkina [5], K. Tanwar and A. Prasad [11] and S. Tsymbaliuk [2] define the external and internal context of the employer brand, which differ in purpose, goals, audience, HR management tools, communications and results. The target audience of the external employer brand is potential employees and job seekers, while the internal employer brand is the existing employees.

The internal context of the employer brand is aimed at retaining and developing the company's employees, forming the company's own qualified specialists. It involves monitoring compliance with labor laws, compliance of working conditions and remuneration with the employment contract, transparency and flexibility of the compensation policy, career and professional development, and employment guarantees. The external context of the employer's brand is aimed at creating an attractive image to attract potential candidates for vacancies in accordance with the established requirements.

According to the Rating of The Best Employers in Ukraine 2020–2021 [16], the employer brand includes the company's stability in the market, financial solvency, corporate culture (mission and values), social responsibility, and the attractiveness of goods and services offered by the company.

The employer's brand is formed in the labor market every time a company contacts the candidate: advertising on social media, job descriptions on job search sites,

a conversation with the recruiter, or the employee's feedback on a portal. The clearer the message conveyed by the employer, the more recognizable and competitive the company is.

The employer brand evokes associations among target candidates about the company and the desire to develop a career there. But this image evokes both positive and negative emotions and is constantly compared by candidates with other companies in the labor market.

Summarizing the approaches to defining the employer brand [2–15], the following characteristic features have been identified:

1. A set of characteristics and emotions that are associated with the company's employees and potential candidates and distinguish it from other employers in the labor market.
2. Financial stability of the company.
3. The company's reputation.
4. A list of tangible and intangible incentives aimed at creating a positive image of the company among the target audience.
5. The company's communication policy for recruiting staff.
6. Corporate culture (strategic vision, mission, values).
7. Competitiveness of the company's products and the company as a whole.
8. Social responsibility of the company.
9. Two-level structure: internal (for company employees) and external (for potential candidates).

Thus, the employer brand is seen as the image that a company builds to attract and retain talented staff and through which it is known and valued in the labor market by job candidates. It includes the company's reputation as the employer, work environment, company culture, tangible and intangible employee benefits, and attitude toward staff. The employer brand plays an important role in attracting and retaining talented employees, and influences their commitment and job satisfaction.

The employer brand is a component of the company's brand as a whole and determines its rating in the labor market. It is the part of the corporate culture, as it is aimed not only at external candidates (talent) but also at current employees. Both aspects of the brand, both the company and the employer, can interact with each other, creating a comprehensive image of the company in the eyes of both customers and employees.

The structure of the employer brand formation is shown in **Fig. 2.1**. This determines the existence of the complex and interconnected set of relations that arise at the enterprise in terms of various managerial influences on the employer brand.

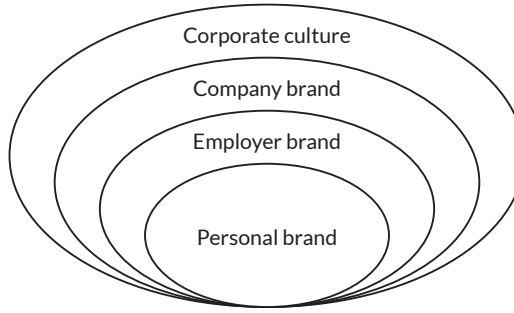

Fig. 2.1 Structural orientation of employer brand formation
Source: constructed by the authors

At the lowest level, let's consider the personal attitude of each employee to the employer brand, which is determined by his or her ethical position, the way he or she behaves and treats the company. Group behavior and the underlying organizational culture also influence the formation of the employer brand. In general, the employer brand is subordinated to the identity of the enterprise in the market of goods and services.

2.3 Employer brand content for Generation Z

To create the employer brand to attract Generation Z, it is necessary to understand the target audience. According to the Employer Branding Strategy 2021 study by Blu Ivy Group, 20 % of employees are Generation Z [14]. This is the largest and most attractive part of the labor market, as this generation is the future of the nation's development in each country. In addition, the share of Generation Z in the global labor market is increasing. Accordingly, employers should adapt their employer brand to the requirements of the new generation of candidates.

K. Gomez, T. Mawhinney and K. Betts [13] consider Generation Z as people who were born between 1995 and 2012, E. Jones [14] considers this generation between 1996 and 2015.

K. Gomez, T. Mawhinney and K. Betts [13] note that in order to attract the attention of Generation Z, companies and employers need to demonstrate their commitment to a broader set of social challenges, such as sustainability, climate change, and hunger.

Generation Z is growing up in the era of rapid technological development, so they have a high level of technological literacy, they are supporters of digital

technologies and the use of the Internet, own several digital gadgets (phone, laptop, tablet, etc.), and are able to quickly adapt to new technologies. E. Jones [14] notes that this generation does not distinguish between the physical and digital worlds. For them, a critical element is the ability to smoothly transition between them. Zoomers are changing consumer behavior due to their fluency with digital tools and formulating a new paradigm of digital experience.

Generation Z is characterized by the active use of social media, online communication, video games and other digital platforms, and a preference for bloggers' opinions on social media. They are accustomed to the speed and instantaneousness of information and communication. They have a tendency to creative expression and actively use social media to create their own image, express their thoughts and ideas.

According to the study of E. Jones [14], Generation Z is the most dependent on the Internet and social media compared to other generations: 58 % of them cannot help but use the Internet for more than 4 hours; in 5 years, 64 % of Generation Z representatives believe that the Internet will determine what they do every day; 56 % of Generation Z representatives are friends with those they know only online.

Imran Anwar Mir and Jari Salo consider the direct impact of social networks on the level of attractiveness of the employer's brand [18]. This indicates that it is appropriate to form and develop a brand for Generation Z on the social network Instagram, which is the most popular for learning and sharing information [19]. For Generation Z candidates, brand ambassadors or bloggers play an important role. Therefore, advertising the employer's brand through opinion leaders among the target audience on Instagram and other social networks is one of the most effective tools for communicating with candidates, especially those without work experience [20–22].

L. Löffler and C. Giebe [12] analyzed the theory of generations and its impact on the components and characteristics of the employer brand and determined that for Generation Z, mobility, multiple functions, the ability to work remotely and an individual approach from the manager are important when choosing a job.

Generation Z prefers work and study that allow them to develop their own brand and individual identity. They are looking for a job that aligns with their values and interests. Representatives of the younger generation are accustomed to change and fast pace of life, have a tendency to flexibility and mobility in work, study and life in general, and are characterized by a choice of hybrid or remote work formats. This is a certain level of freedom while working in a corporation. Remote work helps students to combine work and study.

Under the influence of the development of digital technologies, typical behavior for Zoomers is closedness to live meetings and the choice of online communication. The Zoomers are less brand loyal, but they are focused on brand authenticity.

A new trend in the labor market among young people is the choice to work in a startup or young company as opposed to international companies. The tech sector is a particularly interesting area of work for them.

The buzzer generation prioritizes their own financial well-being in life first and foremost. But some studies have shown that Generation Z values salary less than any other generation [13]. It is important for the employer to offer competitive salaries when recruiting for an internship or a job to the generation of buzzers.

Generation Z will demand more personalization in how they progress in their career path [13].

In line with the trends of the global economy, the buzzer generation did not come of age during the communist regime. This generation is living in a period of rise and leadership in the global economy of the United States and China.

Generalized portrait of Generation Z representatives based on four main characteristics: age, behavioral, professional indicators, and global economic trends that is shown in **Fig. 2.2**. However, there is no need to succumb to stereotypes, as Generation Z cannot be assigned a standard and then use it without changes.

Age indicators born from 1995 to 2015	**Behavioral indicators:** Proponents of digital communication than face-to-face meetings. They listen to the opinion of bloggers and social networks. Choose online education. Online shopping. Volunteering and social activities. Active use of social media. Fast pace of life. Commitment to the challenges of society	**Professional indicators:** Mixed or remote work format. Priority of material well-being. Individual approach to work, personalization. Diversity and diversification of the functional. High level of technological literacy. Digital literacy. Ability to learn and retrain	**Trends of the world economy:** Development of digital technologies and artificial intelligence. Internet distribution. After the communist regime. The USA and China occupy leading positions in the world economy

Fig. 2.2 Portrait of representatives of Generation Z
Source: summarized by [12–14, 17–22]

Thus, the employer brand for Generation Z is a set of characteristics and measures aimed at forming positive associations with the company among potential employees, taking into account the peculiarities of behavioral, psychological, economic and social views of this generation.

2.4 Employer brand value proposition

Each company independently determines its desired image for potential candidates. This is defined as the concept of employer value proposition (EVP) [23]. The list of characteristics of the value proposition is broken down into tangible and intangible benefits of the company for future and current employees.

It has been shown that EVP components directly affect the level of employee productivity, their loyalty to the employer, increase the value of fulfilling promises for employees and determine further communication in the company [24]. It also helps to increase the duration of work and retain talent in the company [25]. The economic impact for companies is reflected in 10 % reduction in labor costs, 25 % reduction in recruitment costs, and 28 % reduction in staff turnover [26].

A. Maslow [27] proposed a hierarchical system of human needs, according to which he ranked human needs by importance, namely: physiological needs, safety (health, life, future), social (friendship, family, intimacy), respect (self-esteem, confidence, achievement), self-expression (creativity, morality, problem solving). All of these needs should be reflected to some extent in the formation of the employer brand EVP.

The EVP employer brand should answer two main questions: "What does the offer mean to me as the employee or candidate?" and "What can your company offer more than others in the labor market?" P. Avinash and S. Kuldip Charak consider a value proposition to be a set of associations and tangible and intangible offers that employee will receive [28].

Growth-oriented companies need to determine how well their internal culture aligns with the values of those they want to see among their employees. If a company can clearly communicate its values, it will be able to attract employees who share them, and this will contribute to the company's development [26]. M. Tkalich notes that EVP also determines the number of tasks for employees and their balance between work and personal time [29].

C. Seemiler and M. Grace [15] proposed the "Reward of Work" (ROW) model, which identifies the winning elements and processes of creating an attractive workplace. In particular, these are: compensation – material remuneration in the form of salary and additional payments; benefits – cash payments for health insurance, retirement and dismissal (at the request of the employee) from the company; job task component – satisfaction and level of employee involvement in the fulfillment of tasks and goals; career – professional development and prospects in the company; belonging – the level of employee involvement in the corporate culture and the formation of a favorable atmosphere in the company.

F. Huang, P. Liu, Yu. Si, L. Zhao, Z. Shi and X. Huang [30] consider the following components of the employer brand value proposition: career development opportunities, realization of personal value, corporate culture, material rewards, social responsibility and workspace.

Most researchers believe that the main components of the value proposition are the level of salary, additional benefits (health insurance, bonuses), career development in the company, the company's image as the employer, and a comfortable workplace.

Less important, but also influencing the choice of a future job, are: the company's business rating, employee training and development system, use of the latest technologies, company values, and the company's rating as the employer.

One of the advantages of working for a company is compliance with information security standards. This selection criterion is the least popular among employers, but it requires attention due to the electronic exchange of information. L. Maznyk and O. Dragan believe that the criteria for determining the effectiveness of compliance with information security standards are the number of security breaches, recovery time after breaches, the number of employees who have been trained in data protection, the number of viruses and malware [31].

N. Samoliuk, G. Mishchuk and V. Mishchuk [32] consider comfortable workplace, material incentives and additional material benefits, employer's rating in social networks, image, career development opportunities and use of the latest technologies to be important components of the employer's brand value proposition.

V. Oberemchuk and O. Degtyar [33] consider a wide range of components of the employer brand value proposition, among which, in addition to the previous list, they identify the opportunity to gain international experience, the availability of social projects, and a positive impact on the environment. E. Jones [16] also considers the presence of social projects as an important component of the employer brand value proposition.

S. Firsova and A. Kozhukhivska [34] also identify the company's training system, its capabilities and adaptation to environmental changes, and compliance with modern innovation challenges as an important component.

A. Jogola [35], characterizing the value proposition for the employer from the perspective of Generation Z, identifies the need for the employer to take care of the environment, not be tainted by gender-based outrages, and not infringe on anyone's rights. Zoomers want to hear a clear position that turns the employer into a friend who cares about the same issues and shares their values. It also suggests that the content of the products and services offered by the company on the market also affects the employer brand.

I. Volobaeva, O. Kravchuk and D. Warshava [36] believe that reviews about the company in social networks and on various portals are also important for attracting

staff. Generation Z primarily receives information from social networks and, based on this information, creates an image of the employer in their minds.

O. Dragan, O. Solomka and L. Maznyk [8] believe that the list of benefits of working in a company varies depending on the level of responsibility of the company's employee.

M. Dzhulai, I. Fedulova and I. Bolotina [37] define the need to take into account the possibility of working remotely or in a mixed format when determining the value proposition of the employer's brand.

Table 2.1 summarizes the attributes of the employer brand value proposition and defines the parameters of their management based on the results of the monographic analysis of scientific works.

Table 2.1 Employer brand value proposition attributes

A value proposition	Essence	Management parameters
1	2	3
Salary	Material motivation of employees in the amount of a monthly financial reward	Analysis of the labor market for relevant positions (below average level, average, above average level). Periodic revision of the size depending on the results of the employee or a certain period
Additional payments (premiums, bonuses)	Additional material motivation depending on the fulfillment of the set goals	KPI (Key Performance Indicator) system
Career development	Vertical or horizontal promotion of an employee in a company with a defined period and positions	Organizational structure of the company. Flexibility of powers
Work outside the office	Work outside the office	Software for the work of employees. The task control system
Flexible work schedule	Ability to combine study and work (for initial positions) or lack of fixed working hours in the company	KPI (Key Performance Indicator) system. Labor productivity
Training within the company	Ensuring continuous training and development as a qualified specialist within the company	Building a career path within the company. Evaluation of the level of competence of employees
Official employment	Activities of the employment company in accordance with the labor legislation of the country	Reliability and stability for employees. A sense of security. Official employment and salary issuance

Continuation of Table 2.1

1	2	3
The impact of business on the environment	How the company's activities affect the environment and public health	What UN sustainable development goal does the company fulfill, performance in 1 year
New projects and tasks of employees	Experience while working in a team: work on a large-scale project, international team, tasks	Development of practical skills of employees
Technology of the company's processes	Digitization of processes within the company	The speed and efficiency of the company's operational processes
Security	How does the company take care of the safety of the workplace and the employee within the company and beyond	The level of occupational health and safety, availability of shelter
Company image	The company's reputation as an employer, the company's rating according to a certain criterion	Place in the company's ranking (market share, cash turnover, amount of tax payments, etc.)
Social responsibility	The company's activities to support different segments of the population	Amount of material assistance; availability of social programs
Team	Qualification level and age of employees	Support of equality and inclusiveness in the team, opportunity for development and exchange of experience
Corporate culture	Company values, work principles, behavior models, communication within the team	Adequacy of the chosen culture. Common interests of the team. Adaptability of culture
Events for company employees	Internal company events for employees to support relationships and communication	The level of job satisfaction of employees in the company. Corporates, team building, etc.
Medical Insurance	Medical care for employees during sick leave	Availability of medical insurance

Source: improved by [23–38]

In view of this, the main components of the value proposition have economic, emotional and functional characteristics.

The employer brand value proposition also focuses on internal customers – employees. Employees themselves have an impact on the formation of the company's values. High-quality interaction between employer and employee is the alignment between the desired and actual level of EVP. Satisfaction feedback is obtained using the following tools: anonymous audience survey, exit interviews with dismissed employees, and analysis of trends in the employer market [38].

Typification of the employer's value proposition incentives is shown in **Fig. 2.3**.

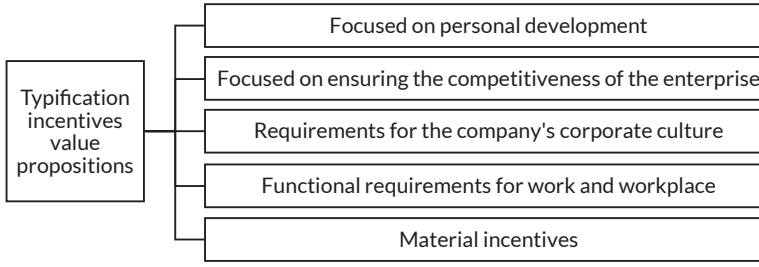

Fig. 2.3 Typing incentives of the employer's value proposition
Source: constructed by the authors

Financial incentives are one of the most important factors in choosing a job. These include: salary level that should be compared with the labor market and competitive, official employment, additional benefits and compensation. These include health insurance, maternity leave for both men and women, retirement benefits, performance bonuses, partial or full coverage of gym memberships, and enrollment of employees' children in school or kindergarten.

Value propositions focused on personal development include opportunities for employee training and development, international experience, and career development. These values are often the first priority when choosing a first job or gaining experience.

The company's image as the employer, the company's rating as the employer, the company's business rating, and the products/services the company creates are value propositions focused on ensuring the company's competitiveness. The higher the company's rating, the more attractive the employer is to job seekers.

Work schedule, work-life balance, use of the latest technologies, creativity/design of the office, office location, comfortable workplace are requirements for the functionality of the job and workplace. This type of value proposition is partially losing its relevance in the context of remote work, as most companies have been working remotely due to the COVID-19 epidemic and now due to the war. Thus, the usual 9 to 18 hours work schedule is no longer an advantage. The priority for company leaders is to fulfill their tasks and achieve goals by their employees.

The requirements for corporate culture include the company's values, which relate to the formation of relationships between all employees of the company and are determined by the behavior of each member. This is manifested in the company's attitude to society, which can be manifested in the presence of social projects.

Each international company chooses one or more UNICEF Sustainable Development Goals. Nowadays, candidates are looking not only for the most attractive salary option, but also for the employer with common goals and values. This is especially true for Generation Z, for whom volunteering and addressing environmental and social issues are important in their daily lives.

The employer brand value proposition for Generation Z is the ecosystem of support, recognition and values that exist in the company to achieve the highest level of professional development of employees and potential candidates and which is aimed at achieving the company's strategic goals. It is a key element of employer brand management aimed at attracting and retaining talented professionals.

To study the employer brand, a survey of young people was conducted in 2021 and 2022. The full-scale war in Ukraine is a key macroeconomic factor influencing students' choice of future employment since 2022. The total number of respondents is 1332. According to the field of study, the audience of the surveyed students was distributed as follows: 51.9 % – social sciences (business, law, economics, management, sociology, etc.); 15.59 % – technical sciences (engineering, metallurgy, mechanical engineering, etc.); 17.95 % – exact sciences (cybernetics, computer science, mathematics, etc.); 9.45 % – humanities (history, philosophy, etc.); 6.61 % – natural sciences (geography, physics, chemistry, biology, medicine, etc.).

The majority of students at the time of the full-scale invasion in 2022 had no work experience in the company (50.39 %). Almost 31 % of respondents have up to 1 year of internship experience, so they are familiar with the selection processes for entry-level positions and are able to evaluate the employer's brand more objectively. Almost 30 % of students have 1 to 3 years of experience in companies. 20.63 % have more than 3 years of work experience.

In 2021, the top 5 most attractive components of the employer brand value proposition for Generation Z representatives were company training, salary, official employment, internship schedule, and the company's business rating and reputation.

In 2022, the most important factor for students was the level of salary, due to the economic and labor crisis in Ukraine. The internship schedule remained in the TOP 5 criteria for choosing future employer, but moved up to the second position in the ranking. This is primarily due to the migration of candidates abroad or to the western part of Ukraine. Accordingly, due to the safety of employees in the first year of the full-scale war, most employers were engaged in the relocation of employees and opened offices in cities with the largest presence of employees. Secondly, the absence of the need to visit the office expanded the ability of recruiters to reach the target audience of candidates without reference to their place of residence. As the result, the ability to work remotely took the fourth position in the ranking in 2022.

In 2022, the company's training ranked the third place instead of first one. The training and development system is one of the tools to retain employees during the crisis. Accordingly, it is an important component of the employer's value proposition. Official employment remains in the top 5 factors in choosing future employer. It is important for candidates to support the state budget by paying taxes. This is one of the factors for checking the employer's reputation and compliance with labor laws. Important factors for students when choosing a future job are the company's withdrawal from the Russian market and the company's support of the Armed Forces and/or humanitarian aid (**Fig. 2.4**).

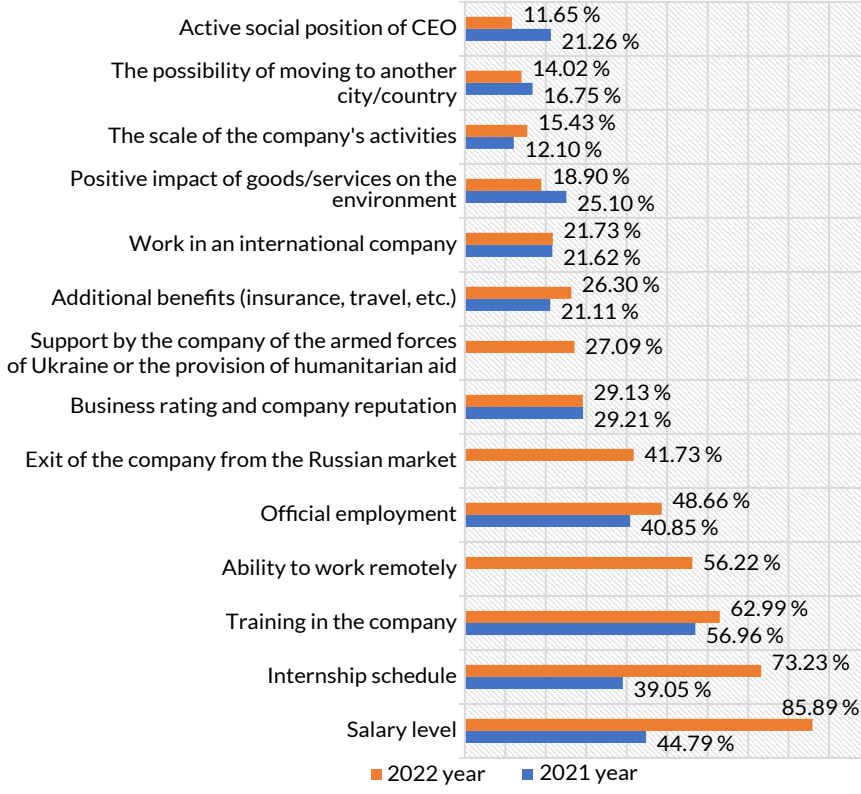

Fig. 2.4 Comparison of the level of significance of the components of the value proposition when choosing a future workplace by representatives of Generation Z in 2022 and 2021, % of surveyed respondents
Source: calculated based on survey results

The patriotic consciousness of students is manifested at all levels of job search. Candidates refuse to consider vacancies or internships if the company is involved in the Russian market or has hidden influence. To check the integrity of the company, students use official sources and company statements on the website of the global office.

2.5 Employer branding process

Organizing the process of forming the employer brand helps to create a strategy and justify actions to positively represent the company in the labor market. It also includes defining the company's values, developing a culture of employee support, active communication with the public, and improving the work environment.

The process of forming the employer brand for Generation Z representatives can be divided into three main stages: analyzing the current situation, creating an image of the desired employer brand, activating steps to achieve the desired goals and supporting them (**Fig. 2.5**).

The first stage of the employer brand forming process involves determining the current state of the company's value proposition, image, and brand.

It is advisable to determine the current state of the value proposition by the state of development of the components of the employer brand value proposition. Thus, companies can determine which value propositions are in the best condition and which need to be developed. Such analysis allows identifying the problems of forming the employer brand for Generation Z representatives.

It is also advisable to analyze what is effective and valuable for employees, what should be abandoned, and identify problems and opportunities for development. To do this, it is necessary to assess the current state of employer brand performance indicators in the retail network, office and their dynamics.

To analyze the employer brand in the retail sector, it is advisable to analyze important indicators in the context of companies as a whole, individual employees, and the retail network. These include, in particular, the following:

1. *Staff turnover in the first month of employment, quarter, year.* It is advisable to pay attention to the dynamics of changes in the indicator. The higher the percentage change in this indicator, the more attention should be paid to the reasons for this change.

2. *Reasons for leaving during the exit interview.* To collect answers, it is recommended to use a short online survey form with options that the employee receives on the last working day and a place for comments or feedback. The answers should be considered in the context of the company's performance.

3. *Conversion of the number of targeted questionnaires of employed employees.* The higher the conversion rate, the more attractive the employer is in the labor market and the strategy of forming the employer brand is correct. A low conversion rate indicates that the employer is unattractive and that its value proposition is not competitive with other employers.

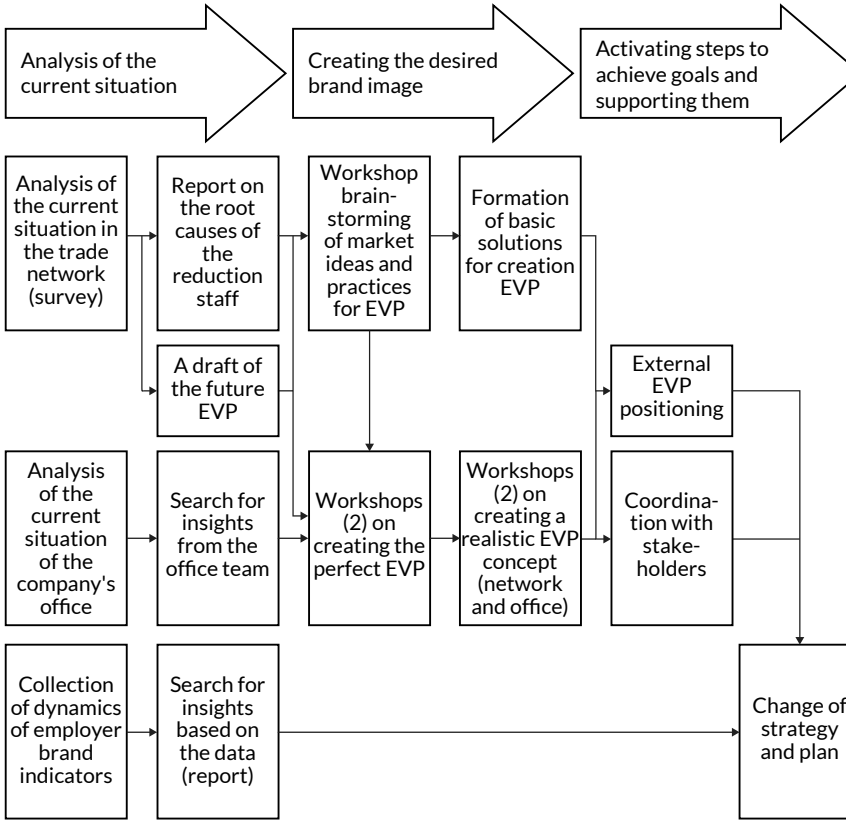

Fig. 2.5 The process of forming the employer brand
Source: constructed by the authors

This analysis also includes the report about the main causes of employee departures that have been voiced. After analyzing the responses of office employees,

we search for insights that will help to identify unexpected problems among the components of the employer's brand from the employee's side and determine their impact on the retail network. Based on the results of this analysis, the report is created with the outlined needs for change.

The exit interview template for a retail chain employee should be concise. It is recommended to use automatic SMS notifications for dismissed employees on the last working day to reduce the involvement of recruiters. The list of questions for the exit interview may be as follows:

1. Why did you decide to leave our company (multiple choice):
– I want to receive a higher salary.
– Insufficient or no opportunities for career development in the company.
– Difficult or uncomfortable working conditions.
– I want to develop my career in another specialty.
– It is difficult to form a work schedule.
– Other (open answer).
2. Are you considering another job?
– No.
– If "yes", please indicate the criteria for choosing a future job:
a) format and schedule of work;
b) career development with international experience;
c) the level of salary;
d) the company's rating as the employer;
e) social projects of the company;
f) the possibility of moving to another city/country;
g) business rating of the company;
h) creativity/design of the office, comfortable workplace;
i) reviews about the company on various portals;
j) office location (distance from the place of residence);
k) additional benefits (insurance, meals, transportation, etc.)
l) official employment;
m) products/services created by the company;
n) company values;
o) the company's image as the employer;
p) the company's training and development system.
3. Would you recommend working in our company?
– Yes.
– More yes than no.
– No.

4. Any comments and suggestions to improve the work in our company.

The answers to the questions will help HR managers to improve the employee experience and reduce the level of staff turnover in the retail chain.

The second stage of the employer branding process is to create the desired employer brand image. To create the desired image of the employer brand, it is possible to determine the deviation between the existing ranking of value propositions for each company and the desired one from the point of view of Generation Z representatives.

This stage involves holding workshops by the team of HR managers to search for ideas and learn best practices in HR management. It is necessary to organize workshops aimed at improving, developing or creating new components of the EVP and eliminating unnecessary elements. As the result, the basic formation of solutions for creating the updated EVP emerges.

For retail companies, it is typical to divide employees into office and network (store or outlet) employees. At this stage, it is necessary to identify problems in brand management and determine the established image of the employer among the target audience (or find out that it is absent). To do this, it is advisable to use the collection of results of the employer brand performance over the past year in general and in the context of each outlet in the network, conducting the employee survey and analyzing competitors.

To identify problems in the formation of the employer brand, it is advisable to use *the method of assessing employee loyalty (eNPS)*. It determines the likelihood that the employee will recommend the company as a place of work and helps the HR department understand what employees like or dislike about the company at the moment [39].

This index can be used to quantify the willingness of employees to recommend working for the company to their family, friends, etc. in the long term. The frequency of the index assessment is usually 2–4 times a year. The company's employees are divided into 3 categories: scores of 1–6 – do not recommend, 7–8 – neutral attitude to the company, 9–10 – brand ambassadors.

The calculation is based on the formula:

eNPS = Share of brand ambassadors (%) – Share of employees *who do not recommend working in the company (%).*

The scale is used to analyze the results:

– 0–60 – low level, employees do not recommend the employer;
– 70–80 – a sufficient level of commitment to the employer;
– 90–100 – the level of loyalty corresponds to the level of labor market leaders.

The following principles are recommended for conducting the survey to collect employee responses:

1. Anonymity. For truthful answers, each respondent must be confident in the confidentiality of the survey. To analyze retail companies in the context of the structural elements of the organization, it is recommended to add the number or name of the network location to the questionnaire.

2. Use the interactive platform to collect responses. The more gamified and interactive the questionnaire is for the target audience of respondents, the higher the percentage of employee engagement in answering and the larger the data sample for analysis.

3. Develop communication campaign among employees. In order to collect a sufficient number of responses (at least 70 %), it is recommended to use the survey announcement in several sources of communication in the company and reminders to provide answers. Internal communication tools for employees in companies may differ depending on the specifics of management activities, but the main ones are as follows: letter to corporate mail, an internal news platform, company news digest, chats or trading network group.

4. Taking into account the peculiarities of the company's activities requires an individual approach to brand management and analysis. Depending on the specifics of the company's activities and the formed value proposition, the list of questions differs.

The list of questions for a survey of retail chain employees using the eNPS methodology for retail employers should include the following questions:

1. Employee attitude to work and assessment of the level of trust in the company as the employer:

– How likely are you to recommend the company as a place to work to your friends or acquaintances?

– Do you intend to continue working for the company in the next 1–2 years?

2. Employee's attitude to teamwork and direct supervisor:

– Assess the extent to which your manager encourages you to make independent and prompt decisions for the business.

– Assess the level of effectiveness of interaction between the company's office team and the sales network.

– Do you agree with the statement that your manager makes decisions that are most appropriate for the company as a whole, not just for the retail chain? If not, please explain.

– Do you agree with the statement that everyone in the company has equal opportunities for career development?

– How comfortable are you with arguing and defending your opinion to a manager who has an opposing opinion?

– Do you consider the environment within your retail network team to be safe to provide feedback to each other?

– Do you feel that it is safe to express ideas to improve the performance of your job and the company as a whole?

3. Attitude to the company's value proposition:

– Rate the extent to which the company provides training for each employee.

– Evaluate the extent to which the company provides transparent and regular opportunities for your career development in the retail network.

– Rate the level of alignment with company values and their implementation in decision-making.

– Rate the level of satisfaction with your salary.

– Evaluate how comfortable and practical the workwear provided by the company is.

– Do you use the company's health insurance? If yes, please rate your level of satisfaction. If not, please explain why you refused.

– Please rate your satisfaction with the supplementary bonuses programs.

– Please rate the level of provision of necessary materials and resources at your workplace to achieve your work goals.

4. The level of belonging to the company as the employer and interaction within a large retail network:

– To what extent do you agree with the statement "It is easy for me to find all the information I need about company policies and processes for my job"?

– What extent do you agree with the statement "I feel that my work is valued within the network and the company as a whole"?

– To what extent do you agree with the statement "I feel that my contribution to the development of the company is important and ensures the smooth execution of processes in the sales chain"?

– To what extent do you agree with the statement "I feel that the office team and our sales chains work closely together"?

– To what extent do you agree with the statement "I clearly distinguish and understand what communication channels exist in the company and how to use them"?

It is recommended that at the end of the survey form you leave a place for wishes and any comments that the employee could make to improve their experience in the company.

It is also necessary to create the up-to-date portrait of retail and office employee. Characteristics of the portrait: age, gender, length of working time in the company,

work format, motivation. To do this, it is suggested to select at least 10 employers: direct competitors operating in the retail sector and indirect ones that hire a similar target audience.

The criteria for the study are as follows:

1. Requirements for candidates for employment: age, education, work experience, soft and hard skills, level of English language proficiency. For retail employers, the requirements for an entry-level position in retail chain are minimal: 18 years of age or older, work experience is optional.

2. Selection stages: online application form or feedback through job search sites, telephone interview, interview with a recruiter in the retail chain. For managerial positions, candidates are additionally evaluated using case studies, logic and number tests, and an interview with a manager.

3. The schedule and format of work is important for young people when choosing their first job, so we analyze the use of full-time or part-time work and the mode of work (remote/office/mixed).

4. Salary. To analyze this indicator, it is important to take into account not only the level of competitors' pay, but also the general trend of the labor market. For entry-level positions, hourly rates are in priority for candidates.

5. Non-financial motivation, which includes value propositions: insurance, training and development system in the company, opportunities to move to another city or country, etc.

6. Activities to build the employer brand among young people. These can include cooperation with higher education institutions in the format of dual education or internships, participation in career fairs, online or offline educational projects for young people, interactive questionnaires with a prize draw, etc.

7. Internships/leadership programs for young people. During these programs, students gain the necessary knowledge and skills and, after completing the program, are ready to receive the offer and take a position in the company or get management position.

8. Social media about careers. Building the employer brand in the online environment is essential. Most student candidates respond to online jobs through social media advertising and look for work on their own in Telegram channels. For candidates without work experience, we recommend actively developing the page on the social network Instagram.

We study the most successful examples of employer brand management of competitors, which, in our opinion, could be used to create our own employer brand.

To create an attractive employer brand, it is also advisable to interview employees and graduates of internship or work placement program (if the employer

has one). This approach creates opportunities to assess the value proposition and the brand in general at different levels of management. The optimal interview duration is 30 minutes. Factors that should be analyzed using open-ended questions include the employee's experience, work atmosphere, motivation, professional goals, and pain points for the employee. For each question, positive and negative indicators are identified to assess the level of engagement of the intern.

The first question is the analysis of the skills used by the intern during the internship period. Such skills are aimed at quick adaptation in the company, a structured internship program and the formation of a positive experience in the company. The next question is to analyze whether the planned description of responsibilities for the internship period and the number of tasks correspond to the actual level. The analysis of the workplace conditions during the internship in a retail chain is important criterion for assessing and deciding on further employment in the retail sector. To create a positive experience for employees, the employer must provide them with comfortable working conditions throughout the entire work cycle. This ensures the achievement of internship goals and the possibility of exceeding them. We analyze the advantages and disadvantages of working in the company based on the value propositions voiced by the intern. Upon completion of the internship, the intern makes a decision on further employment based on the overall impression of the company as the employer and the analysis of further prospects for career development in the retail chain.

After the interview, the level of the trainee's involvement in the internship is assessed based on the summation of the number of positive and negative indicators voiced by the trainee. Accordingly, the greater the prevalence of positive indicators over negative ones, the higher the level of the trainee's involvement. We believe that at least 80 % of positive indicators define the employer as desirable for employment after the internship and a high level of intern loyalty.

To create the image of a desirable employer brand, it is also advisable to conduct workshops using the Miro online interactive whiteboard tool. This is a convenient tool for quickly generating ideas and collecting market practices for solving employer branding problems. The workshop methodology is as follows: the moderator takes turns voicing the problems identified from the preliminary data analysis and gives 7 minutes for brainstorming. Each participant individually generates any ideas that could help solve the existing problems within 7 minutes and writes them down on online sticky notes. There is no limit to the number of ideas. The moderator monitors the time for the brainstorm and organizes all the ideas after the workshop.

Activation of steps to achieve the desired goals and their support is **the third and final stage** for the formation of updated value proposition and employer brand

positioning. At this stage, it is important to hold meetings with stakeholders to finalize the EVP for development. The format of the meeting is the presentation of the updated proposal and questions and answers. Once agreed, the strategy and plan for employer brand development is created. It is recommended to monitor the implementation of the planned results on a quarterly basis for a comprehensive review of the dynamics of employer brand performance indicators. We believe that if there is a positive change in the indicators, such as a decrease in staff turnover, an increase in the number of target candidates for one job, and a decrease in the number of reasons for dismissal, the strategy is being implemented successfully. The desired percentage change in indicators is determined at the planning stage.

2.6 Strategic directions of employer brand development

Implementation of successful strategy for forming the employer brand for young people should be based on the following components: updating the brand book, communication strategy, management action plan to create the desired image of the employer among talents (**Fig. 2.6**).

Component strategies of employer brand development		
Brand book	Communication strategy	Formation of the desired image of the employer

Fig. 2.6 Component strategies of employer brand development
Source: constructed by the authors

The employer's brand book is a structured document that includes:

– definition of the employer's business profile, mission, and strategic vision;

– description of the employer through the prism of indicators. Such indicators may include: the number of employees who have been promoted over the past year; place in the employer rating; number of interns who stay with the company, etc.;

– employer's value proposition: what is done for interns and students and how it is done;

– key messages to be used for advertising among target candidates or forming a certain image of the employer;

– visual design with the definition of mandatory elements to be observed (logo placement, colors, style, photos of employees, etc.);

– communication channels with the target audience;

– examples of advertising campaigns in various sources.

The description of the company as the employer should be clear and measurable. We recommend 4–5 sentences, which would include information about the company's activities, the scale of the employer (number of employees or office branches in the country or retail network, place in the employer rating), the employer's mission (broadcasting the main and unique value). The most common mistake made by HR professionals is a broad description of the company as the employer without defining a unique offer, focusing more on the company's activities than on the place it occupies for employees and interns.

The employer's value proposition is a list of tangible and intangible benefits of working for the company. For external and internal communication, it is customary to distinguish between a wide range of them, since not all advantages are criteria for choosing future job or, on the contrary, are significant for a student.

Typically, 3–5 key messages are used for advertising. These should be slogans or appeals to the target audience to pay attention and respond to the vacancy or internship that stimulate the candidate while viewing it. If several portraits of the target audience have been identified during the development of the updated employer brand, we create key messages for each of them accordingly. Key messages for the general audience, which are aimed more at shaping the image of the employer's brand in the labor market, are created based on their generalization.

Each employer develops different versions of visual design templates for materials depending on the sources of use.

The mandatory templates are:

– printed materials: printable banner for career recruitment events (job fairs at universities/colleges), stickers, hoodies, eco-shoppers, etc.;

– information messages on the Internet: website about career opportunities in the company, postings on job search sites, social media of the company as the employer, advertising on various online platforms. For students and recent graduates, we recommend advertising on Instagram and TikTok;

– placement on offline platforms: billboards or city lights in the city. It is recommended to use it only in small cities where there is a limited choice of companies for internships or first jobs.

The list of visual characteristics of the employer brand may differ from the general company brand used for consumers. However, it is not recommended to make the brands for candidates and consumers as opposite in color as possible, as the employer brand is a component of the company's brand. It is recommended to create several approaches to communication for young people: static and video for social media.

Communication channels for the target audience differ in the tools used to attract the candidate's attention (**Table 2.2**).

Table 2.2 Tools for communication between the candidate and the employer

Source of communication with candidate	Tool for formation employer brand
Printed materials on advertising space or in the company's retail network	Posters, billboards, banners, bigboards, city lights
Video	Advertising on YouTube or Instagram about an employee's working day, an interview with a manager or an intern
Social networks	Adapted advertising on various platforms: LinkedIn, Instagram, Facebook
Offline events (career events at universities or job fairs)	A set of branded printed materials, stickers, "set of the newbie of the company", banners, presentation about the company as an employer, surveys
Video Job search sites	Designing the employer's value proposition in the job description and in the company section

Source: constructed by the authors

The use of different platforms for interacting with the candidate contributes to effective communication and the correct format for broadcasting the employer's value proposition. Modern employer communication in the labor market takes place as much as possible in the digital environment. Formation of video content about the employer with a focus on the interest and partly the requirements of candidates, creating a realistic picture of work in the company. The popularity of social media or YouTube is natural, as the candidate quickly gets to know the company as the employer and, based on the analysis of the visual component and content, decides whether to apply for an internship or a vacancy. A modern employer who does not develop a brand on social media loses a significant portion of candidates and complicates the process of forming new company's positioning or value proposition.

The level of employer attractiveness depends on the set of tools for communication between the candidate and the employer. Several scenarios for using a set of communication tools to develop the employer brand are shown in **Table 2.3**.

If the employer's attractiveness is low, it is necessary to use all the proposed communication tools shown in **Table 2.3.** First, the use of communication tools is aimed at forming the desired image of the employer and associations among the target audience of candidates. Second, positioning the employer brand as a desirable place of work with the necessary value propositions for the candidate. With a low level of

employer brand attractiveness, there is a risk that vacancies will not be filled due to lack of candidates. Therefore, the predictable result after using the communication toolkit is to receive responses from target candidates for vacancies or internships.

Table 2.3 Scenarios for choosing a set of communication tools by the employer

The level of attractiveness of the employer's brand	The recommended tool kit list	The predicted result
Low	Printed materials for interaction on the advertising level or in the company's trade network. Video. Social networks. Offline events (career events at universities or job fairs). Job search sites	1. Increasing the number of supporters of the employer brand. 2. Feedback on internships and vacancies of target candidates. 3. Changing the level of attractiveness of the employer brand to an average level
Average or sufficient	Printed materials for interaction on advertising space or in the company's retail network. Video. Social networks. Job search sites	1. Strengthening the position of the employer's brand in the labor market. 2. Increasing the number of feedback on an internship or vacancy
High	Social networks. Job search sites	1. Strengthening the level of attractiveness for candidates. 2. Reduction of costs for closing vacancies

Source: constructed by the authors

An average or sufficient level of employer attractiveness does not require significant financial resources. The main goal is to keep the attention of target candidates and increase the level of attractiveness. Therefore, the expected result is to strengthen the position of the employer's brand in the labor market and increase the number of responses to internships or vacancies from target candidates.

If the employer's attractiveness is high, its support will strengthen its position in the labor market and reduce the cost of filling vacancies. Inactivity and limited use of communication tools will lead to a loss of employer attractiveness and a transition to a lower level.

The components of communication for forming an attractive employer brand among Generation Z representatives are shown in **Fig. 2.7**.

Key messages (slogans) for students are formed based on their pain points or problems. In general, it is important for young people to communicate career development opportunities and the main advantages of choosing a company as the

employer. For students, this may include rapid career development from an entry-level position to a manager in an accelerated mode during an internship compared to the usual career development of an employee. Also, students may be attracted to working on an international project or the opportunity to work in different departments to choose their future career.

Key messages (slogans)	Components of the value proposition	Communication channels	Additional promo activities
• Calls to action about career opportunities • Calls to action about the reasons for choosing the company as an employer	• Competitive salary • Official employment • Flexible work schedule (remote work format if possible) • Teaching • Additional bonuses (premium programs, provision of high-quality special clothing, insurance) • International experience	• Job search sites • Social networks Instagram, TikTok, LinkedIn, Telegram • The company's career site	• Social networks about careers in the company Telegram, Instagram, LinkedIn • Employer Brand Ambassador Program • Promotion of activities on university/college resources

Fig. 2.7 Components of employer brand communications among representatives of Generation Z
Source: constructed by the authors

It is recommended to include the following in the employer's value proposition for young people: competitive salary, official employment, flexible working hours (remote work if possible), training, career development, additional bonuses (bonus programs, provision of quality workwear, insurance), and international experience. This list is based on the analysis of the 2021–2022 youth survey, as shown in **Fig. 2.4**.

The main channels of communication with young people are job search sites, social networks Instagram, TikTok, LinkedIn, Telegram, and the company's career website. It is recommended to use Telegram channels for students or recent graduates to disseminate information about career events, internship opportunities, or employer vacancies. Usually, each university has its own Telegram channel moderated by the student council. They inform students about university events and offers from employers. It is also recommended to pay attention to Telegram channels from

the university's career and employment centers. To advertise on Instagram, TikTok, LinkedIn, you should use video or animation to capture the student's attention from the first seconds. To describe an internship program or a vacancy, it is recommended to describe the company as an employer with the most attractive image for young people, a clear description of the work format, value advantages, and a convenient form of response to the position. The application form should be short and easy to use. The simpler the response format, the greater the number of target candidates for the position. Offline advertising is the least appropriate for advertising among young people, as the generation of buzzers are fans of digital technologies and social networks.

Additional promotional activities to form the employer's brand may include: social networks about careers in the company on Telegram, Instagram, LinkedIn, the employer brand ambassador program, promotional activities on university/college resources. It is recommended that each employer maintain pages about the company's career on Telegram, Instagram, and LinkedIn. In the youth labor market, it is important to identify unique sections about the company as the employer. It is recommended to tell candidates about the employer (interesting and unique facts), the company's team (video interviews with colleagues about work in different departments, interests of employees), value components, work in the company (typical working day, atmosphere in the office/retail network), internship opportunities and vacancies.

The employer brand ambassador program involves students who are supporters of the company as the employer and present the company's opportunities to young people at their respective educational institutions. The goal is to increase the company's recognition as the employer. It is recommended to form a team of student ambassadors who will be responsible for presenting the employer's opportunities during university career events, disseminating them in internal student chats, increasing the number of subscribers in social networks and responses to vacancies. Additional actions to promote the company as the employer on university/college resources are advisable in the period between the seasons of active recruitment for internships or vacancies. This helps to form the company's image as the employer and to be remembered by students who will look for new opportunities in the future. For example, recommendations for successful selection for an internship for subscribing to the company's Instagram page.

It is proposed to divide the employer brand communication plan with Generation Z into several stages: preparatory, testing, implementation, and analysis of the results. It is believed that one project manager – the employer brand development specialist or HR manager – should be responsible for the implementation of the plan.

The preparatory stage is the most costly in terms of human resources and involves the fulfillment of tasks:

– formulating the purpose and goals of the communication plan (first week);

– determination by the team of the key message to be broadcast to the target audience (first week);

– selecting the value propositions that are important to Generation Z and matching them with the employers' capabilities to provide them (second week);

– creating and selecting the most appropriate or all of the channels proposed in **Fig. 2.2** communication channels and the formation of planned efficiency goals for each of them (third week);

– selecting additional promotional activities if it is necessary to increase the level of coverage of the target audience. This depends on the objectives of the communication plan for task 1 (week four);

– formation and approval of the necessary budget for the implementation of the communications plan (fifth week);

– selecting a contractor – an advertising agency (if necessary) (week six);

– creating visuals and text for communication with Generation Z (sixth and seventh weeks).

The next stage of the communication plan is to test the prepared plan among the target audience. It takes at least 4 weeks to implement this stage. The main tasks are:

– finding a focus group with the target audience. These can be newly hired employees or candidates from the talent pool who will be open to sincere feedback and will be able to share advice on which communication channels to choose (week eight);

– organizing a meeting and presenting the visual design of the communication and the components of its implementation plan, collecting feedback from the focus groups (week nine);

– making changes to the communication plan (week ten).

After testing, the communication plan is implemented. Accordingly, the following principles are recommended for this stage:

1. Phasing. That is, access to the selected communication channels occurs at different times.

2. Structured approach. When preparing a communication plan that involves forming the desired image of the employer and recruiting new employees, it is necessary to communicate with the audience in several approaches.

3. Regularity. Communication with the target audience should take place on an ongoing basis using various channels of interaction without long interruptions.

To form the desired image of the employer and achieve the set goals, it is necessary to communicate with the target audience for at least 13 weeks. It is advisable

to plan a periodic analysis of the communication plan regarding the level of achievement of the desired results at least once every 2 weeks.

The final stage of the communication plan among targeted Generation Z candidates is to analyze the results, draw conclusions and recommendations for the future (week twenty-four). It is important to determine which channels and value propositions were most attractive to the candidate during the hiring process. On the other hand, it is advisable to analyze what were the negative results in relation to the goals set and make assumptions about what influenced them.

When updating the employer brand, it is advisable to plan activities for one year that will help to achieve the goals. The goals of the updated brand are determined at the design stage during the employer brand management process.

The goals of forming a positive employer brand of the retail chain for representatives of Generation Z are shown in **Fig. 2.8**.

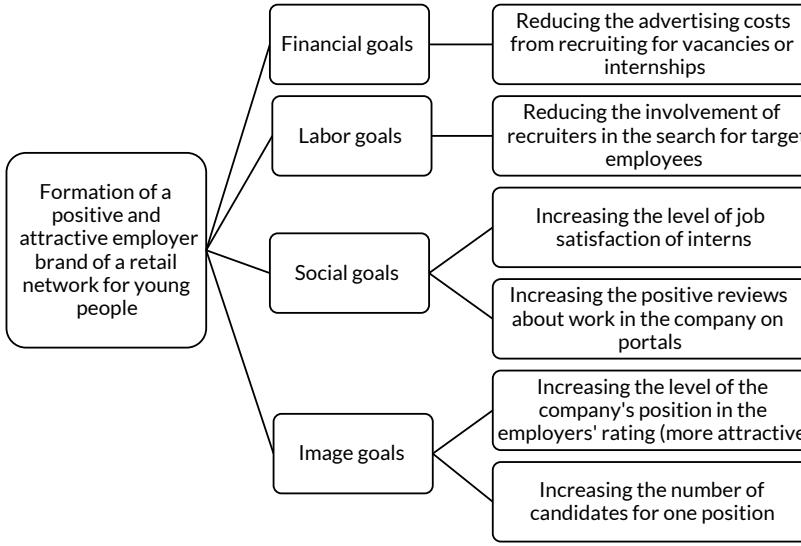

Fig. 2.8 A system of goals for the formation of a positive employer brand of the retail network for representatives of Generation Z
Source: constructed by the authors

To form a positive and attractive employer brand of a retail chain, we propose to set financial, labor, social, and image goals. It is advisable to measure them using the percentage change in the indicator for a certain period: quarter, six months, and a year.

The financial goal is to reduce advertising costs for recruiting for vacancies or internships. The effectiveness of advertising in attracting the attention of target candidates is gradually decreasing. The response rate to internships is increasing due to the desire of students to start working for the company.

If a company is known for its support and recognition of employees, it can have a positive impact on their engagement, reduce recruiting costs, and shorten the time it takes to fill vacancies. The goal of HR staff labor costs is to reduce the involvement of recruiters in finding target employees. That is, the HR team spends less time processing responses to positions that do not meet the requirements and focuses on evaluating targeted student profiles.

Social goals for forming the employer brand among students include: increasing positive feedback about working in the company on portals and increasing the level of job satisfaction of interns. Recommendations of the company as the employer on portals, feedback about working in the company to friends/acquaintances is always one of the ways to disseminate information about the employer's value proposition. Changes in communication approaches, work format and components of the interns' value proposition have a positive impact on the company's image in the labor market. Increasing the level of interns' job satisfaction affects their choice to stay with the company.

Image goals determine the growth of the company's position in the employer rankings and the increase in the number of candidates for one position. Annual ratings by independent agencies or media allow us to analyze changes in the level of attractiveness of the company as the employer in the labor market. The increase in the number of student responses per vacant position is an indicator of the effectiveness of the youth promotion campaign and the ambassadorship program.

The proposed plan for the formation of management actions for the development of the retail chain employer brand to achieve the set goals is shown in **Fig. 2.9**.

The following areas of the employer brand development strategy are highlighted: employee experience, company talent management, and recruitment. For each area, at least two activities are planned to reduce the risk of failure. It is advisable to set key metrics for each of the selected areas to achieve the goals, which, after implementation, will be used to evaluate the effectiveness of the chosen strategy and solutions. Also, to achieve each of the goals, it is necessary to plan the necessary resources to achieve them.

Implementation of the updated employer value proposition is planned for at least 1 year. Such plan should be aimed at achieving the main goal of creating a competitive employer brand. It is proposed to allocate at least one evaluation criterion for each planned direction of the employer brand development strategy (recruitment, employee experience, talent management) (**Fig. 2.10**).

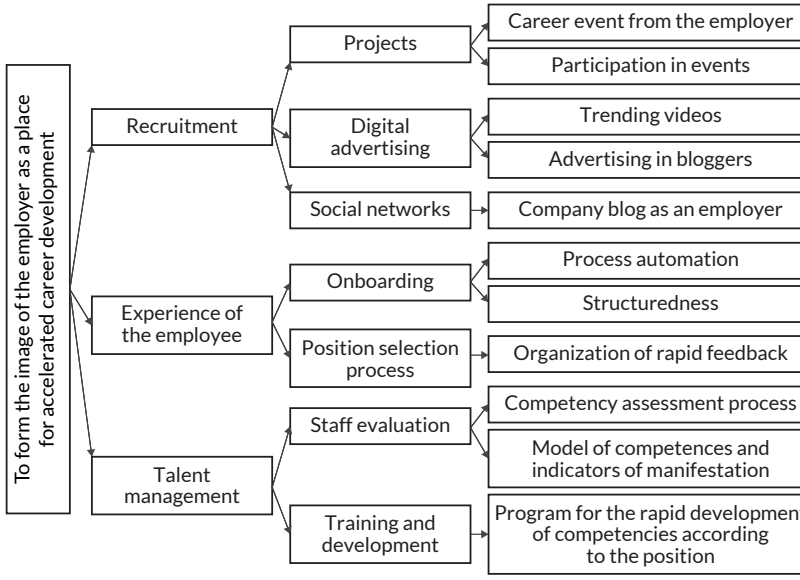

Fig. 2.9 Directions of employer brand development strategy for representatives
Source: constructed by the authors

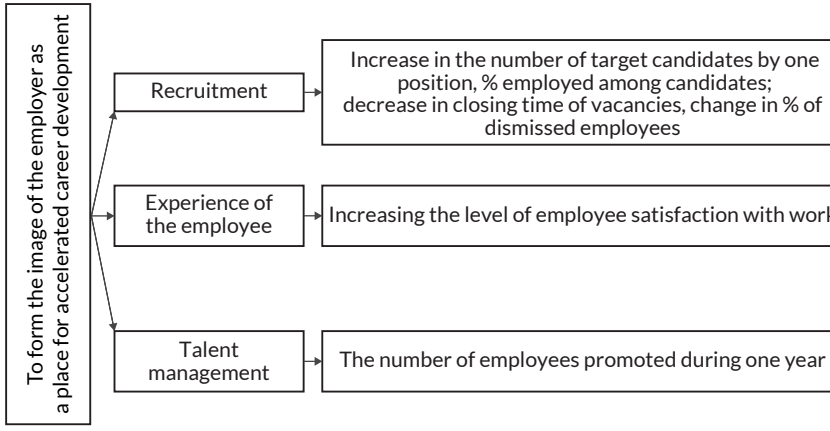

Fig. 2.10 Criteria for evaluating the target indicators of the employer brand development strategy
Source: constructed by the authors

An increase in the number of target candidates (the number of responses from target candidates to a vacancy) and the percentage of employed candidates among all candidates determines the level of attractiveness of the employer's brand and characterizes the work of the HR team. Reducing the time to close a vacancy is a positive result of employer brand management. A high level of maturity of HR processes helps to reduce the time of recruitment for a vacancy. It means how quickly and efficiently the selection process is carried out for the initial position in the retail chain. The change in the percentage of dismissed employees in the first month and quarter of work in the retail chain characterizes the achievements of the HR team when analyzing the employees attracted to the retail chain.

A competency development plan and training program for retail chain employees is an essential component of achieving the goals of developing the employer's brand. The level of employee satisfaction with work in the company is determined by the employee's experience. This can be measured by the results of a survey as a percentage increase in the level of employee satisfaction with the company in the first year.

An effective talent management process increases the level of job satisfaction in the company. It is proposed to determine the percentage of employees promoted within 1 year as an indicator of talent management assessment. The change in the percentage of employees promoted to a managerial position over a certain period (for example, in the first year) is determined by the work aimed at career development and staff training. The more structured and standardized the process of competence development, the faster employees are promoted and receive the necessary development.

2.7 Conclusions

Forming the employer brand is an important aspect for both companies and job candidates. This process affects the success of the company and the level of satisfaction of its employees. Therefore, the employer brand is seen as the opportunity for companies to attract and retain highly qualified specialists in the team that ensure the vital activity of the business in the context of the global crisis. It includes the reputation of the company as the employer in the labor market, namely, what makes the company stand out from others.

The employer brand for Generation Z is considered taking into account the behavioral, psychological, economic and social views of today's young generation to form positive associations about the company among potential employees. The portrait of Generation Z representatives is based on four indicators: behavioral,

professional, age and global economic trends. The main characteristics of Generation Z representatives are their commitment to digital technologies with several gadgets, a tendency to choose remote or mixed work formats, a preference for startups or small agencies rather than corporations for career development, a preference for online communication over face-to-face communication, and a tendency to choose influencers among publicly known individuals on social media. Employer brand positioning for Generation Z is seen as a strategic process of creating and maintaining a unique image of the company in the eyes of potential and current employees in the labor market, which distinguishes it from other companies and creates certain associations and impressions. The most important characteristics of employer brand management for Generation Z are establishing a connection and long-term communication with the employer's target audience, forming the desired image among the target audience of talents and a unique mission as an employer.

The content and attractiveness of the employer brand for Generation Z is determined by its value proposition. The competitiveness of the employer's value proposition affects the increase in the number of responses from candidates for a vacant position and the willingness to recommend the company as the employer in the labor market. The constituent elements of the employer's value proposition for Generation Z representatives that they use to analyze its attractiveness are those focused on personal development, ensuring the competitiveness of the enterprise, requirements for the company's corporate culture, job and workplace functionality, and material incentives.

Based on the results of the study of Generation Z representatives in 2021–2022, the main components of the employer's brand value proposition were identified and ranked. The TOP 5 most important components of the employer brand value proposition in 2021, in order of importance, were: company training, salary level, official employment, internship schedule, and business rating and reputation. In 2022, due to the war in Ukraine, changes occurred and the top 5 value propositions in order of importance were: salary, internship schedule, company training, the ability to work remotely, and official employment. The most attractive employers in the retail sector are companies with established value propositions aimed at the young audience. The criteria for choosing future employer by young people should be flexible for the changes of generation requirements.

The article proposes the process of forming the employer brand for representatives of Generation Z, which includes the following stages: analysis of the current situation, creation of the image of the desired employer brand, activation of steps to achieve the desired goals and their support. Each stage of the process has developed step-by-step tasks to ensure its continuity, structuredness, and effectiveness.

Analysis of the current state of the employer's brand determines the level of similarity between the requirements of the value proposition from the point of view of Generation Z representatives and the value proposition in terms of their development in the company. The purpose of this analysis is to determine how the assessment of the level of development of the employer brand value proposition meets the expectations of Z Generation representatives. This allows us to substantiate the directions of creating the desired employer brand image. For this purpose, a list of questions for a survey of retail chain employees has been formed, which helps to activate steps to achieve the desired goals and support them, including the employee's attitude to work, assessment of the level of trust in the company as an employer, teamwork and manager, attitude to the company's value proposition, level of affiliation with the company as the employer and interaction within the retail chain. In view of this, the criteria for evaluating the employer brand of competitors include requirements for candidates during employment, selection stages, work schedule and format, salary, non-financial motivation, activities to form the employer brand among young people, internships/leadership programs for young people, and social media about careers, which, according to the analysis of the survey of Generation Z representatives, are of the highest importance when choosing the future job.

It is proposed to develop the employer brand development strategy based on the following components: updating the brand book, communication strategy, and the action plan for forming the desired employer image among talents. The employer's brand book defines the visual design of advertising among the target audience on various media platforms, design features and color scheme that form associations with the employer, and key messages (slogans) of the employer. The components of the communication plan include key messages (slogans), components of the value proposition, communication sources and additional promotional activities. The developed tools for communication between Generation Z candidate and a retail employer help to attract attention and convey the employer's value proposition in a way that is relevant and relevant to the target audience. It is advisable to use the following communication channels for Generation Z: job search sites, social networks Instagram, TikTok, LinkedIn, Telegram, and the company's career website. We also suggest the following additional promotional activities to form the employer's brand: social networks about careers in the company Telegram, Instagram, LinkedIn, the employer brand ambassador program, promotional activities on university/college resources. The employer brand communication plan with Generation Z is considered by stages with the definition of tasks and the time period for their implementation. To create an attractive employer brand of a retail chain for Generation Z, it is proposed to define four types of goals: financial, labor, social and image. The target

indicators for these goals are as follows: reducing advertising costs for recruiting for vacancies or internships (financial); reducing the involvement of recruiters in the search for target employees (labor); increasing positive feedback about the company's work on portals and increasing the level of satisfaction with the work of interns (social); increasing the level of the company's position in the employer rating (more attractive) and increasing the number of candidates for one position (image).

The analysis of the components of the employer brand development strategy forms the management action plan to achieve the goals of the employer brand development among young people in three areas: recruitment, employee experience and talent management. The following criteria are proposed to be used as criteria for successful implementation of the employer brand development strategy: increase in the number of candidates for one position, % of candidates employed, reduction in the time to close a vacancy, reduction in the % of dismissed employees, increase in the level of job satisfaction in the company and increase in the number of promoted employees in the first year. The employer brand development strategy strengthens the positive feedback on the work of the company's employees.

References

1. Osadchuk, K. (2021). IT-rynok 2022-ho prodovzhyt zrostaty, a z talantamy vzhe problemy. De yikh shukaty. Forbes.ua. Available at: https://forbes.ua/leadership/it-rinok-2022-go-prodovzhit-zrostati-a-z-talantami-vzhe-problemi-de-ikh-shukati-04122021-2900
2. Tsymbalyuk, S. (2018). Brend robotodavtsia: metodolohiia doslidzhennia ta praktyka formuvannia. Kyiv: KNEU, 227. Available at: https://ir.kneu.edu.ua/bitstream/handle/2010/35635/Tsymbalyuk_brend_18.pdf?sequence=1&isAllowed=y
3. Mokina S. (2014). The employer brand concept: essence, functions, classification, instruments of formation. Herald of Khmelnytskyi national university. Economic sciences, 6, 189–196.
4. Bilorus, T. V., Firsova, S. H. (2018). Orhanizatsiine zabezpechennia formuvannia ta rozvytku brenda kompanii robotodavtsia. Biznes Inform, 7, 314–326.
5. Stepanova, L., Tuzhilkina, O. (2018). Formation of positive employer brand in modern conditions. Scientific Bulletin of Poltava University of Economics and Trade. Series "Economic Sciences", 5, 125–130.
6. Khytra, O., Vykhovanchuk, M. (2019). Synergy of employer's brand and staff brand as a result of successful HR-branding at an enterprise. State and Regions. Series:

Economics and Business, 4 (109), 149–156. https://doi.org/10.32840/1814-1161/2019-4-27
7. Vonberg, T., Dmytruk, S., Zubova, J. (2024). Employer brand: the process of forming and researching effectiveness. Economic Scope, 189, 25–29. https://doi.org/10.32782/2224-6282/189-4
8. Dragan, O., Solomka, O., Maznyk, L. (2022). Employer brand of food industry enterprises. Market Infrastructure, 67, 111–115. https://doi.org/10.32843/infrastruct67-20
9. Halvorsen, C. J., Emmanuel, E. (2020). An Encore in Social Work? How Our Schools Can Become More Age Inclusive. Journal of Social Work Education, 57 (4), 676–687. https://doi.org/10.1080/10437797.2020.1762269
10. Macalik, J., Sulich, A. (2019). External employer branding of sustainable organizations. Proceedings of 6th International Scientific Conference Contemporary Issues in Business, Management and Economics Engineering '2019. Vilnius: Vilnius Gediminas Technical University, 539–550. https://doi.org/10.3846/cibmee.2019.054
11. Tanwar, K., Prasad, A. (2016). Exploring the Relationship between Employer Branding and Employee Retention. Global Business Review, 17 (3), 186–206. https://doi.org/10.1177/0972150916631214
12. Löffler, L., Giebe, C. (2021). Generation Z and the War of Talents in the German banking sector. International Journal of Business Management and Economic Review, 4 (6), 130–141. https://doi.org/10.35409/ijbmer.2021.3319
13. Gomez, K., Mawhinney, T., Betts, K. (2021). Understanding Generation Z in the workplace. Deloitte United States. Available at: https://www2.deloitte.com/us/en/pages/consumer-business/articles/understanding-generation-z-in-the-workplace.html
14. Jones, E. (2020). Generation Influence: Gen Z Study Reveals a New Digital Paradigm. Business Wire. Available at: https://www.businesswire.com/news/home/20200706005543/en/Generation-Influence-Gen-Z-Study-Reveals-a-New-Digital-Paradigm
15. Seemiller, C., Grace, M. (2017). Generation Z: Educating and Engaging the Next Generation of Students. About Campus: Enriching the Student Learning Experience, 22 (3), 21–26. https://doi.org/10.1002/abc.21293
16. Reitynh naikrashchykh robotodavtsiv Ukrainy 2020–2021 (2021). European Business Association. Available at: https://eba.com.ua/rejtyng-najkrashhyh-robotodavtsiv-ukrayiny-2020-2021/
17. 2021 Employer Branding Strategy. Blu Ivy Group. Available at: https://bluivygroup.com/blog/2021-employer-branding-strategy/

18. Mir, I. A., Salo, J. (2023). Analyzing the Influence of Social Media Influencer's Attributes and Content Esthetics on Endorsed Brand Attitude and Brand-Link Click Behavior: The Mediating Role of Brand Content Engagement. Journal of Promotion Management, 30 (1), 1–28. https://doi.org/10.1080/10496491.2023.2251461
19. Gross, J., Cui, Z., von Wangenheim, F. (2023). How to Make Influencer Advertising Engaging on Instagram: Emotional Storytelling in Sponsored Posts. Journal of Interactive Advertising, 23 (4), 388–408. https://doi.org/10.1080/15252019.2023.2211579
20. Grgurić Čop, N., Culiberg, B., First Komen, I. (2023). Exploring social media influencers' moral dilemmas through role theory. Journal of Marketing Management, 40 (1-2), 1–22. https://doi.org/10.1080/0267257x.2023.2241468
21. Chen, C., Han, J. A., Ractham, P. (2022). Cultural influence on using mobile instant messaging applications to develop and maintain friendships. Cogent Social Sciences, 8 (1). https://doi.org/10.1080/23311886.2022.2141428
22. Gross, J., von Wangenheim, F. (2022). Influencer Marketing on Instagram: Empirical Research on Social Media Engagement with Sponsored Posts. Journal of Interactive Advertising, 22 (3), 289–310. https://doi.org/10.1080/15252019.2022.2123724
23. Barrow, S., Mosley, R. (2005). Bringing the best of brand management to people at work. NewYork: John Wiley & Sons Ltd, 240.
24. Nagpal, A. D., Nagpal, G. (2019). Influence of Employee value Proposition on Employer Brand. International Journal of Innovative Technology and Exploring Engineering, 8 (12), 673–676. https://doi.org/10.35940/ijitee.l1163.10812s19
25. Pandita, D., Ray, S. (2018). Talent management and employee engagement – a meta-analysis of their impact on talent retention. Industrial and Commercial Training, 50 (4), 185–199. https://doi.org/10.1108/ict-09-2017-0073
26. Kak postroyt sylnyi HR-brend y chto eto vam dast (2019). HR-liga. Available at: https://hrliga.com/index.php?module=news&op=view&id=19855
27. Maslow, A. H. (1943). A theory of human motivation. Psychological Review, 50 (4), 370–396. https://doi.org/10.1037/h0054346
28. Pawar, A., Charak, K. S. (2015). Employee value proposition leading to employer brand: the indian organizations outlook. International Journal of Management Research & Review, 5, 1195–1203.
29. Tkalych, M. H., Yakupova, O. Yu. (2019). Employer Value Proposition (EVP) in work-life balance programs for personnel. Problems of Modern Psychology, 1 (15), 136–140.
30. Huang, F., Liu, P., Si, Y., Zhao, L., Shi, Z., Huang, X. (2012). The Construction of an Employer Branding Model and Its Measurement. Journal of Beijing University of Aeronautics and Astronautics (Social Sciences Edition), 25 (1), 85–92.

31. Maznyk L., Dragan O. (2023). Information security of the organization as a factor for strengthening the employer brand. Kyiv Economic Scientific Journal, 1, 39–44. https://doi.org/10.32782/2786-765X/2023-1-5
32. Samoliuk, N., Mishchuk, H., Mishchuk, V. (2021). Gender aspects of the employer value proposition formation on the labor market. Herald of Khmelnytskyi National University, 296 (4), 147–155. https://doi.org/10.31891/2307-5740-2021-296-4-24
33. Oberemchuk, V. O., Degtyar, O. V. (2019). Brend robotodavtsia ta stratehichni oriientyry yoho rozvytku. Bulletin of the Kamianets-Podilskyi Ivan Ohiienko National University. Series: Economic sciences, 14, 344–351.
34. Firsova, S., Kozhuhivska, A. (2020). Strategic aspects of employer brand management. Efektyvna Ekonomika, 9. https://doi.org/10.32702/2307-2105-2020.9.51
35. Dzhohola, A. (2023). Yak stvoryty brend robotodavtsia, yakyi pryvabliuvatyme pokolinnia zumeriv? Hurma.work. Available at: https://hurma.work/blog/yak-stvoryty-brend-robotodavczya-yakyj-pryvablyuvatyme-pokolinnya-z/
36. Voloboieva, I. O., Kravchuk, O. I., Varshava, D. V. (2021). The Value Dimension of the Employer Brand: Influencing the Staff Engagement. Business Inform, 4 (519), 302–309. https://doi.org/10.32983/2222-4459-2021-4-302-309
37. Dzhulai, M., Fedulova, I., Bolotina, I. (2022). Analysis of employer brand for young people. Eastern-European Journal of Enterprise Technologies, 1 (13 (115)), 80–91. https://doi.org/10.15587/1729-4061.2022.252549
38. Staniec, I., Kalińska-Kula, M. (2021). Internal employer branding as a way to improve employee engagement. Problems and Perspectives in Management, 19 (3), 33–45. https://doi.org/10.21511/ppm.19(3).2021.04
39. What is Net Promoter Score or how to use it to increase an employee loyalty? (2019). Outsourcing Team. Available at: https://outsourcing.team/en/blog/management/what-is-net-promoter-score-or-how-to-use-it-to-increase-an-employee-loyalty/
40. Shpak, N., Maznyk, L., Dvulit, Z., Dragan, O., Doroshkevych, K. (2022). Influence of Digital Technologies on the Labor Market of HR Specialists. CEUR Workshop Proceedings, 3171, 1475–1487. Available at: https://CEUR-WS.org/Vol-3171/paper103.pdf

CHAPTER 3

Synergy of digital technologies and green development and their impact on achieving a sustainable environment in the conditions of instability

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Abstract

The aim of this research is to assess the influence of digital technologies on fostering sustainable green development, thereby enhancing resource efficiency, reducing emissions, improving energy efficiency, and advancing environmental management. Investigating the impact of digital technologies on sustainable green development is pertinent due to their potential to enhance the effectiveness of renewable energy sources, like solar panels and wind turbines, through weather forecasting, system optimization, and energy storage. Moreover, digital technologies can facilitate resource efficiency and the adoption of circular economy models, converting waste into valuable resources. The paper aims to scrutinize leading international practices in leveraging digital technologies for sustainable development and to delineate their role in achieving sustainable green development. Sensor networks and Internet of Things (IoT) systems enable precise data collection on resource utilization, air and water pollution, enabling targeted interventions. The paper delineates how digital technologies optimize energy consumption in buildings, industry, and transport, and how automation systems, smart grids, and data analytics contribute to enhanced energy efficiency and reduced emissions. The study examines exemplary global practices, such as Far EasTone's commitment to the RE100 Global Renewable Energy Initiative, aiming to transition to 100 % renewable energy usage across its facilities by 2040. Far EasTone Telecommunication is leveraging artificial intelligence to

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optimize 5G base station selection and minimize power consumption while maintaining user satisfaction. The study underscores the extensive and wide-ranging impact of digital technologies on sustainable green development, enabling comprehensive data collection on environmental metrics like CO_2 emissions and water usage. Utilizing this data can inform better decision-making by businesses and governments to mitigate environmental impact. Digital technologies play a pivotal role in expediting innovation and ensuring efficient resource utilization for environmental preservation. Additionally, the RE100 Initiative, a global coalition of companies committed to sourcing energy exclusively from renewable sources, is discussed for its role in reducing carbon footprints and promoting sustainable energy transitions. The article analyzes fundamental principles of green sustainable management and highlights best practices in employing digital technologies for sustainable green development. Theoretical insights into the potential of digital technologies for sustainable green development contribute to the formulation and execution of practical initiatives to address global environmental challenges.

The chapter thoroughly examines both the theoretical underpinnings and practical applications of digital technologies in sustainable green development, positioning it as a valuable contribution to ongoing discourse in this field. The chapter analyses the impact of digital technologies on sustainable green development, in particular their role in increasing resource efficiency, reducing emissions and implementing circular economy models. International practices of using digital technologies to optimize energy consumption, environmental monitoring and environmental management are explored.

Keywords

Digital technologies, sustainable green development, green management, international practices, environmental impact, RE100 Initiative, renewable energy sources, CO_2 emissions.

3.1 Introduction

The significance of studying the impact of digital technologies on advancing sustainable green development lies in their ability to enhance the efficiency of renewable energy sources like solar panels and wind turbines. This is achieved through accurate weather forecasting, optimized system operations, and effective energy storage solutions. Furthermore, digital technologies contribute to more efficient resource utilization and support the adoption of circular economy models, where waste is transformed into valuable resources.

The relevance of this study is emphasized by several key factors:

1. **Climate change and environmental instability**: human activities have contributed to climate change and an increase in natural disasters, highlighting the urgent need for a balanced approach to sustainable development. Digital technologies can play a crucial role in reducing environmental impact through improved efficiency and smarter resource management.

2. **Digital technologies in green development**: the effective use of resources and reduction of emissions are essential for sustainable development. Digital technologies are critical to these efforts, supporting everything from monitoring environmental performance to optimizing production and transportation processes.

3. **Synergy as a driver for results**: the integration of digital technologies with green development initiatives can create powerful synergies, helping to achieve sustainable environmental outcomes. Understanding how these areas interact will uncover the most effective pathways to reach sustainability goals.

4. **Challenges of instability and the need for new approaches**: global instability, driven by factors such as economic crises and pandemics, creates new challenges for sustainable development. By studying the relationship between digital technologies and green development, it is possible to develop adaptive strategies that are resilient in the face of uncertainty.

The aim of this study is to analyze the best international practices on the role of digital technologies in sustainable development, with the goal of identifying how these technologies can support the achievement of sustainable green management.

The object of this study is the creation of a sustainable environment under conditions of instability, viewed as a multifaceted social, economic, and environmental phenomenon. The subject of the study is the impact of the synergistic interaction between digital technologies and green development in fostering a sustainable environment amidst instability.

The main tasks:

– to study the impact of digital technologies on reducing the negative impact of human activity on the environment by increasing resource efficiency and reducing emissions;

– to analyse international practices of integrating digital technologies into sustainable green development processes to optimise production, transport and environmental monitoring;

– to determine the synergistic effect of combining digital technologies and green initiatives as the main driver for achieving sustainable environmental results;

– to assess the impact of instability on green development processes and formulate recommendations for increasing the resilience of socio-economic and environmental systems through digital solutions.

These tasks allow to deepen our understanding of the interaction between digital technologies and green development, as well as to contribute to the creation of effective strategies to ensure a sustainable environment in the face of instability. By combining digital technologies with green development strategies, a substantial positive impact can be achieved, particularly in uncertain conditions. Instability, characterized by unpredictability and turbulence, arises from various sources such as economic crises, political upheaval, natural disasters, and technological or socio-cultural shifts. This instability affects multiple sectors, including business, politics, economics, society, and the environment. Responding to these conditions demands adaptability, flexibility, and the development of strategies that reduce risks and enhance resilience.

Digital technologies like the Internet of Things (IoT), real-time data analytics, and smart systems can effectively monitor and address environmental concerns such as air quality, water pollution, and climate change. Smart grids and automated processes can significantly reduce energy consumption, lowering greenhouse gas emissions and promoting more sustainable urban and industrial environments. By enhancing the efficiency and reliability of renewable energy sources, digital technologies help optimize power generation and storage, while waste management systems enable better recycling and resource use.

Furthermore, digital tools can raise public awareness on environmental issues, fostering sustainable consumption and behavior among individuals and businesses. This integrated approach will be essential in addressing the challenges posed by instability and ensuring a greener, more sustainable future. Mobile apps, online courses, and other digital resources can provide information and skills for conservation. They can work synergistically, reinforcing each other to promote sustainable environmental development, even in times of instability.

3.2 Research methodology

The research employs a combination of system analysis and synthesis, Agile methodology, and a variety of other approaches, including axiological, synergistic, ecological, and humanistic methods. This methodological framework enables a comprehensive analysis of international best practices regarding the impact of digital technologies on sustainable development and facilitates the identification of how these technologies contribute to achieving sustainable green development. These approaches provide valuable insights into addressing environmental challenges and developing sustainable strategies for the responsible use of the planet's resources.

1. Ecological approach: this interdisciplinary method has evolved alongside environmental challenges and advancements in research, prioritizing environmental protection and the rational use of resources across all areas of human activity. The key principles of the ecological approach encompass international best practices for the role of digital technologies in sustainable development, strategic planning, reducing environmental impact, promoting resource recovery and recycling, increasing the use of renewable materials, managing waste, fostering social responsibility, and ensuring sustainable development.

The ecological approach is vital for preserving natural resources and ecosystems while promoting sustainable interactions between humans and the environment. It emphasizes the responsible use of resources and the interdependence of human and ecological systems.

In studying the impact of digital technologies on sustainable green development, this approach helps identify strategies to:

– use resources more efficiently;
– reduce emissions and pollution;
– increase energy efficiency;
– improve environmental management practices.

By adopting these principles, the ecological approach contributes to advancing both sustainability and the long-term protection of ecosystems.

2. The method of systematic analysis and synthesis is a powerful tool for combining various facts and best international practices into a system aimed at increasing resource efficiency and implementing circular economy models. This method allows for a comprehensive approach to resource and waste management aimed at maximizing their use and recovery. The main stages of the systematic analysis and synthesis method in this context may include: analysis of the current state; identification of key issues and challenges; analysis of international best practices; development of an integrated strategy; implementation and monitoring of existing practices. Assessment of current resource use and waste management in different countries and sectors. This includes collecting and analyzing data on resource use, waste volumes and the effectiveness of existing management models. Identify the main challenges and obstacles that hinder the efficient use of resources and the implementation of the circular economy. Research and analysis of best practices in resource and waste management from around the world. This may include successful projects, technological innovations, legislative and regulatory measures, etc. Develop a comprehensive strategy that combines best practices and innovations to increase resource efficiency and implement circular economy models. Implementing the strategy and continuously monitoring the results to identify opportunities for further

improvement. This method allows to take into account all aspects of the resource use and waste management system, creating an integrated approach that contributes to the goal of resource efficiency and sustainable use.

3. An axiological method based on the values of digital technologies for achieving sustainable green development as a factor of green sustainability; An axiological method that considers the values of digital technologies in the context of achieving sustainable green development can be based on the following aspects – defining values, assessing impacts, developing strategies. Digital technologies can stimulate innovation in solving environmental problems and contribute to the creation of a sustainable environment. An axiological analysis helps to identify the values that these technologies can embody, such as efficiency, environmental friendliness, innovation, etc. Digital technologies can have different types of impact on green development, including reducing emissions, optimizing resources, improving environmental monitoring, etc. An axiological approach allows to assess this impact in terms of the values of sustainability and green sustainability. An axiological analysis can help develop strategies for using digital technologies to increase their favorable impact on the sustainability of the environment. This can include prioritizing projects and initiatives that are most in line with green development values. An axiological approach can also help to take into account the ethical aspects of using digital technologies in green development, including issues of transparency, responsibility and justice. Thus, the axiological method allows for a deeper understanding of the value aspects of using digital technologies to achieve sustainable green development and develop strategies aimed at increasing their positive impact on environmental sustainability [1].

4. The synergistic method, which is based on self-organizing processes and the possibility of finding an attractor that can lead to synergy and overcome all the problems of the impact of digital technologies on achieving sustainable green development and environmental sustainability. A synergistic approach to the study of digital tools for the effective functioning of a sustainable ecological environment in conditions of instability, reflecting a new understanding of the analysis of complex systems, such as production systems, tax systems, ecological systems, using the tools of the synergetics methodology. According to this approach, the interaction of individual components of a complex system can lead to emergent properties and unexpected results that cannot be explained by analyzing each part of the system separately. When studying digital tools in the field of complex systems in a state of instability, the synergistic methodology is used to understand the interaction of different technologies, processes and participants in this system in order to reveal their impact on the overall result.

The synergistic method of studying this problem provides some important advantages and opportunities. The synergistic approach allows to consider the problem in the context of a complex system, taking into account the interconnections and interactions between its constituent parts. It helps to understand how digital technologies and green sustainable management interact with each other and with other elements of the system.

The synergistic approach allows to identify the emergent properties of a system – those that arise as a result of the interaction between its components.

It allows to identify unexpected or non-linear effects of digitalization in green sustainable management [2].

The synergistic method allows studying system changes over time and identifying key phase transitions or critical points when the system moves from one state to another. This helps to predict and manage changes in the system.

The synergistic approach allows for the inherent instability and nonlinearity of the system, which are characteristic of many complex systems. This helps to develop more effective change and risk management strategies. The synergistic method may include elements of various research methods, such as modelling, data analysis, expert opinions, and others. This allows for a comprehensive and in-depth analysis of the problem. The synergistic method of researching this problem provides an opportunity for a deep understanding of the relationships and interactions between digital technologies and green sustainable management strategies, which allows for the development of more effective and innovative approaches to their integration. The synergistic method involves an integrative analysis that takes into account the technical, social, economic and political aspects of using digital tools to analyze complex systems. interaction between different digital tools, socio-economic and political aspects of introducing digitalization into tax systems, as well as identifying potential risks and challenges.

5. The use of the Agile method in addressing the synergy of digital technologies and green sustainable management can have several advantages. The Agile approach allows for flexible adaptation of strategies and plans in line with changes in requirements, market conditions and technological capabilities. This is especially important in the case of complex innovation projects where digital technologies need to be combined with green sustainable management. The Agile method considers a project as a set of short iterations, each of which brings a specific result or functionality. This allows to quickly test hypotheses, experiment and make changes in the early stages of the project. The Agile approach promotes the active involvement of stakeholders in the development process, including experts in digital technologies and green sustainable management. This helps ensure that

the solutions developed meet the real needs and requirements of users. The Agile approach supports active communication and collaboration between project team members. This helps to solve complex problems through collective problem-solving and the exchange of ideas. Thanks to the iterative and flexible nature of the Agile approach, teams can quickly develop and launch new products or services. This minimizes time-to-market and allows to get feedback from users faster. In general, the use of the Agile method in addressing the synergy of digital technologies and green sustainable management allows to effectively solve complex problems and respond quickly to changes, ensuring high quality and compliance with market and consumer needs.

6. General philosophical methods – analysis and synthesis, generalization, comparison, which allowed to formulate the concept of the impact of digital technologies on achieving sustainable green development, optimizing energy consumption in buildings, industry and transport, creating smart grids and helping to use energy more efficiently and reduce emissions. "Eco-agriculture" based on a digital culture of green management. Thanks to the methods and approaches used, it is proved that the impact of digital technologies on achieving sustainable green development can be very significant and multifaceted. Digital technologies can help to implement monitoring and management systems that ensure the optimal use of resources such as energy, water and materials. The use of sensors and artificial intelligence systems to optimize production or transport system management can help reduce resource consumption and emissions. Overall, digital technologies can play a key role in achieving sustainable green development by helping to optimize resource use, reduce emissions and encourage environmentally conscious consumption [3].

Despite the significant potential of digital technologies in fostering sustainable green development, several unresolved issues remain:

1. *Inconsistent integration across sectors:* there is a lack of uniformity in the adoption and integration of digital technologies across various sectors and regions, leading to uneven progress in sustainability initiatives.

2. *Digital divide:* disparities in access to digital infrastructure, particularly in developing countries, hinder the global implementation of green development strategies.

3. *Data privacy and security concerns*: the increased use of digital tools raises concerns about data protection, privacy, and cybersecurity, which can impede the widespread adoption of these technologies.

4. *Uncertainty in measuring synergy effects*: the non-linear and emergent nature of the interaction between digital technologies and green management strategies presents challenges in quantifying their combined impact.

5. *Resource constraints and high costs*: implementing advanced digital solutions often requires substantial financial and technical resources, which can be a barrier for smaller enterprises or economically disadvantaged regions.

6. *Regulatory and ethical challenges*: the rapid evolution of digital technologies outpaces regulatory frameworks, creating gaps in governance, ethical standards, and accountability mechanisms.

3.3 Literature review

Based on the results of new research and practical findings, let's try to emphasize the importance of digital technologies that can help in implementing monitoring and control systems, ensuring optimal use of resources such as energy, water and materials. For example, the use of sensors and artificial intelligence systems to optimize production or transport system management can help reduce resource consumption and emissions. In this paper, let's rely on the research of V. Nikitenko, V. Voronkova, R. Oleksenko, H. Matviienko, O. Butkevych "Sustainable agricultural development paradigm formation in the context of managerial experience of industrialized countries" [4].

The authors rely on the applied aspects of this mechanism, that digital technologies such as solar panels and wind turbines are becoming more affordable and efficient due to continuous development. Data analytics and forecasting can help optimize energy production from renewable sources for the purpose of environmental protection and international legal protection what it is possible to found in the work of A. Getman, O. Danilyan, O. Dzeban, Yu. Kalynovsky, J. Crespo "International legal environmental protection: Historical aspect" [5]; O. Danilyan, O. Dzeban, Yu. Kalynovskyi "Social instability as a global trend of the modern world" [6].

The analysis of the work by V. Nikitenko, V. Voronkova, R. Oleksenko, H. Matviienko, O. Butkevych "Sustainable agricultural development paradigm formation in the context of managerial experience of industrialized countries" [4] proved that the use of digital technologies such as blockchain can help track, recycle and recover resources within the circular economy, reducing waste and promoting sustainable use of resources. The work of N. Metelenko, I. Klopov, V. Voronkova, V. Nikitenko, R. Oleksenko, A. Brytvienko, N. Runcheva played a major role in our research "Development of flexible management structures in the context of digital transformation of industry 5G" [7] and T. Teslenko, V. Voronkova and M. Hakova "Green agro-production as a factor of competitiveness, sustainability, efficient and ecologically safe agriculture" [8]. The literature analysis shows that digital technologies can be a powerful

tool in achieving sustainable development, helping to reduce emissions, optimize resource use and promote environmentally conscious consumption [9].

Digital technologies, such as sensors, monitoring and data analytics systems, allow companies and governments to collect and analyze large amounts of information about energy and water consumption, CO_2 emissions and other environmental indicators. This helps to identify opportunities for efficient resource use and emissions reduction, which has been confirmed in the literature: M. Graham, R. Jorgen "In search of prosperity. Managing economic development to reduce unemployment, inequality and climate change" [3]; N. Klein "Everything changes. Capitalism against the climate" [10]; D. Meadows, J. Randers, D. Meadows "The limits of growth. 30 years later" [11]. An analysis of the literature has shown that the impact of digital technologies on achieving sustainable green development can be significant and multifaceted. Digital technologies can optimize energy use in various sectors such as construction, transport and industry. Remote control, intelligent building management systems and energy-efficient networks are just a few examples.

The literature and concepts analysis of the synergy of digital technologies and green sustainable management includes an overview of modern technologies such as the Internet of Things (IoT), artificial intelligence (AI), blockchain, data analytics, etc. and their possible impact on green sustainable management. Concepts such as digital transformation and others are used to understand and describe this impact. The literature review includes research into green sustainability strategies and concepts, such as the Sustainable Development Goals (SDGs), the circular economy concept, ESG (environmental, social, governance) principles, and others. These concepts point to the importance of environmental and social responsibility for businesses. The literature review helped to identify key links between digital technologies and green sustainable management. It can include the use of digital technologies to monitor and optimize energy consumption, production and logistics, as well as to improve resource efficiency and reduce emissions and waste [12].

The literature review helped to uncover innovative approaches and practices in using digital technologies to achieve green goals. This includes using blockchain to track the production chain, implementing smart energy and water management systems, and using artificial intelligence to analyze and predict environmental performance. The literature review revealed challenges and barriers to the integration of digital technologies and green sustainable management. These may include technological limitations, cost aspects, data privacy risks, as well as cultural and organizational challenges. Overall, the literature and concepts review allow to explore various aspects of the synergy of digital technologies and green sustainable management, opening up opportunities for further research and development in this area.

3.4 Results of the study

3.4.1 Areas of influence of digital technologies on sustainable green development

The impact of digital technologies on sustainable green development is extensive and multifaceted. Key areas of influence identified in the study include:

1. **Data collection and environmental monitoring**: digital technologies facilitate the collection of vast amounts of data on environmental indicators such as CO_2 emissions, water consumption, and more. Analyzing this data enables companies and governments to make informed decisions aimed at reducing environmental impact.

2. **Sustainable mobility**: the rise of electric vehicles (EVs), charging infrastructure, and ride-sharing mobile applications have contributed to lowering emissions and reducing fuel consumption. Smart transport systems, combined with GPS, routing data, and advancements in EV technology, further enhance the efficiency of transportation, leading to reduced emissions.

3. **Circular economy and resource management**: digital technologies play a crucial role in tracking and managing resource use within a circular economy. Blockchain and similar technologies provide transparency and reliability in resource recovery and recycling, supporting the shift to a sustainable resource loop.

4. **Public awareness and sustainable consumption**: information technologies promote environmental awareness by providing easy access to information about the environmental performance of goods and services. Social media and online platforms enable companies and organizations to advocate for environmentally conscious consumption, influencing consumer behavior towards sustainable choices.

5. **Geographic information systems (GIS) and environmental modelling**: GIS and modelling tools help assess the environmental impact of construction and infrastructure projects, aiding in the mitigation of negative effects and optimizing environmentally friendly solutions.

6. **Renewable energy optimization**: digital technologies improve the efficiency and reliability of renewable energy sources, such as solar and wind power, by using weather forecasting and data analytics to predict and optimize energy production.

7. **Waste management and IoT**: Internet of Things (IoT) systems allow for real-time monitoring and management of waste and resources, improving waste management practices and increasing recycling efficiency [13].

8. **Supply chain sustainability and ESG Data**: high-quality environmental, social, and governance (ESG) data is now essential for companies seeking to build trust in the market. The 2023 revisions of the Dow Jones Sustainability Indicators (DJSI)

and the Carbon Disclosure Project (CDP) emphasize the importance of sustainable supply chain management. Digital tools such as big data analytics and AIoT allow businesses to better monitor the sustainability performance of their supply chains, helping to identify risks early and make informed decisions.

9. **Sustainable enterprise development**: companies are increasingly incorporating digital sustainability tools into their operations to enhance sustainability actions and manage costs effectively. A truly sustainable enterprise integrates sustainability from the product or service source to the deployment of digital capabilities, supporting decision-making through effective data management.

10. **Green logistics and carbon reduction**: enterprises in the logistics sector are adopting smart technologies and innovative applications to reduce carbon emissions and enhance energy efficiency. Advanced technologies like AI computing, automatic identification systems, and modern mail processing equipment significantly improve operational efficiency and accuracy, contributing to greener logistics systems.

11. **Sustainable competitive advantage through ESG**: as businesses undergo digital transformation, ESG considerations are becoming a key competitive advantage. Companies that integrate sustainability into every decision, from production to logistics, can achieve long-term success while ensuring a positive environmental impact.

Overall, digital technologies are accelerating innovation and enabling more efficient use of resources to protect the environment. However, ensuring that these technologies are employed in a sustainable and socially responsible manner is critical to maintaining the balance between technological advancement and environmental preservation [9].

Back in 2021, the EU's Digital Europe Project Group proposed the concept of a "double transition", which includes harnessing the power of digital technologies to achieve corporate sustainability goals, including corporate greenhouse gas emissions reduction, service modernization, and strengthening corporate governance. The World Economic Forum's report notes that the use of digital tools will lead to a reduction in the trinity of global leaders in the energy, materials and transport sectors. As a result, emissions will reach the goal of reducing global carbon emissions by 20 %. This shows that the use of digital tools for sustainable development has unlimited potential. In recent years, digital management platforms have become an integral trend in the transformation of sustainable development, including resource efficiency, improving sustainability performance and supporting businesses in implementing sustainable strategic development. It is necessary to use new technologies that will help reduce carbon dioxide emissions and become an indicator of success. These technologies include:

1. Introduction of carbon-free hydrogen production.

2. Development of batteries capable of storing energy for the entire season for cities.

3. Use of electric fuels.
4. Improvement of biofuels.
5. Production of carbon-neutral cement.
6. Production of carbon-neutral steel.
7. Development of carbon-neutral fertilizers.
8. Use of new generation nuclear reactors.
9. Development of nuclear fusion.
10. Implementation of technologies for carbon capture directly from the air and point removal.
11. Development of underground power lines.
12. Production of carbon-neutral plastics.
13. Use of geothermal energy.
14. Implementation of hydroaccumulation.
15. Increasing the accumulation of thermal energy.
16. Development of carbon-neutral alternatives for palm oil.

To achieve these goals, it is necessary to:

1. Increase funding for clean energy and climate change research and development fivefold.
2. Focus on ambitious but risky research.
3. Develop cooperation with industry.
4. Build appropriate infrastructure.
5. Change the emissions pattern and recognize the right choice of trajectory.

If countries start taking action today, using the power of science and innovation, they have a chance to avoid repeating the mistakes of the past. The key is to embrace innovations that not only improve technologies and processes, but also reflect the possibility of new approaches to business models, supply chains, markets and regulation. This will help to realize ideas and implement them on a global scale. Innovations are new tools and ways of doing things that are already available to humanity, but achieving zero global emissions requires the combined efforts of all nations, as it is a global problem for.

3.4.2 Global climate change as one of the greatest challenges to humanity in the 21st century

The study of the topic is that every day the economic progress of the world is accompanied by the aggravation of environmental problems. Air, water, and ocean pollution is increasing, threatening ecosystems and the survival of wild animals and

plants. The exploitation of forests and minerals poses a threat to humanity. Global climate change is having an unprecedented impact, altering weather patterns and increasing the risk of catastrophic events that threaten food production and increase flood risk. Adapting to these changes will be more difficult and costly in the future if urgent action is not taken now. Global climate change is one of the greatest challenges of the 21st century. The use of carbon-based energy, such as coal and oil, meets needs but causes climate change. Immediate action by countries and governments is needed to address this issue. Transitioning to a low-carbon climate is a challenge that encompasses climatic, political, technical, economic, environmental, social, ethical and security aspects [6].

To address global climate change and reduce greenhouse gas emissions, a wide range of technologies must be used:

1. Solar, wind, hydro, tidal and natural gas can replace coal and other fossil fuels. The use of these energy sources helps to reduce greenhouse gas emissions.

2. Energy efficiency, which is based on reducing energy use through more efficient technologies and methods of energy consumption, can significantly reduce CO_2 emissions.

3. Carbon capture and storage (CCS), which allows carbon dioxide to be removed from industrial plant emissions and stored in underground tanks, reducing emissions.

4. Green building, which is based on the use of energy-efficient materials and design, the installation of photovoltaic elements on roofs and the use of other energy-efficient systems can help reduce energy consumption in the construction and operation of buildings.

5. Electric vehicles, which aims to shift to electric cars and public transport, which can reduce oil use and reduce carbon dioxide emissions from motor vehicles.

6. Forest protection and growth, as forests play an important role in absorbing carbon dioxide. Preserving forests and increasing their area can help reduce carbon dioxide in the atmosphere.

7. Increasing environmental education and awareness, aimed at raising public awareness of global climate change and promoting environmental initiatives, can lead to changes in consumer habits and support for environmental policies. These technologies, when used together, can help combat global climate change and reduce greenhouse gas emissions.

One of the main means of addressing these issues is the Kyoto Protocol, which has the status of a legally binding document. It sets emission reduction targets that developed countries must meet. This protocol includes two commitment periods: from 2008 to 2012 and from 2013 to 2020. As of today, 198 parties to the Climate Change Convention are bound by the Kyoto Protocol, which means that

192 countries are signatories. In 2015, the 21st session of the Conference of the Parties to the Convention on Climate Change took place in Paris, during which the Paris Agreement was signed.

The Paris Agreement is a historic event, as it unites all countries of the world for the first time to achieve a common goal – to combat climate change. It provides for decisive measures to reduce emissions and adapt to the effects of climate change, in particular by attracting more support from developing countries. The main goal of the Paris Agreement is to keep the global temperature rise within 2 °C compared to pre-industrial levels and to limit the temperature increase to 1.5 °C. This agreement sets a new course for global climate action aimed at strengthening the global response to the threat of climate change [10].

In today's world, growing threats and disasters are forcing to address the well-being and security of all people as never before. This topic not only unites under unprecedented pressure, but also creates unique opportunities and motivation for change. Countries with large carbon emissions must actively work to reduce their carbon footprint. This can be done by developing sustainable development strategies that focus on energy conservation and emissions reduction. This includes energy efficiency, optimization of the energy mix and other measures. In terms of technology, it is important to develop energy-saving technologies and the use of renewable energy sources.

Investing in clean and efficient technologies will help reduce our dependence on fossil fuels and reduce greenhouse gas emissions. It is important to reduce the cost of clean energy and make it accessible to all. Through the full implementation of scientific developments and technological innovations, it is possible to achieve control over climate change and ensure the well-being and security of all people.

Greenhouse gases from human activity play an important role in providing the heat on Earth that is necessary for life. However, following industrialization, deforestation and large-scale agriculture, the amount of greenhouse gases in the atmosphere has reached levels not seen in millions of years. Population growth, economic development and rising standards of living lead to an increase in greenhouse gas emissions. The concentration of these gases in the atmosphere has a direct impact on the global average temperature. The most common of these gases is carbon dioxide, which is produced mainly by the combustion of fossil fuels. In recent years, there have been significant changes in the climate system, such as weather instability and other anomalies that have not been seen for centuries or even millennia. This indicates the need for immediate measures to reduce greenhouse gas emissions and minimize the negative impact on the Earth's climate system.

Climate change, induced by human activity and extreme weather events, has already led to a number of disasters, such as heat waves, heavy rainfall, droughts and

tropical cyclones, in different parts of the world. Approximately 3.3–3.6 billion people live in areas vulnerable to climate change. If global temperatures remain above 1.5 °C, many human communities and ecosystems will face significant risks. Reducing greenhouse gas emissions across the energy sector requires significant changes, such as a rapid reduction in the use of coal and other fossil fuels, a shift to low-emission energy sources, and increased energy efficiency and conservation. Scientific evidence suggests that the Earth›s ecosystems and climate system may be on the verge of, or have already passed, important tipping points that could lead to irreversible.

Various ecosystems, such as the Amazon rainforest and the Arctic tundra, are currently experiencing severe changes due to warming and drought. To limit global warming to 1.5 °C, rapid and profound transformations are needed in a variety of areas, including land use, energy, industry, construction, transport and urban planning. By 2030, global carbon dioxide emissions should be reduced by around 45 % compared to 2010 levels, and by 2050 they should be almost zero. This means not only reducing emissions, but also removing carbon dioxide from the atmosphere to balance the remaining emissions. Climate change can be caused by both natural internal processes and external influences, but anthropogenic factors such as changes in the composition of the atmosphere and land use play a major role in modern climate change. These changes have been observed for a long time and have serious consequences for ecosystems and life on the planet.

The greenhouse effect is the process of thermal insulation of the atmosphere, which occurs due to the trapping effect of greenhouse gases and leads to global climate change. There are several types of greenhouse gases on Earth, but the main ones are water vapor, carbon dioxide, methane, nitrous oxide, perfluorocarbons and sulphur hexafluoride. The total contribution of water vapor to the greenhouse effect is about 60–70 %, and carbon dioxide is about 26 %. Carbon dioxide is considered the most important greenhouse gas because of its long-term presence in the atmosphere, which can last up to 200 years. Even if carbon dioxide emissions stop today, the effect of previous emissions will be felt for the next two centuries [14].

Carbon dioxide is the result of both natural and human activity, and its impact on the climate is significant. Since the Industrial Revolution, human production has indeed reached unprecedented levels, leading to significant changes in the natural environment. Efforts to limit greenhouse gas emissions are indeed at the heart of the future international climate regime. Recent years have shown that more and more countries are realizing the need for sustainable development that meets social needs without endangering future generations. The transition from carbon-based energy to clean energy sources is becoming a key principle in modern energy construction. We, as a society, are not only facing the consequences of historical pollution in other

countries, but also have the right to develop today while ensuring a responsible attitude towards the future of our descendants [7].

The development of new renewable energy technologies and energy-efficient systems is becoming a critical step in reducing environmental pollution. The energy challenges are global, and the transition to new energy sources is inevitable.

All developed countries, which primarily relied on carbon-based energy sources, have gone through a period of high carbon dioxide emissions. Today, almost 90 % of the world's primary energy consumption depends on three main fossil sources: oil, coal and natural gas. However, 70 % of primary energy consumption is based on coal, which is a seriously polluting source and emits significant amounts of carbon. There is an urgent need to adjust the energy mix, reducing dependence on coal and other carbon-intensive sources and promoting a transition to clean and sustainable energy sources [15].

Currently, coal power remains the largest source of energy, determining the absolute dominant position in the energy mix. However, China is taking decisive measures to effectively control air pollutant emissions, especially from thermal power plants. The country is developing clean power generation technologies, reducing coal consumption for electricity generation, eliminating outdated production facilities, increasing energy efficiency and reducing emissions. The closure of small thermal power units and the promotion of restructuring of the electricity sector have yielded significant results. The use of wind energy is also important, especially for remote regions where other energy sources may not be available. Today, solar energy is considered to be the most ideal substitute for coal energy, as it has become a reliable and efficient source of energy without having a significant impact on the environment.

The benefits of using solar energy are enormous:

1. Sunlight is available almost everywhere and has no geographical restrictions. The production and use of solar energy can be carried out locally, which reduces the need for transportation.

2. The use of solar energy is not accompanied by emissions of harmful substances and does not pollute the environment. This reduces dependence on energy sources that have a harmful impact on the environment.

3. Solar radiation is a limitless source of energy that can be used without restrictions. Its potential exceeds the needs of modern society and can provide energy for future generations [14].

4. Solar energy reserves are infinite compared to other energy sources. The sun will continue to emit energy for tens of billions of years, making solar energy a reliable and long-term source of energy. Although there are disadvantages, such as solar radiation scattering, which reduces the efficiency of energy use, the benefits of solar

energy outweigh the disadvantages, making it one of the most attractive and environmentally friendly energy source.

Despite its advantages, solar energy also has its disadvantages:

1. A large area of photovoltaic elements or collectors is often required to generate a certain amount of solar energy conversion power, which can be costly in terms of equipment and installation.

2. Solar energy is not a stable source of energy due to the influence of weather conditions such as clouds or rain. This can make it less efficient and impractical for some areas or applications.

3. Storing solar energy for use when the sun is not shining is challenging. Currently available technologies for storing solar energy, such as batteries, can be expensive and not very efficient.

4. Some devices for collecting and using solar energy may have low efficiency and high cost, making them uncompetitive with other energy sources [16].

The development of technologies to overcome these obstacles is key to the further deployment of solar energy as a clean and efficient energy source. According to the latest data, solar energy production has the potential to become a key source of energy for the future. Although the cost of this technology is currently relatively high, with the development of technology, its production may become more affordable. This will pave the way for the large-scale use of solar energy and contribute to the development of a low-carbon economy. Climate change poses a serious threat to global food security, poverty alleviation and sustainable development. It is important that all sectors, including public and private financial institutions, commit to promoting a green economy. This will help reduce global greenhouse gas emissions and address climate change. The next decade is critical for reducing greenhouse gas emissions. In order to limit global warming to 1.5 °C by 2030, emissions must be reduced by 45 %. This will require significant efforts from governments, industry and society as a whole.

The synergy of digital technologies and green development can play a key role in addressing these challenges. Digital technologies, such as satellite observation, sensor networks and big data analytics, can help collect and analyze information on climate change. This will allow for a better understanding of the causes and impacts of climate change and more effective decision-making on how to manage it.

The use of digital technologies to optimize energy production and consumption can help reduce greenhouse gas emissions and natural resource consumption. For example, smart energy and grid management systems can automatically adjust electricity consumption depending on needs and conditions.

The development of renewable energy sources, such as solar and wind power, is helping to reduce greenhouse gas emissions and dependence on hydrocarbons.

Digital technologies can help in the efficient deployment of these energy sources and the management of energy systems [17].

Digital technologies can help to implement systems and infrastructure for climate change adaptation, such as water purification systems, flood defenses and other measures to reduce the risk of climate disasters.

Digital technologies can stimulate cooperation between sectors and countries in developing and implementing innovative solutions to reduce the impact of climate change.

Thus, the synergy of digital technologies and green development can significantly improve our ability to address the challenges of global climate change by providing more effective and innovative solutions.

3.4.3 Implementing a green strategy in the context of the ESG (environmental, social, governance) paradigm

Implementation of a green strategy in the context of the ESG (Environmental, Social, Governance) paradigm is the practice of planning and managing the urban environment to ensure sustainable development, protect the environment and improve the quality of life of residents. The main goals of a green urban development strategy include:

1. Conservation of natural resources, which includes reducing energy and water consumption, rational use of land and biodiversity, and encouraging the use of renewable energy sources.

2. Reducing emissions and pollution, which includes minimizing emissions of harmful substances into the atmosphere, water sources and soil, and promoting the use of clean technologies and environmentally friendly modes of transport.

3. Improving the quality of the environment, including increasing the number of green areas, parks, squares and other urban landscapes that contribute to improving air quality, deepening groundwater and maintaining biodiversity. Stimulating an environmentally friendly lifestyle, which includes promoting and supporting environmentally conscious habits and consumer behavior, and developing public transport, pedestrian and bicycle paths.

4. Ensuring sustainable economic growth aimed at developing green technologies and economic sectors related to environmental protection and sustainable development, as well as creating new jobs in green industries. Green urban development is aimed at creating a harmonious and environmentally balanced and synergistic urban environment that meets the needs of the current population without harming future generations [18].

The transformation of green urban development plans can include various strategies and initiatives to preserve the environment, reduce emissions, improve air and water quality, promote the conservation of natural resources and use green technologies. Improving the energy efficiency of buildings can include promoting the use of green technologies in construction, such as photovoltaic systems, energy-efficient heating and air conditioning systems, building insulation and other methods. Promoting the use of public transport can help reduce car emissions and traffic congestion, and include expanding the public transport network, promoting the use of bicycles and pedestrian paths. Increasing the number and area of green spaces in the city will help improve air quality, reduce temperature differences and improve the overall comfort of residents. Developing waste management systems, material recovery and recycling can help reduce the amount of waste going to landfills and reduce the negative impact on the environment. Promoting environmental education and awareness, including developing programmes for residents and businesses to live greener and support sustainable practices, can help to preserve the environment and increase environmental awareness. These examples are just a few of the possible green urban development strategies that can be used to improve the quality of life of residents and preserve the environment.

The following cities stand out in the context of implementing the green ESG (Environmental, Social, Governance) paradigm Singapore (city-state) is renowned as one of the most densely populated and greenest cities in the world. It is known for its innovations in green building and environmental design. The city is actively promoting its 2030 Green Development Plan, which aims to improve the quality of life for residents and reduce greenhouse gas emissions. Singapore is also a leader in sustainable tourism, striking a balance between environmental protection and economic stability. New Taipei (Taiwan) is known for its green environment and natural beauty. A large number of parks and green areas throughout the city contribute to the active use of these areas for recreation, sports and education. New Taipei actively develops and supports environmental initiatives such as green buildings, recycling programmes and energy efficiency. An extensive public transport system and bicycle paths help reduce traffic congestion and carbon emissions. Both of these cities show a strong interest in green development and sustainable environmental solutions, making them examples for other cities around the world [11].

Some countries are actively working to preserve the natural environment and implement sustainable development strategies and green technologies. Here are some examples: Copenhagen is known for its bike lanes, parks, and CO_2 reduction initiatives such as the Copenhagen Climate Plan programme. Curitiba has one of the best public transport systems in the world and many parks and green spaces for

residents. Portland is actively working to create a sustainable city, with many bike paths, parks and energy efficiency programmes. Malmö is known for its innovations in energy efficiency and renewable energy, such as green building facilities and wind turbines. Wellington has a large number of green spaces and parks, and actively encourages the use of public transport and green technologies [19]. Stockholm has an impressive amount of green space that includes parks, forests and lakes, creating natural oases in the middle of the city, and is actively implementing energy-efficient technologies and working to reduce CO_2 emissions. Freiburg is known for its environmental awareness and developed renewable energy system, and has a large number of bike paths and pedestrian areas, promoting an active lifestyle. Amsterdam is known for its cycling culture and the green corridors that run through the city. A well-developed public transport system adds to the convenience of residents, and many parks and squares add a touch of green to the city. Kyoto is renowned for its traditional Japanese gardens and green spaces, reflecting the city's natural beauty and tranquility. It is also home to energy efficiency and renewable energy initiatives. Both of these cities have demonstrated their commitment to sustainable development and nature conservation, serving as excellent examples for other cities around the world.

To create a livable and sustainable zero-emission future, the New Taipei City government held the International Forum on Zero Emission Transformation 2023 to Create a Sustainable Home, inviting experts from around the world. The government is actively working to implement the zero-emission city model, waste reduction and energy conservation, which is contributing to the rapid transformation into an international zero-emission city. In addition, the New Taipei City government has made continuous efforts in the areas of gender equality, labor rights and housing justice. The city's leadership is always innovating and pushing the envelope, bringing innovative thinking and working methods to government departments. This has helped to achieve outstanding achievements in the Sustainable Development Goals and gender equality, and to actively engage in the international arena to achieve these goals. New Taipei City Government's efforts were recently recognized by the 2023 Asia Pacific and Taiwan Sustainable Development Action Award and the "Great City" award [4].

In the context of implementing a green strategy, the Sustainable Development Goals (SDGs) and the ESG approach (Environmental, Social, Governance) are important for ensuring sustainable transformation of the urban environment, which aim to achieve a sustainable society by addressing environmental, social and governance issues, although they differ in terms of their functions and scope. The SDGs are an updated version of the Millennium Development Goals launched by the UN in 2000.

Its goal was to successfully eradicate poverty and hunger, promote basic education, advance gender equality, reduce child mortality, improve health and combat AIDS within 15 years. These 17 Sustainable Development Goals apply to all countries and encompass business, local governments and civil society. The SDGs emphasize the inextricable link between the Sustainable Development Goals, which are based on cross-sectoral integration and cooperation between countries, governments, businesses, civil society groups and individuals. Despite the fact that the SDGs are not legally binding, many companies are taking the initiative to implement them and incorporate them into their business strategies. The ESG approach (Environmental, Social, Governance) assesses the environmental, social and corporate aspects of a company's operations. It is an important tool for investors and businesses to identify and assess environmental, social and governance risks and to implement more sustainable and resilient practices. ESG criteria help companies to focus on sustainability and responsibility in their operations, as well as to meet the requirements of social responsibility and environmental standards. Both SDGs and ESGs play an important role in promoting sustainable urban development and ensuring a resilient future [20].

ESG is an acronym made up of the first letters of three English words: Environmental, Social and Governance, and is used to assess and manage risks related to the environment, social aspects and corporate governance.

Environmental includes an assessment of the environmental impact of the company's operations. It covers energy and water use, waste management, climate change and other environmentally relevant issues.

Social aspects assess the company's interaction with society, employees, customers and other stakeholders. It may include issues related to employee rights, equality, safe working conditions, community development and other socially important aspects.

Governance assesses a company's governance systems and corporate leadership. It includes questions about the governance structure, corporate ethics, anti-corruption, and openness and transparency in decision-making.

Together, these three components help companies and investors to assess the overall impact of their business on the environment and society, and to ensure that their operations are sustainable and responsible.

ESG investing is a growing trend in the financial world, as more and more investors believe that a balanced focus on environmental, social and governance aspects can improve the long-term sustainability and return on their investments:

1. Environment covers the reduction of carbon emissions and the protection of the environment. Investors take into account environmental aspects such as the impact of companies on the climate and the conservation of natural resources [21].

2. Social refers to improving the working environment, promoting diversity and other social aspects. Investors care about the impact of companies on society, including the issues of employees, consumers and other stakeholders.

3. Governance refers to fair and transparent management and proactive disclosure. Investors analyze how companies are governed, their corporate ethics and anti-corruption practices.

ESG aims to assess the risks of sustainable urban development, explore opportunities for risk control and readiness to respond to climate change, epidemics and social turbulence. Investors are also looking at zero-carbon supply chain achievements and water management, assessing companies' readiness for the environmental and social challenges of the future.

Indeed, analysis suggests that the worsening climate crisis could have a significant impact on financial markets in the long term. It is predicted that changing climate conditions will lead to radical changes in the world order, and this will require corporate organizations to adapt to new realities. In particular, they will have to respond to political and economic changes, while at the same time stabilizing their sustainable development strategies.

The adoption of the Taiwan Climate Change Response Act in 2023 is an important step in this direction. The law sets ambitious targets, such as achieving zero emissions by 2050, and introduces regulations, such as carbon pricing, to help reduce negative environmental impacts. Corporations will have to proactively define their position and develop strategies to meet the requirements of the new legislation and adapt to the changing climate. In light of these developments, corporate organizations are encouraged to actively pursue ESG strategies to ensure their future sustainability and respond to the challenges posed by climate change and increased environmental risks [22].

Indeed, the carbon issue is becoming increasingly important and influencing corporate sustainability strategies. In order to ensure a more sustainable and systematic sustainability plan, the relationship between internal and external governance must be actively considered. Thus, it is important to understand that environmental, social and governance aspects are interconnected in the process of sustainable development and transformation of enterprises. Integrating these aspects into management strategies will allow businesses to cope more effectively with the challenges posed by climate change and increasing environmental risks and ensure sustainable development in the future.

Changing the sustainability cycle in 2024 is crucial, as only about 15 % of the goals are on track. The onset of the "global boiling point" announced by UN Secretary-General Antonio Guterres requires cities to accelerate the transition from the

Net Zero initiative to discuss real strategies and solutions. It also means refocusing on social aspects, the "S" in ESG, and equity [4].

The European Union's adoption of the Green Claims Directive and the introduction of strict rules on "eco-friendly" claims on UK product labels demonstrate the growing focus on environmental issues and the need for transparency in the marketplace. The introduction of carbon dioxide emission reduction targets demonstrates the growing awareness of companies of the need to take concrete steps to reduce their impact on the climate. It is a very important step towards achieving a more sustainable and environmentally conscious world. Synergy analysis does indeed reflect important trends in the field of sustainable development and climate change. This shift from consciousness to action is indeed reflected in various sectors of society, from governments to businesses and civil society organizations, and the implementation of sustainable development requires to constantly deepen our understanding and find new ways to achieve goals in the context of the synergy of digital technologies and green development and their impact on achieving a sustainable environment in an uncertain world.

Thus, the synergy of digital technologies and green development is manifested in the implementation of a green strategy in the context of the ESG (environmental, social, governance) paradigm as follows. Digital technologies allow collecting, analyzing and using large amounts of data related to environmental and social indicators. This helps companies develop effective green development strategies, taking into account the impact of their activities on the environment and society [23].

The use of digital technologies such as the Internet of Things (IoT), artificial intelligence and data analytics can improve energy efficiency and reduce emissions. For example, smart energy management systems can optimize energy consumption and reduce waste. Digital technologies are driving innovation in green technologies and the development of environmentally friendly products and services. This can include the development of new energy-efficient technologies, the use of renewable energy sources and waste reduction. Digital technologies allow companies to collect and analyze data on their environmental and social responsibility and make this information available to stakeholders. This increases the transparency of companies' operations and helps to improve the management of environmental and social risks. Digital technologies can be used to involve stakeholders in decision-making and planning of green development strategies. This can include using online platforms to communicate with stakeholders and collect their feedback and ideas.

Overall, the synergy of digital technologies and green development allows companies to more effectively implement green strategies in the context of the ESG paradigm, which contributes to the creation of more sustainable and environmentally friendly business models [8].

3.4.4 International practices of companies in achieving sustainable green development

Far EasTone is a leading telecommunications operator in Taiwan. Joining RE100 is an important step in reducing their carbon footprint and contributing to a more sustainable development. The RE100 initiative is a global platform that brings together companies from around the world who are committed to using exclusively renewable energy sources for their operations. RE100 members are committed to reducing their carbon footprint and contributing to the transition to a more sustainable energy system.

Some key RE100 initiatives include:

1) commitment to 100 % renewable energy: companies that join RE100 commit to achieving 100 % renewable energy for their operations within a specified timeframe;

2) collaboration and knowledge sharing: RE100 members share experiences and best practices in the use of renewable energy sources, which helps to spread these practices in the business environment;

3) supporting sustainable development: RE100 members demonstrate their commitment to sustainable development and reducing their impact on climate change through the use of clean energy;

4) influencing policy: by bringing together large companies and committing to 100 % renewable energy, the RE100 initiative can influence policy development and create favorable conditions for the development of clean energy;

5) visibility and leadership: companies that join RE100 act as leaders in the transition to renewable energy, which can encourage other companies to make similar commitments. The RE100 initiative has a significant impact on promoting sustainable development and reducing climate change impacts by accelerating the transition to renewable energy in large corporations and companies.

It can also serve as an example for other companies in the telecoms industry and other sectors to switch to cleaner energy sources.

To achieve the zero-emission sustainability goal, Far EasTone continues to develop environmentally friendly information and communication technologies through technological innovation. They are implementing low-carbon operations, collaborating with value chain partners and corporate customers to move towards sustainability together [8].

RE100 is a global initiative that brings together leading companies from around the world who are committed to using exclusively renewable energy sources for their operations. Far EasTone's joining RE100 means that they have committed to switching to exclusively renewable energy sources for their needs.

To accelerate the transition to zero net energy, Far EasTone has joined the RE100 Global Renewable Energy Initiative, committing to use 100 % renewable energy in all IDC computer rooms, offices and stores in Taiwan by 2030 and to achieve full use of renewable energy across the company by 2040.

Far EasTone Telecommunication is committed to building the most environmentally friendly telecommunications network. The company is using artificial intelligence to select 5G base stations to maximize network efficiency and is introducing technology to effectively reduce base station power consumption without compromising user experience.

Far EasTone is the first telecoms operator in Taiwan to join the Global Plan for the Recycling of Telecommunications Equipment for Environmental Protection. The recycling rate of base stations will reach 98 %, effectively reducing e-waste and allowing everyone to enjoy the quality of the 5G network while considering sustainability and environmental protection. Far EasTone is actively investing in environmental protection and greenhouse gas emission reduction through technological innovation to help enterprises with one-stop smart management capabilities. In addition, the company is investing in the construction of remote microgrids, uninterruptible power supply systems for traffic signs, universal intelligent control systems, and 5G remote diagnostics to create a sustainable smart city [24].

Far EasTone's efforts are aimed at creating an environmentally friendly, sustainable and innovative telecommunications network that demonstrates their commitment to environmental protection and the development of a sustainable society. Through the use of advanced technologies such as artificial intelligence and remote diagnostics, the company is developing in an environmentally friendly way, reducing its environmental impact and promoting sustainable development. In summary, the integration of digital technologies into companies' operations is becoming a key factor in achieving sustainable development [25].

Far EasTone is an example of a company that actively uses these technologies to ensure efficiency, sustainability and innovation in its operations, contributing to the preservation of the environment and the development of a sustainable society. Humanity will ultimately follow the path of "digital sustainability" as it will have a profound impact on the future development of humanity. Some companies propose to add digital technologies as the SDG 18, as digital advancement and the original 17 goals are interconnected. For example, digital transformation impacts employment opportunities, the digital divide exacerbates social inequality, remote learning can bridge the educational resource gap in rural areas, smart grids can enhance the resilience of key institutions, and digital healthcare can improve human health and well-being. Therefore, it is essential to comprehensively study the potential

impact of digital development on humanity's sustainability, and digital evolution itself should also incorporate the concept of sustainability.

Digital resilience can be defined as the integration of virtual and real systems, fostering innovative viability, continuously advancing digital transformation, and practicing social, economic, and environmental sustainability to create a sustainable future for humanity [2].

Here are examples of companies that have joined the RE100 initiative:

1. Google: this tech giant has committed to using 100 % renewable energy for all its operations and data centers.

2. Apple: Apple has also joined RE100 and announced its goal to transition entirely to renewable energy sources for all its factories, offices, and data centers.

3. Microsoft: Microsoft has committed to achieving 100 % renewable energy usage for its operations and software production.

4. IKEA: the Swedish retail company produces and uses its own renewable energy, such as wind and solar, for residential construction and its stores.

5. Inditex: one of the world's largest clothing manufacturers, known for brands like Zara, has pledged to use 100 % renewable energy for all its operations by 2025.

These companies are just a few examples among many organizations that have joined RE100, committing to reducing their carbon footprint through the use of renewable energy. Joining RE100 signifies their pledge to operate using energy generated from renewable sources such as solar, wind, water, and other inexhaustible sources. This commitment is a significant step for these companies in reducing their carbon emissions and promoting sustainable development. They recognize the importance of transitioning to clean energy sources to protect the environment and mitigate climate change [26].

Achieving synergy between digital technologies and green development requires a comprehensive and systematic approach. A key step is defining common goals for both areas – digital technologies and green development. This can include reducing carbon emissions, improving energy efficiency, and protecting biodiversity.

Implementing modern digital technologies, such as the Internet of Things (IoT), data analytics, and artificial intelligence, for the collection, analysis, and monitoring of environmental data will help understand the effectiveness of environmental measures and uncover new opportunities for green development [27].

Creating incentives for the development and implementation of innovative solutions that combine digital technologies and green development can include financial support, competitions, startup incubators, and other initiatives. Establishing partnerships between digital technology industries and green businesses will facilitate

knowledge and experience exchange, allowing for joint development and implementation of initiatives aimed at reducing environmental impact.

Raising awareness among the public, businesses, and government structures about the benefits of synergy between digital technologies and green development will help engage more participants in this process and support the creation of a favorable environment for these initiatives to grow.

All these steps will contribute to fostering an effective synergy between digital technologies and green development, leading to the creation of a sustainable and eco-friendly future. These examples show that companies from various industries recognize the importance of adopting responsible, sustainable practices and are taking steps to reduce their carbon footprint by switching to renewable energy sources.

International company practices in achieving sustainable green development can provide valuable insights for Ukraine. Many global companies are taking measures to reduce emissions and resource usage, which helps decrease their environmental footprint. Ukrainian companies can prioritize responsible production and resource management approaches. International companies are actively adopting renewable energy sources, such as solar and wind power, to reduce their carbon footprint and dependency on fossil fuels. Given Ukraine's strong potential in wind and solar energy, there are significant opportunities in this area [28].

*Companies are also embracing the prin*ciples of the circular economy, aimed at minimizing waste and maximizing resource use. This can include waste recycling, reducing packaging use, and producing more durable goods. Furthermore, businesses are developing strategies to adapt to climate change, as their operations may be at risk due to its impacts. This includes taking measures to mitigate climate-related risks and ensuring the sustainability of raw material supplies.

Many international companies adhere to global sustainability standards, such as ISO or the UN Global Compact. These helps ensure high standards of environmental and social responsibility.

It is crucial for Ukrainian companies to consider these international practices and incorporate them into their operations to achieve sustainable green development. This approach will not only reduce the negative environmental impact but also ensure competitiveness and stability in the long term [29].

Some examples of practical applications of digital technologies can be incorporated, among them:

1. *Google's use of Artificial Intelligence for renewable energy optimization.*

Google applies advanced AI algorithms to predict energy demand and optimize the use of renewable energy sources in its data centers. For instance, its AI-driven system predicts weather patterns to determine the most effective times to store

and utilize solar and wind energy. This approach has enabled Google to achieve 100 % renewable energy usage across its operations while minimizing costs and energy waste.

2. *Microsoft's carbon negative initiative and IoT solutions.*

Microsoft has committed to being carbon negative by 2030 and employs IoT technologies for efficient resource management in its buildings. Smart IoT sensors track real-time data on energy and water usage, allowing for precise adjustments and reducing wastage. Additionally, Microsoft's AI solutions help businesses worldwide optimize energy consumption and minimize emissions.

3. *IKEA's circular economy platform and digital solutions.*

IKEA integrates digital solutions to promote its circular economy initiatives, such as its buy-back and resell program for furniture. Digital tracking systems monitor the lifecycle of products, helping reduce waste and encourage recycling. The company also uses blockchain to ensure transparency in its supply chain, focusing on sustainable sourcing and waste minimization.

4. *Tesla's smart grid and energy storage systems.*

Tesla has revolutionized renewable energy integration with its digitalized Powerwall and Powerpack systems. These systems enable smart grids to store surplus renewable energy and distribute it efficiently during high-demand periods. Coupled with real-time data analytics, Tesla's solutions reduce energy loss and improve the sustainability of energy grids.

5. *Siemens' smart cities initiative.*

Siemens leverages digital technologies, including IoT and AI, to optimize urban infrastructure for sustainable green development. The company's smart building systems monitor energy use and automatically adjust settings to minimize consumption. Additionally, Siemens provides digital platforms for managing smart grids, improving energy efficiency, and integrating renewable energy into urban areas.

6. *Unilever's digital water management solutions.*

Unilever uses advanced digital tools to monitor water usage across its production facilities. With IoT sensors and AI analytics, the company has significantly reduced water consumption and improved its wastewater recycling processes, contributing to more sustainable manufacturing.

These examples not only demonstrate the diversity of digital technologies being used globally to achieve sustainable green development but also highlight their practicality and scalability.

Ukrainian companies can adopt and adapt these practices to local contexts, focusing on renewable energy, resource efficiency, and waste reduction to foster long-term sustainability.

3.4.5 Key principles for implementing green sustainable management strategies

"Green sustainable management" is a business management approach that combines strategic planning, management practices, and innovative solutions to achieve sustainable development while minimizing negative environmental impact.

Principles in **Table 3.1** align with the core tenets of green sustainable management and contribute to fostering a more sustainable and responsible business environment. In essence, green sustainable management aims to strike a balance between environmental, social, and economic responsibilities to support sustainable development.

Table 3.1 Key principles of green sustainable management

No.	Principle	Contents and development direction
1	Environmental responsibility	Green management aims to reduce waste, use renewable energy sources and conserve resources
2	Social responsibility	Companies practicing green management pay attention to social aspects such as employees, communities and general well-being
3	Economic efficiency	Green management also aims to reduce costs, optimize processes and create new opportunities for sustainable development, leading to economic benefits
4	Innovations	Green management promotes innovation in production, technology and management to ensure more efficient use of resources and reduce environmental impact
5	Long-term perspective	Green management takes into account the long-term consequences of its actions and makes decisions aimed at preserving resources and sustainable development in the future
6	Transparency and reporting	Companies applying green management report on their sustainability actions and achievements to ensure transparency with stakeholders and consumers
7	Effective risk management	Green management takes into account potential environmental and social risks in its strategy and activities, and develops mechanisms for their management to prevent negative consequences
8	Involvement of interested parties	Green management takes into account the opinion and interests of various stakeholders, such as customers, employees, shareholders and public organizations, in the decision-making process
9	Environmental innovation	Green management stimulates the search and development of new environmentally friendly technologies, products and services that contribute to reducing the impact on the environment
10	Training and development	Companies that practice green management provide training opportunities for their employees on the principles of sustainable development and environmental responsibility

Source: developed by the authors

It ensures that both public and private sectors remain operational in the face of various changes, including the introduction of new commercial and public services, protection of critical assets, and the rapid accumulation of digital resources like data and NFTs. Therefore, leveraging digital technologies effectively is essential to building a national ecosystem of resilience. This is crucial for securing critical infrastructure, managing vital resources, facilitating rapid disaster recovery, enhancing interagency and public-private cooperation, and ensuring seamless information sharing [30].

The practice of digital sustainability will enhance people-centered governance, strengthen digital government functions, foster a culture of innovation, and complete the establishment of digital legal frameworks to bolster social trust. It also promotes broadband development in both urban and rural areas. For example, smart governments can implement comprehensive data management systems to protect citizens' personal information, making government services more accessible online. This will empower citizens to effectively engage with online services. Digital sustainability also promotes social inclusion, fosters an inclusive online community, strengthens democratic digital practices, and ensures equal opportunities for public digital development [31].

To achieve digital sustainability, enterprises should adopt the following strategies:

1) establish a robust digital governance system to safeguard digital human rights and promote digital trust, democracy, and stability. This includes the right to lifelong learning of digital skills, broadband access, personal data management, participation in online public affairs, and equal digital development opportunities;

2) foster innovation and embrace digital diversity as key drivers of sustainable development. This approach should reflect the diversity of national behaviors, cultural and environmental variations, and expand workforce participation to create an optimized economic structure;

3) strengthen national digital capabilities and connect diverse talent. This strategy involves raising digital literacy across the population, developing new digital talents, and leveraging the global digital elite. Human capital is foundational to sustainability;

4) enhance information security management and bolster national digital resilience. This involves creating a national ecosystem that is adaptable, integrating communication systems and human resources for effective national mobilization;

5) promote the integration of digital technologies and foster an inclusive digital economy and society. This includes advancing the digital and zero-carbon transformation in both public and private sectors, promoting smart and low-carbon operations, and ensuring digital innovations align with societal values of trust and democracy;

6) expand the digital frontier and uphold core values. The strategy should focus on "responsible manufacturing" by producing eco-friendly and secure digital solutions, positioning enterprises as global suppliers of sustainable digital technologies.

Developing strategies for digital sustainability within enterprises is critical. Green sustainable management encompasses the resilience to digital threats, safeguarding confidential information, and maintaining operational continuity, even during cyber-attacks or other disruptions [26].

Key components of these development strategies include:

1) conducting a comprehensive risk analysis to identify potential digital threats and vulnerabilities within the enterprise;

2) developing and implementing policies, procedures, and technological solutions to protect digital assets from potential threats;

3) ensuring that all employees are well-informed about digital threats, preventive measures, and incident response procedures for security breaches;

4) establishing and implementing data backup and recovery strategies to prevent the loss of critical information due to cyberattacks or unforeseen incidents;

5) adopting advanced technologies and protection methods, as well as continuously updating software and hardware to mitigate emerging digital threats;

6) performing regular security audits to identify vulnerabilities in information protection and ensure effective internal controls;

7) engaging security experts for consultations and developing more effective strategies to safeguard against digital threats [32].

Implementing these strategies will help enterprises maintain digital resilience and reduce the risk of data loss or security breaches, which could severely impact their operations. Digital technologies can play a pivotal role in achieving sustainable green development by accelerating innovation and minimizing negative environmental impacts. Below are some best practices in utilizing digital technologies for sustainable green development that have been successfully implemented internationally (**Table 3.2**).

These best practices demonstrate that digital technologies can serve as a powerful tool for achieving sustainable green development, accelerating the transition to environmentally friendly and sustainable economies. They not only help reduce negative environmental impacts but also contribute to economic growth and enhance competitiveness, making them key components in achieving sustainable green development.

The theoretical significance of the impact of digital technologies on sustainable green development lies in their potential to address complex environmental challenges, ensure the sustainability of natural resources, and reduce the negative effects of human activity on the environment [33].

Table 3.2 Best practices for using digital technologies in sustainable green development

No.	Best practices	Content and direction of sustainable green development
1	Intelligent energy networks	The introduction of digital monitoring and control systems in energy networks allows optimizing energy production and consumption, increasing efficiency and reducing harmful gas emissions
2	Smart agriculture	Use of data from sensors, drones and other digital technologies to optimize crop production, reduce the use of chemical fertilizers and resources, while conserving water and soil
3	Digital technologies in urban planning	The use of smart systems to control transport, lighting and water supply can reduce energy consumption and pollution, and improve the quality of life for city dwellers
4	Digital platforms for waste management	Developing digital systems that help track, manage and recycle waste more efficiently, promoting recycling and reducing emissions
5	Internet of Things (IoT) for sustainable production	The introduction of IoT sensors and communications in production processes can improve monitoring, planning and resource management, reducing costs and environmental impact
6	Using Artificial Intelligence (AI) for environmental monitoring	The use of AI to analyze large volumes of data allows for the timely detection of environmental problems and the development of effective strategies to solve them
7	Digital carbon credit markets	The emergence of digital platforms and blockchain technologies is enabling the creation of carbon credit markets where businesses can trade CO2 emissions and incentivize environmental investments and emissions reductions
8	Digital solutions in water supply and water treatment	The use of digital technologies in water supply and water treatment enables efficient management and monitoring of treatment processes, reducing energy and chemical consumption, which helps to conserve water resources and reduce pollution
9	Digital solutions in forestry and logging control	The use of drones, satellite monitoring and artificial intelligence allows for effective monitoring and management of forest resources, preventing illegal logging and promoting sustainable forestry
10	The use of blockchain technologies in renewable energy	Blockchain can be used to track and certify renewable energy, ensuring transparency and integrity of data on its production and use
11	Electronic payment systems to encourage sustainable purchases	The introduction of electronic payment systems and loyalty programmes that provide discounts and bonuses for environmentally friendly goods and services can encourage consumers to consume sustainably
12	Digital technologies for climate change adaptation	The development and use of digital tools for predicting, monitoring and managing the effects of climate change helps to reduce its negative impact and increase resilience to its consequences

Source: compiled by the authors

Theoretical aspects include:

1. **Efficient resource utilization** – digital technologies enable the optimization of production processes and resource consumption, leading to reduced waste and pollution.

2. **Environmental monitoring and management** – through sensors, IoT, and data analytics, it is possible to effectively monitor the environment and respond to emerging negative trends.

3. **Promoting eco-friendly consumption** – digital solutions can raise consumer awareness of their environmental impact and encourage more environmentally conscious decision-making [34].

4. **Climate change forecasting and response** – the use of data analytics and artificial intelligence allows for more accurate climate change predictions and timely responses to their effects.

The synergy between digital technologies and green sustainable management strategies can be realized through several key principles:

– digital technologies enable the collection of large volumes of data on environmental indicators such as emissions, resource, and energy use, as well as the social impacts of businesses. Analyzing this data helps companies understand their environmental footprint and the social implications of their operations;

– the integration of technologies like the Internet of Things (IoT), artificial intelligence, and data analytics allows for the creation of "smart" management systems that optimize resource and energy usage, while minimizing waste and emissions;

– digital technologies facilitate efficient planning and resource management, reducing losses and optimizing resource usage, which aligns with the principles of green sustainable management;

– they also enable enterprises to ensure transparency and openness in their operations, including environmental and social performance, which enhances stakeholder engagement and trust in the business;

– stimulating innovation and green initiatives;

– digital technologies can drive innovation and the development of green solutions, supporting the implementation of green sustainable management strategies;

– digital tools can engage employees and stakeholders in the development and execution of green sustainable management strategies, fostering greater involvement and accountability.

Overall, the synergy between digital technologies and green sustainable management strategies allows businesses to more effectively implement green initiatives, reduce their environmental footprint, and contribute to sustainable development [35].

3.5 Conclusions

The theoretical significance of researching the synergy between digital technologies and green sustainable management strategies is determined by the following key aspects:

1. The research reveals the opportunities that digital technologies offer in green sustainable management. This includes identifying effective ways to leverage information technologies, the Internet of Things (IoT), data analytics, artificial intelligence, and other tools to optimize environmental efficiency and reduce negative impacts on the environment.

2. The study promotes the development of concepts and models that explain the mechanisms of interaction between digital technologies and green sustainable management. This could involve the creation of synergy theories, concepts of digital transformation in green business, and other related aspects.

3. The research defines key principles and strategies that help effectively integrate digital technologies with green sustainable management. This includes developing methodologies, guidelines, and recommendations for businesses and government organizations.

4. The study allows for the comparison and analysis of best practices in using digital technologies for green sustainable management. This helps identify successful strategies and methods that can be applied in various contexts.

5. The research fosters the development of new ideas and innovations in green sustainable management, including new approaches to solving environmental problems, developing new products and services, and building a sustainable economy.

The research on the synergy between digital technologies and green sustainable management strategies holds significant theoretical value as it contributes to advancing scientific knowledge and understanding the interconnectedness of these two areas of management.

The practical significance of the research includes real-world initiatives and projects that are already being implemented and showing successful results in achieving sustainable green development. The practical aspects of the impact of digital technologies on sustainable green development include:

1. Implementation of smart technologies in urban planning and transport: smart cities and smart transportation systems contribute to reducing emissions, improving energy efficiency, and enhancing the quality of life for residents.

2. Digital carbon credit markets and ecosystems: these platforms support the financing and promotion of projects aimed at reducing emissions and preserving the environment.

3. Smart agriculture and data-driven optimization: the use of advanced technologies in agriculture increases crop yields while reducing the negative impact on the environment.

4. Electronic waste management systems and resource recovery: digital solutions enable effective waste management and ensure the reuse or recycling of materials.

Theoretical knowledge about the potential of digital technologies for sustainable green development contributes to the development and implementation of practical initiatives that can genuinely improve the global environmental situation.

The synergy of digital technologies and green development plays a crucial role in achieving a sustainable environmental future, especially in the face of instability. Digital technologies such as artificial intelligence, the Internet of Things, and data analysis can be used to collect, analyze, and monitor environmental data, aiding in environmental management and problem detection. They also help optimize production processes and energy management, which can lead to a reduction in harmful emissions and resource consumption. For example, the use of "smart" energy management systems in construction can reduce electricity and water consumption.

Green development emphasizes an environmentally protective approach to development, considering the needs of modern society. This includes the use of renewable energy sources, reducing emissions into the atmosphere, and preserving natural resources. The synergy of these two directions lies in the fact that digital technologies can support the implementation of green initiatives. For instance, modern technologies in the transport sector can facilitate the introduction of electric vehicles and the development of charging infrastructure. Data analysis can help identify areas with the highest environmental stress and develop effective protection strategies.

In conditions of instability, such as climate change, economic instability, or crisis situations, the importance of this combination becomes even more evident. It enables more effective responses to challenges, ensuring a sustainable environmental future and reducing its vulnerability.

References

1. Altrade, D. (2021). New thinking. From Einstein to artificial intelligence: science and technology that changed the world. Kharkiv: Vivat, 368.
2. Fon Vaytszeker, E. U., Anders, V. (2019). Capitalism, Short-termism, Population and the Destruction of the Planet. Kyiv: Samit-Knyha, 276.

3. Maxton, G., Randers, J. (2017). In search of prosperity. Managing economic development to reduce unemployment, inequality and climate change. Report to the Club of Rome. Kyiv: Pabulum, 320.
4. Nikitenko, V., Voronkova, V., Oleksenko, R., Matviienko, H., Butkevych, O. (2023). Sustainable agricultural development paradigm formation in the context of managerial experience of industrialized countries. Revista de La Universidad Del Zulia, 14 (39), 81–97. https://doi.org/10.46925//rdluz.39.05
5. Getman, A. P., Danilyan, O. G., Dzeban, O. P., Kalynovskyi, Y. Y., Crespo, J. E. (2021). International legal environmental protection: historical aspect. Revista Notas Históricas y Geográficas, 27, 389–413. Available at: https://dspace.nlu.edu.ua/handle/123456789/19663
6. Danilyan, O. G., Dzeban, O. P., Kalynovskyi, Y. Y. (2022). Social instability as a global trend of the modern world. Cogito, 14 (3), 141–161. Available at: https://cogito.ucdc.ro/COGITO_SEPTEMBER_2022.pdf
7. Metelenko, N., Klopov, I., Voronkova, V., Nikitenko, V., Oleksenko, R., Brytvienko, A., Runcheva, N. (2023). Development of flexible management structures in the context of digital transformation of industry 5G. International Journal of Membrane Science and Technology Review of Economics and Finance, 10 (3), 2052–2060. Available at: https://refpress.org/wp-content/uploads/2023/12/Oleksenko-3_REF.pdf
8. Teslenko, T., Voronkova, V., Hakova, M. (2023). Green agro-production as a factor of competitiveness, sustainability, efficient and ecologically safe agriculture. E3S Web of Conferences, 452, 01001. https://doi.org/10.1051/e3sconf/202345201001
9. Eco Forum – 2021 (2021). Zaporizhzhia, 311.
10. Naomi, K. (2016). Everything changes. Capitalism against the climate. Kyiv: Nash Format, 480.
11. Meadows, D., Randers, J., Meadows, D. (2018). Growth limits. 30 years later. Kyiv: Pabulum, 464.
12. Gulac, O., Marchenko, O., Kapitanenko, N., Kuris, Y., Oleksenko, R. (2022). State environmental policy on the issue of legal regulation of fire safety in the forests of Ukraine. Cuestiones Políticas, 40 (74), 195–206. https://doi.org/10.46398/cuestpol.4074.10
13. Gramchuk, M., Nikitenko, V. (2023). Present trends and prospects of smart city development. Humanities Studies, 91 (14), 35–41. https://doi.org/10.32782/hst-2023-14-91-04
14. Klopov, I., Shapurov, O., Voronkova, V., Nikitenko, V., Oleksenko, R., Khavina, I., Chebakova, Y. (2023). Digital Transformation of Education Based on Artificial Intelligence. TEM Journal, 12 (4), 2625–2634. https://doi.org/10.18421/tem124-74

15. Metelenko, N., Voronkova, V. (2021). Pytannia hlobalnoho poteplinnia klimatu yak rezultat diialnosti liudyny. Eco Forum – 2021. Zaporizhzhia, 104–105.
16. Metelenko, N. G, Voronkova, V. G., Nikitenko, V. O., Silina, I. V.; Tabachnikov, S. (Ed.) (2023). Formation and development of the smart economy and its modifications in the context of digital development. Vectors of the development of science and education in the modern world. Sherman Oaks: GS Publishing Services, 79–95. https://doi.org/10.51587/9798-9866-95976-2023-014
17. Metelenko, N., Voronkova, V., Silina, I., Ohloblina, V.; Tabachnikov, S. (Ed.) (2023). Evolution from traditional to intelligent logistics models in digitalization conditions (using international experience). Socio-humanitarian and technicaltechnological explorations of modern science. Sherman Oaks: GS Publishing Services, 79–94. https://doi.org/10.51587/9798-9866-95983-2023-015-64-78
18. Marienko, V. (2024). The influence of information and communication technologies (ict) on the development of society, humans, and technology: a social and philosophical analysis. Educational Discourse: Collection of Scientific Papers, 47 (12), 61–72. https://doi.org/10.33930/ed.2019.5007.47(12)-6
19. Nikitenko, V. O., Voronkova, V. G., Oleksenko, R. I. (2023). Rozumne eko-misto yak chynnyk uprovadzhennia zelenoho budivnytstva ta tsyfrovykh tekhnolohii. Green Construction. Kyiv: Kyiv National University of Construction and Architecture, 166–172.
20. Nikitenko, V., Voronkova, V., Oleksenko, R., Filoretova, L., Lanoviuk, L., Khvist, V. (2023). Perspectives of civilizational political development of world regions in the context of current challenges and opportunities. Cuestiones Políticas, 41 (76), 274–291. https://doi.org/10.46398/cuestpol.4176.15
21. Nikitenko, V., Andriukaitiene, R., Punchenko, O. (2019). Formation ofsustainable digital economical concept: challenges, threats, priorities. Humanities Studies, 1 (78), 140–153. https://doi.org/10.26661/hst-2019-1-78-11
22. Nikitenko, V. A., Voronkova, V. H., Andriukaitiene, R., Oleksenko, R. I. (2021). The crisis of the metaphysical foundations of human existence as a global problem of post-modernityand the ways of managerial solutions. Propósitos y Representaciones, 9(SPE1). https://doi.org/10.20511/pyr2021.v9nspe1.928
23. Oleksenko, R., Kolokolchykova, I., Syzonenko, O. (2019). Ukraine in the Context of the World Organic Production of Agricultural Products. Modern Development Paths of Agricultural Production. Cham: Springer International Publishing, 507–514. https://doi.org/10.1007/978-3-030-14918-5_51
24. Trusova, N. V., Oleksenko, R. I., Kalchenko, S. V., Yeremenko, D. V., Pasieka, S. R., Moroz, S. A. (2021). Managing the Intellectual Potential in the Business-Network

of Innovative Digital Technologies. Studies of Applied Economics, 39 (5). https://doi.org/10.25115/eea.v39i5.4910
25. Kyoto protocol (1992). United Nation. Available at: https://en.wikipedia.org/wiki/Kyoto_Protocol Last accessed: 14.11.2022
26. Voronkova, V. G., Azhaja, M. A., Nikitenko, V. (2021). Tsyvilizatsiia, zalezhna vid-vykopnoho palyva. Eco Forum – 2021. Zaporizhzhia, 80–81.
27. Voronkova, V., Nikitenko, V. (2021). Suchasni shliakhy zmenshennia vykydiv-vuhlekysloho hazu yak indykator dosiahnennia uspikhu. Eco Forum – 2021. Zaporizhzhia, 78–79.
28. Voronkova, V. H., Nikitenko, V. A., Teslenko, T. V., Bilohur, V. E. (2020). Impact of the worldwide trends on the development of the digital economy. Revista Amazonia Investiga, 9 (32), 81–90. https://doi.org/10.34069/ai/2020.32.08.9
29. Woomeck, J., Jones, D. (2019). Berezhlyve vyrobnytstvo. Yak pozbutysia vtrat i dobytysia protsvitannia vashoi kompanii. Kharkiv: Ranok: Fabula, 448.
30. Voronkova, V., Nikitenko, V., Oleksenko, R., Andriukaitiene, R., Kharchenko, J., Kliuienko, E. (2023). Digital Technology Evolution of the Industrial Revolution From 4G to 5G in the Context of the Challenges of Digital Globalization. TEM Journal, 12 (2), 732–742. https://doi.org/10.18421/tem122-17
31. Voronkova, V., Nikitenko, V., Oleksenko, R., Andriukaitiene, R., Polysaiev, O. (2023). Environmental crisis overcoming as a factor for achieving economic sustainability in the context of the European green course. Cuestiones Políticas, 41 (77), 612–629. https://doi.org/10.46398/cuestpol.4177.41
32. Voronkova, V., Burashnikova, O. (2024). Synergistic methodology for researching digital tools for the effective functioning of the tax system. Digital Economy and Economic Security, 1 (10), 60–66. https://doi.org/10.32782/dees.10-11
33. Vysochanska, M., Zubchenko, V., Koval, A. (2023). Ecological and economic process of adaptation of berry cultivation in Ukraine. International Journal of Innovative Technologies in Economy. 2 (42). https://doi.org/10.31435/rsglobal_ijite/30062023/7996
34. Cherep, A., Voronkova, V., Nikitenko, V., Cherep, O. (2023). The concept of circular or closed-cycle economy as a variety of a new type of economy. Vectors of the development of science and education in the modern world. Sherman Oaks: GS Publishing Services, 96–113. https://doi.org/10.51587/9798-9866-95976-2023-014-96-113
35. Cherep, O. H., Babajanov, B. A., Voronkova, V. H. (2022). Digitalization of the economy as a platform for creating new values in a transformational environment. Financial Strategies of Innovative Economic Development, 54 (2), 25–28. https://doi.org/10.26661/2414-0287-2022-2-54-04

CHAPTER 4

Project management within the national economy in turbulent conditions

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Abstract

Project management is an institutional element in the development of modern management. It involves processes where specific enterprises and organizations receive orders for implementing particular projects and form teams to achieve goals in production and other processes. However, projects also exist at the level of the national economic environment. For instance, the government can organize a tender for completing a certain task, which is also a project executed by entrepreneurs to achieve macroeconomic goals. These projects must be innovative because only high-tech solutions can achieve high efficiency, aligning with the overall development level of the national economy.

It should be noted that the study of management projects at the macro level is a new aspect of economic science. This article reveals the theoretical issues of the development and evolution of macro-projects, assesses the state of project management in the national economy of Ukraine, highlights issues related to the creation of clusters as state projects, and identifies applied issues of project management at the macro level.

The national economy consists of various sectors and enterprises, which can form clusters in different regions of the country. Thus, the Italian economy is characterized by a high degree of clustering. This example can be applied to Ukraine by stimulating regional economic growth. Clusters are regional projects that unite related and supporting industries and enterprises. In Ukraine, a cluster such as "agriculture – food industry" could be formed, serving as a national economic development project while taking into account the specificities of different regions.

Ukraine is currently in a state of war, a highly critical situation. The full-scale invasion by Russia has revealed numerous vulnerabilities in both individual enterprises

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and the national economy as a whole, including dependency on imported raw materials and their equivalents, a lack of high-tech innovations of Ukrainian origin for defense systems, and more. Given this, it is important to recognize that the country's economy is in a state of turbulence, and there is a need to propose solutions for overcoming the military crisis.

Keywords

Project management, project management on the macro level, industrial districts, turbulent conditions.

4.1 Theoretical approaches to project management at the macro level

It is important to note that the aim of this research is to determine the conditions for the development of project management at the macro level in the context of an unstable national and international environment.

The objectives that allowed to achieve this aim were as follows:

– define the scientific approaches and existing schools of thought regarding project management at the macro level;

– characterize the conditions for the creation of projects at the macro level in Ukraine;

– explore the possibilities of establishing clusters as macro projects in Ukraine, drawing on Italian experience;

– assess the state of project management in Ukraine amid turbulence.

The primary objective of management bodies at the macro level is the stable development of the state and its society, while adhering to routine processes established by legislation. However, turbulence in both the external and internal environments of the state leads to constant changes. New technologies, digitalization, the information surge, along with new challenges and tasks focused on the needs of citizens and businesses, require adaptations at the macro level.

The application of project management principles and fundamentals by government institutions, alongside functional activities, is aimed at addressing and implementing the strategic directions of the state, developing new products, or enhancing the quality of public services. Consequently, public sector institutions face the challenges of managing interrelated processes and ensuring the successful execution of projects. Specifically, project management holds a critical position in the development of any organization, and the public sector (macro level) is no exception. Government projects implement unique directions that demand specific strategies for success. In this article, let's explore the key principles, essential tools and

methods, as well as the importance of building a competent public project management team in the context of turbulence.

At the macro level, the value of project management for managing complex projects and initiatives of government bodies has long been recognized. It provides an effective tool for managing resources, adhering to timelines, establishing budgets, tracking progress, controlling costs, and ensuring quality outcomes. Project management is rapidly becoming a critical component of effective government operations due to the increasing complexity of modern public policy initiatives.

By integrating project management principles into operational activities, government organizations can enhance their efficiency while simultaneously reducing risks and costs associated with large-scale programs.

It should be noted that research on the use of projects in the corporate world is extensively analyzed [1], while empirical studies at the macro level are currently lacking [2]. Specifically, questions arise about what can be done to scale project management concepts practiced in business to the macro level [3] and what role government management bodies should play in this process [4].

It should be noted that in 1969, the Project Management Institute (PMI) was established in the United States, which led to the development of the first standards that have been refined and implemented in corporate activities: A Guide to the Project Management Body of Knowledge (PMBOK Guide), Prince2 Projects in Controlled Environments, ISO 21500 Guidance on Project Management, etc. [5].

When exploring the "Scandinavian school", project management reveals a focus on the embeddedness and interaction of projects within the life of the society [6]. A project is understood as a temporary organization with specific objectives, such as developing a new product or updating an organizational unit, where the process is based on prior activities and encompasses dynamic changes [7]. It is also noted that "projects have become an integral part of our lives" [8]. They are carried out by participants who enter into relationships that "fragment and reconfigure through the practice of episodic project collaboration" [9]. The implementation of projects is influenced by the institutional context, which simultaneously affects their immediate and broader environment [10]. By describing project management as a response to wider social and cultural processes, Packendorff and Lindgren [11] significantly expanded the scope for studying this phenomenon at the macro level.

Project management at the macro level can be understood as a process or development towards the increasing significance of projects at the macro level for state development [12]. On the other hand, it "indicates an interest in the outcomes and impacts of project activities on a segment of society or on society as a whole" [13]. The interaction of projects, programs, and project portfolios is implemented within

and between organizations through networking [14, 15], forming a project business that specializes in project execution. L. Boltanski and E. Chiapello [16] describe project management at the macro level as a pathway to a "new spirit of capitalism", which focuses on projects as an integral form of networked collaboration.

It should be noted that research in project management has long been concentrated on assessing their impact on the economic activities of companies. However, considering the intensive development of project management, it should be highlighted that the field has expanded to higher levels of society. A. Jensen, C. Thuesen, and J. Geraldi [17] note a "project society", where everyone undertakes projects, both personal and collaborative with others. Similarly, R. A. Lundin [18] describes the pathway to a project society, indicating that projects are spreading everywhere. G. Grabher and O. Ibert introduced the term "project ecology" as a concept encompassing "social layers at various levels, from the micro level of interpersonal relationships, the mesolevel of intra- and inter-organizational cooperation, to the macro level of broader institutional structures", which relies on professional organizations and specialists that contribute to cumulative learning [19].

Project management encompasses a wide range of activities, from the narrow conceptualization of project activities as organizational transformation to the use of project management tools for societal development. Projects become the foundation of social life. For a better understanding of project management and its prospects at the macro level, let's propose utilizing institutional theory, as it "examines the processes through which structures, including schemes, rules, norms, and routines, are established as authoritative guiding principles of social behavior" [20]. Institutional theory comprehensively reveals the relationships and collaborative activities of project participants within an institutional context. This theory allows for an analysis of both the influence of institutions on social processes and the reciprocal influence of institutions on those processes.

Researchers, relying on neo-institutional theory, primarily note how organizations and organizational practices are increasingly converging; for instance, "organizations become predictable because other organizations become predictable" [21]. At the same time, institutional theory focuses on institutionalization as the process of creating reality through social interaction. The emphasis here shifts towards the stability and orderliness of institutional mechanisms. This allows to define institutions as comprising "regulatory, normative, and cultural-cognitive elements, which together with related actions and resources provide stability and meaning to social life" [22]. Institutional theory and analysis consider the processes through which structures at the macro level, including both normative and behavioral systems, are established, become stable, and undergo change over time. This is driven by

the participation of individual actors and various collectives, ranging from individual organizations to networks of organizations and organizational or institutional fields, representing a collection of independent and diverse organizations "engaged in a system of shared meaning" [22]. Participants act according to the institutional framework and thus embed it within their environment; conversely, through their activities, they also influence the macro level and change it in a certain direction [23].

Regulatory actions in project management at the macro level entail the authoritative position of the state, which controls and sanctions compliance with laws and regulations and exercises coercion over others, while normative actions aim to ensure adherence to standards and routines in everyday life, thereby influencing participants' habits to comply with these standards.

In addition to the institutional approach, it is important to highlight other approaches to project management at the macro level:

1. **Systemic Approach** – this views project management as part of the overall development system of the state, where all processes are interconnected. In the context of the macro level, the systemic approach assists in integrating projects into the overall strategy of state development, ensuring interaction between various organizations and management levels. This promotes alignment of objectives and more efficient use of resources [24]. The national digitalization strategy in Estonia serves as a successful example of a systemic approach, where various institutions and management levels work in harmony to achieve a unified goal – the digital transformation of public services. A systematic approach provides project managers with the opportunity to apply the differentiation of elements, subjects, and levels for conducting project analysis and to engage project financing tools.

2. **Portfolio Management Approach** – government institutions often manage several projects simultaneously; thus, the portfolio management approach enables effective coordination of their interactions, optimizing resources and time [25]. Portfolio management allows for strategic decisions regarding which projects to prioritize, based on societal needs and political priorities. This approach also encompasses monitoring and evaluating the outcomes of each project to ensure maximum return on investment and to achieve established strategic goals. Portfolio management is employed within the European Union to coordinate funded projects under multi-annual financial programs, allowing for effective allocation of funds and resources across various countries and sectors. The Portfolio Method allows for a comprehensive view of project formation at the level of the national economy and facilitates the presentation of the project plan, utilizing the levers of project management, such as the project office or soft skills, to attract investors and other representatives of the financial system.

3. **Contextual Approach** – this considers that the success of projects at the macro level depends on specific external conditions, such as economic and political factors, culture, and social characteristics of the country. Each project in the public sector must be tailored to the specific political and social context to ensure its effective implementation. The contextual approach helps to avoid "one-size-fits-all" solutions that may not be suitable for the conditions of a specific country or region. Instead, it focuses on the individual needs and specifics of each project. The successful implementation of aid and development projects in Africa relies on understanding local cultural, economic, and political conditions, necessitating a contextual approach. The substantive approach involves filling the content of the project plan, where this content is explored through economic, legal, political, and cultural factors. The content of each section of the project plan should be filled with analyses and summaries regarding the life cycle of the macro-project in question.

4. **Agile Methodologies** – traditionally associated more with the private sector, elements of Agile are increasingly being integrated into public administration. Agile methodologies allow for quicker responses to changes, adapting projects to new challenges, and maintaining a high level of engagement with stakeholders.

Agile entails a cyclical process of planning, implementation, and evaluation, allowing for a swift response to changes in the external environment and the adjustment of project implementation strategies. Flexible methodologies have been employed in the United Kingdom to introduce digital government services, enabling the government to quickly adapt its services to new citizen requirements.

The Agile method involves the implementation of macro-projects as a moving living organism. Thus, any project should be considered in dynamics, when there are transitions from one state to the next and their connection within a particular project.

5. **Results-Based Management** (RBM) focuses on achieving specific, measurable project outcomes, which is crucial for public institutions. Results-Based Management aims to enhance accountability and transparency in project implementation, particularly important for governmental bodies operating with taxpayers' money. RBM encompasses a systematic approach to monitoring, evaluating, and adjusting project activities, focusing on end results and societal impact. If a project at the macro level is result-oriented, this serves as a foundation for the project's success. It is necessary to understand what it is possible to achieve with this particular macro project.

The United Nations Development Programme (UNDP) actively employs a results-based management approach in its aid and development projects, allowing for a clear assessment of the effectiveness of each initiative. In summarizing theoretical research, it should be noted that the primary impetus for the implementation of

project management at the macro level in Ukraine is its European orientation, which integrates project management tools into public administration institutions.

Public institutions are often complex organizations with numerous stakeholders, long-term projects, and a multitude of rules and regulations. Implementing project management in such an environment can be challenging, as there is no one-size-fits-all solution suitable for every organization.

Challenges include managing competing priorities between internal and external stakeholders; navigating the bureaucratic system to ensure compliance with existing laws, regulations, policies, and procedures; establishing clear boundaries of authority and responsibility among teams; effectively utilizing limited resources; adapting project plans to changing needs or unforeseen circumstances; developing a comprehensive risk management strategy; obtaining buy-in from all stakeholders; and coordinating activities among multiple departments or agency divisions.

4.2 Conditions for creating management projects within the national economy of Ukraine

In accordance with project management issues in the context of turbulence in Ukraine, it is important to note that, throughout the entire period of independence, there has been uncertainty as a manifestation of turbulence. Several destructive and complex socio-economic and political challenges can be identified. A significant social conflict, according to M. Dubyna and D. Serdyuk (2023) [26], is the Orange Revolution and the political crisis of 2004. At the same time, these events "open the country" to foreign investors and active changes. As a result, the volume of foreign direct investment increases, the financial sector is reformed, and GDP growth occurs during the years 2005–2007.

The next significant event is the political and financial-economic crises of 2007–2008, which negatively impact the further improvement of Ukraine's investment climate and slow down economic growth. However, at the same time, there is an increase in foreign currency inflows from remittances.

Since 2014, a series of subsequent events have taken place: the Revolution of Dignity; the annexation of Ukrainian territory; and the conduct of an anti-terrorist operation. These events lead, in the long term, to capital outflow at all levels, migration primarily of the working-age population, and the formation of an uncertain security situation throughout the country. The global COVID-19 pandemic did not become an exception for the Ukrainian economy, and therefore a new decline in economic development is observed. Thus, crisis phenomena compel the loss of,

but also the acquisition of, experience in managing national projects during the described events.

Given the above, based on crises, shocks, and disharmony, a powerful "immunity" to overcoming contradictions is established for the future. In other words, mechanisms of unity among the diverse elements of a cohesive system are formed. Turbulence is the driving force behind territorial development, but only under conditions of effective project management aimed at harmonious socio-economic and ecological development. A condition for such development of any system is the harmonious development of all its elements, which is possible through effective project management, regardless of the initiators (state, society, business), size, and duration (long-term or short-term).

The conceptual approach for scientific exploration of viable project management regarding the development of the national economy should be the process of harmonizing the elements of the socio-ecological-economic system, in particular economic relations, which are forms of connections and interdependencies among all market participants, aimed at meeting the needs of participants through the realization of their interests.

The essence of harmony and harmonization as economic categories is characterized by defining features and criteria such as coherence, consistency, proportionality, sustainability, coordination, balance, equilibrium, orderliness, manageability, efficacy, and effectiveness. Thus, harmony in the economy represents a state of system functioning, a coherent interrelationship of its elements with their properties, which simultaneously serves as a condition, goal, and result of the system's existence.

The harmony of economic relations signifies a level of coherence, sustainability, consistency, coordination, balance, optimal correlation, equilibrium, orderliness, and manageability of economic relationships among their participants, which serves as a condition, goal, and result of sustainable (viable) development.

The necessity of harmonious development is emphasized by M. Dubyna and D. Serdyuk [26] in their work "Ensuring Sustainable Development of Ukraine in Conditions of Uncertainty and Turbulence of the External Environment". The authors note that consideration of outlined goals in the process of creating and implementing development strategies for the Ukrainian economy facilitates the transition to a gradual harmonious development of territories.

A condition for the harmonization of economic relations is the alignment of interests among economic entities directed towards achieving a societal goal, namely, enhancing the overall level of welfare for all members of society through effective project management and ensuring sustainable development of the economic system based on inclusivity (in the context of equal access to opportunities).

The identification of the economic interests of individual entities is a necessary step in seeking mechanisms for harmonizing relationships among market participants.

Only the reduction of the level of uncertainty and inequality in access to opportunities, particularly financial ones, in the context of rational distribution of national wealth, is a condition for improving the national investment climate. This is particularly important for managing small and medium-sized business projects, as the number of jobs concentrated in small and medium enterprises amounted to 5.6 million individuals in 2021, or 77.3 % of all hired employees in enterprises and individual entrepreneurs (**Table 4.1**).

Table 4.1 Dynamics and structure of the number of employed workers in enterprises and individual entrepreneurs in Ukraine from 2010 to 2022, thousand people, %

Year	Large business entities		Medium business entities		Small business entities		Total	
	thousand people	%	thousand people	%	thousand people	%	thousand people	%
2010	2,400.3	27.1	3,412.5	38.6	3,033.0	34.3	8,845.8	100.0
2015	1,708.6	26.5	2,630.9	40.9	2,098.1	32.6	6,437.6	100.0
2020	1,574.6	21.7	3,121.4	43.0	2,558.4	35.3	7,254.4	100.0
2021	1,648.7	22.7	2,998.2	41.4	2,601.9	35.9	7,248.8	100.0
2022	1,369.9	22.9	2,608.6	43.6	2,006.0	33.5	5,984.5	100.0

Source: [27]

As demonstrated in **Table 4.1**, there is a significant number of private entrepreneurs in Ukraine. The increase in their quantity and the quality of produced goods (services) should become a state project in the turbulent realities of Ukraine. The state of the fiscal system and, correspondingly, the accumulation of the revenue part of the budget is dependent on the number of entrepreneurs. Medium enterprises form the focus of most countries worldwide, and in Ukraine, this process is just beginning. A well-known scheme for forming a business environment exists: from individual entrepreneurs (IEs) through the establishment of limited liability companies and up to corporations. Such a scheme should be a project for the Ukrainian environment, where it is essential not to hinder entrepreneurs in forming businesses and to create conditions for the effective development of small and medium enterprises. This represents the prospect of macro-projects for the formation of a business environment in Ukraine.

As of the results for 2022, the number of employed workers in small and medium enterprises has decreased to 4.6 million people, or 77.1 % of the total number of

employed workers. It is well-known that the development of small and medium enterprises contributes to the formation of the middle class, the establishment of civil society and the rule of law, the reduction of social inequality, and the provision of social stability, leading to the achievement of societal goals through the overall improvement of quality of life. The main advantage of such entrepreneurship is its relative flexibility in diversifying business, mobility, and the possibility of relocation (especially relevant in conditions of martial law).

A study conducted in December 2023 – January 2024 within the framework of the UNDP project "Support for Ukraine" indicates the following. If prior to the introduction of martial law, 22.3 % of businesses assessed their financial and economic condition as satisfactory or poor, by the end of 2023, such enterprises numbered 78.1 %. One third of small and medium enterprises in Ukraine continued to operate during martial law. 6 % were forced to cease operations for more than one year [28].

The primary focus should be on the rebalancing of the Ukrainian economy, which involves aligning expectations, desires, and expenditures (material, financial, and time) to achieve a level of socio-economic development comparable to that of Central Europe, within the capabilities of Ukrainian management. The adopted management decisions, sometimes populist, particularly in the context of martial law, "inflate" expectations in society, the desire for entrepreneurial rewards in the business environment, and the extent of unreasonable expenditures from budgets at all levels. This situation does not correspond to the actual management capabilities of the current state of the economy. Consequently, we face a disoriented society, unpredictability in the investment climate for business entities, and an increase in the external state debt of Ukraine, ultimately leading to a decline in the overall level of well-being for all members of society without exception. There is no single victim. Everyone suffers: civil society, businesses, the reputation of the authorities, and the image of the country as a whole. The management of existing projects is rendered ineffective.

Creating a favorable investment climate, which is a prerequisite for effective project management, regardless of time and space, is the function of government officials. Article 42 of the Constitution of Ukraine stipulates the obligation of the state to ensure the protection of competition in entrepreneurial activities. This includes, in particular, oversight of the state support system that leads to fair competition.

The mechanisms of state aid are crucial for protecting the interests of national economic entities and consequently for the effectiveness of project management. Forecasted, long-term state aid enables: the protection and development of competition, the enhancement of transparency and efficiency in the management of state and local resources; increasing Ukraine's investment attractiveness, which, in turn,

positively impacts the business environment, job creation, and improves macroeconomic indicators; and streamlining the procedure for economic entities to receive compensation for losses incurred due to emergencies, including military actions.

It is worth listing the government projects already proposed in 2023 that are intended to improve Ukraine's investment climate. Thus, the Cabinet of Ministers of Ukraine has adopted five resolutions, primarily developed by the Antimonopoly Committee of Ukraine, namely:

– Resolution No. 52 "On Approving the Criteria for Assessing State Aid to Economic Entities for the Support of Culture and Preservation of Cultural Heritage", dated January 20, 2023;

– Resolution No. 348 "On Approving the Criteria for Assessing the Admissibility of State Aid to Economic Entities for Regional Development and for Supporting Small and Medium Enterprises", dated April 18, 2023;

– Resolution No. 704 "On Approving the Criteria for Assessing the Admissibility of State Aid to Economic Entities for Providing Services for the Creation and/or Selection, Organisation and Dissemination of Mass Information, which are Services of General Economic Interest", dated July 11, 2023;

– Resolution No. 1087 "On Approving the Criteria for Assessing the Admissibility of State Aid to Economic Entities for Local Infrastructure", dated October 13, 2023;

– Resolution No. 1175 "On Approving the Criteria for Assessing the Admissibility of State Aid to Economic Entities for Recreational Infrastructure", dated November 10, 2023.

Only a consistent long-term economic policy can create the necessary conditions for establishing a competitive investment climate in Ukraine. In the context of financial constraints (due to the increase in external state debt burden), there arises a need for new instruments for attracting funds. Therefore, one tool for addressing long-term challenges is the interaction between state representatives and private business based on contractual public-private partnership principles.

Public-private partnership (PPP) is not a new collaboration tool globally, but it is a managerial innovation for the Ukrainian business environment. Such a partnership, as stated by S. Svirko, T. Vasyuk, O. Shevchuk and I. Suprunova [29], promotes increased efficiency and effectiveness in the use of state and communal property, thereby improving overall governance.

The development pace of the specified partnership in Ukraine, in terms of quantity, investment volume, deal structure, economic activity, and geographical location, significantly differs from global standards.

As of January 1, 2020, according to data from central and local authorities, over 192 contracts have been registered, of which 52 contracts are active (concessions – 34,

joint activities – 16, others – 2); meanwhile, more than 135 contracts are not being executed (including 4 that have expired, and 18 that have been terminated). During the period from 2018 to 2021, over 60 % of the concluded agreements under public-private partnerships (PPP) are not being fulfilled. As of January 1, 2022, only 16 % of PPP agreements are being executed, 22 % have been terminated, and over 62 % are not being fulfilled.

Thus, considering that the interest of the public sector in PPP is effective management of existing production capacities (mainly buildings, structures, and land), rational management of state property, increasing the production volume of goods (fundamental macroeconomic indicators), as well as improving the quality of public services. The interest of private businesses lies in obtaining and increasing entrepreneurial profit, along with improving the investment climate. Therefore, the overall objective of managing projects related to public-private partnerships should be to align interests to ensure long-term cooperation between the state and the private sector (primarily small and medium-sized enterprises) by combining efforts and resources to enhance the overall welfare and move towards harmonious territorial development.

Summarizing the aforesaid within the context of projects in the national economy of Ukraine, it is important to note that only a consistent, long-term socio-economic policy by the authorities is more significant than populist management tools under conditions of turbulence. Although each national economy possesses its own geo-economic and geopolitical characteristics, there are common patterns nonetheless. Therefore, within the Ukrainian economy, project management within small and medium-sized enterprises is of utmost priority, which currently accounts for 77.1 % of hired workers. A projected and transparent long-term state aid system is a prerequisite for improving the investment climate. An effective tool for enhancing the overall well-being of business entities in Ukraine is the management of public-private partnership projects. This ultimately strengthens the subjectivity of Ukrainian businesses on the global stage and enables them to succeed in the global competition for the attractiveness of the investment climate.

4.3 Cluster formation projects within the national economy of Ukraine

The global experience of countries with developed market economies highlights the increasing role of clustering in worldwide, national, and regional cooperation processes, which facilitate the formation of unique and sustainable competitive advantages for participants in these processes. Significant attention is given by

scholars to the processes of cluster creation and development: encompassing historical, organizational, institutional, and cooperative processes and tools for self-development, as well as the justification of various approaches in forming instruments of state economic policy, including the management of the development of cluster associations of small and medium-sized enterprises around leading large companies, ultimately leading to the enhancement of the competitive potential of industries and, consequently, the creation of new jobs. Clusters should be viewed as projects that can be initiated from the bottom up by entrepreneurs, as well as from the top down by the state.

In Ukraine, there are approximately 50 cluster initiatives and clusters in operation, 22 of which are on the European Cluster Collaboration Platform (ECCP). Furthermore, in recent years, there has been a significant increase in activity at the regional level. However, the organizational and economic support for the creation and development of clustering in the state is weakly organized at the national level and tends to grow spontaneously; there is no unified organization representing clusters in Ukraine, and it is necessary to activate the state's efforts regarding the organization of cluster formations as management projects.

In exploring various global experiences with clustering, it can be stated that, in our opinion, the noted trajectory of development is similar to the evolutionary processes of cluster development in Italy. Clustering in Italy is developing in the form of industrial districts based on Italian-type industrial agglomerations. In this context, small and medium-sized manufacturing enterprises typically concentrate within industrial areas and form inter-company networks. The cluster policy of the Italian Government is aimed at developing local production systems and industrial districts through the establishment of special centers and intermediary structures designed to enhance the technological level and innovative capabilities of small and medium-sized businesses, as well as to serve as a project initiated by the state at the micro-level.

For instance, according to Antonio Russo, the added value of the Italian cluster "ASP" lies in its integrated system of methods. Another Italian cluster, "Vega", lacks entities focused on supporting isolated companies in development, as well as those specifically responsible for interaction between research centers and end-users. In managing these processes, many issues remain for self-organization and improvisation. However, the experience of the "Vega" cluster clearly demonstrates that the dialogue and interaction between these structures is not a spontaneously occurring structure; it is a specific project.

Also, for instance, V. Yemtsev [30] draws attention to the fact that a cluster can be regarded as a model of coordination of joint activities based on direct equal relationships among industrial enterprises and organizations concentrated in a compact area.

Thus, the primary criterion for forming further comparative analysis is the tools and methods of self-organization within the cluster as an economic system. It is essential to clarify that a significant number of scientific works are dedicated to the study of the nature of self-organization and the assessment of the synergy effect in the process of clustering economic systems. Generally, in subject-specific studies, the explanation of the effectiveness of self-organization is achieved through the analysis of synergy, as it is this effect that provides the formation of competitive advantages in this developmental process of the economy.

For example, the synergistic effect in a project is attained through the accumulation of resources and the expansion of production scales, optimizing inter-industry connections. As a result of cluster formation, the expectation is to obtain greater profits within the association compared to the outcomes of the independent functioning of the integrating enterprises. Overall, the synergistic effect implies achieving the structuredness of the economic system through effective project management and is the result of the integration of subsystems, while the positive effect is described by the formula 2+2=5.

In our opinion, the conclusions drawn from the methodological research conducted by E. Karapetyan and A. Kvasovskyi [28] are particularly relevant and significant to this topic. They note that the modern concept of clustering has absorbed the achievements of numerous theoretical approaches, simultaneously serving as an "umbrella" model that creates a system of coordinates. Today, it no longer allows for a simplistic spatial interpretation of relationships based solely on the geographical proximity of counterparties. It requires a clear distinction between the general and specific characteristics of local project relationships that emerge in various socio-economic contexts, as well as different variants of establishing such relationships.

Therefore, to form relevant scientific and practical approaches to creating economic tools for the organizational and economic support of the establishment and development of clustering in Ukraine, the experience of Italy is optimal due to the presence of evolutionary processes of self-organization.

In Italian, the category "production clusters" is referred to as *distretti industriali*, which translates literally into Ukrainian as industrial districts. A. Ricciardi offers the following definition of an industrial district: it is a typical organizational model of the Italian economy, characterized as a territorial space with a high concentration of small and medium-sized industrial enterprises specialized in production. These enterprises are generally marked by a high interdependence in their production cycles and are highly integrated within their social and economic location, where they are received. A cluster is an integrated project within the activities of specific economic territories.

Industrial districts are distinct from industrial territories, which are defined as areas where enterprises are not interconnected. Industrial districts represent an organizational model typical of the Italian economy, which is studied worldwide and sought to be replicated. As of 2021, Italy had 156 districts (12.5 million residents, 22.2 % of the population), the majority of which are located in Central Italy and the North-East.

215 million enterprises in the districts and approximately 2 million people employed contribute 27.2 % of GDP and 37.2 % of annual exports. The Italian district system is based on activities that produce products Made in Italy, in sectors such as textile and sewing (28.8 %), traditional machine engineering (24.4 %), furniture (20.5 %), and footwear (12.8 %). These sectors are represented in 135 districts, which also include household appliances, machinery, packaging, and food production.

Most Italian districts originated and expanded during the economic miracle of the 1950s and 1960s. During the growth slowdown in the 1970s and 1980s, industrial districts became centers of development. In the 1990s, districts began to spread in the southern regions of the country.

Enterprises have a certain degree of autonomy in strategy formation, focusing on specific management functions, and the level of enterprise stability. Historical clusters, also known as "districts", differ from free economic zones. Clusters are districts formed by small and medium-sized enterprises. For Italy, the core of the clusters is the family business, which has been supported at the state level. Small businesses found it easier to survive by forming synergistic associations – "districts". These are entrepreneurial alliances that developed business based on the amalgamation of small enterprises.

China, which aimed to create a clustered economy, established free (special) economic zones (SEZs) as territorial centers formed "from above". For Ukraine, clustering is also a relevant phenomenon, in which the creation of clusters "from above" needs to be supported. However, the experience of forming SEZs for our state has been unsuccessful.

The initiative to create clusters originates from the activities of businesses that come together. The territory becomes filled with purpose due to the activation of enterprises within the same industry. In the special economic zone (SEZ), the activities of enterprises are autonomous, but their regulation is entirely subordinate to state policy. However, such state policy may address incentives for the consolidation of businesses "from below". This is akin to the unification of apartment building owners: it is possible to come together and have prospects, but it is also possible to choose not to unite and "live" separately. In any case, the formation of business alliances may be enshrined in state legislation and can contribute to the establishment of industrial clusters.

Table 4.2 Data for cluster analysis of innovation activity in Ukraine

Region	Number of organizations conducting R&D, units, 2018	Number of postgraduates, people, 2018	Internal current expenses for R&D execution, thousand UAH, 2018	Number of innovation-active industrial enterprises, units, 2018	Expenditure on innovations, thousand UAH, 2018
Ukraine	950	22829	16009286.2	777	12180072.5
Vinnytsia	21	568	48908.2	25	365936.9
Volyn	9	242	18434.7	14	85399.8
Dnipropetrovsk	56	1224	1910195.5	71	688062.3
Donetsk	17	266	16126.9	23	725635.8
Zhytomyr	9	208	30151.4	19	123865.0
Zakarpattia	8	517	71323.8	12	20206.2
Zaporizhzhia	26	828	1215306.3	36	4213621.7
Ivano-Frankivsk	14	437	41174.9	28	146153.0
Kyiv	30	378	377097.3	54	663665.1
Kirovohrad	15	123	98291.1	26	163783.4
Luhansk	12	224	31784.3	5	16192.4
Lviv	72	1881	409597.7	44	416914.5
Mykolaiv	24	156	314413.9	14	251812.4
Odesa	46	1529	292290.9	25	225145.3
Poltava	20	513	77713.7	30	105563.0
Rivne	11	261	18278.3	8	5795.2
Sumy	14	696	165518.5	25	559934.1
Ternopil	12	440	29842.2	20	137125.6
Kharkiv	141	3018	3002469.1	119	1270123.9
Kherson	19	331	80229.7	14	50245.4
Khmelnytskyi	8	412	20502.7	11	14638.8
Cherkasy	20	326	94292.2	29	115291.8
Chernivtsi	18	207	86501.2	9	54811.6
Chernihiv	14	516	47750.4	15	108108.2
Kyiv City	314	7828	7511051.3	101	1652641.1

Certainly, the cluster analysis (**Tables 4.2**, **4.3**) conducted by the authors exhibits somewhat different characteristics but delineates the grouping of regions in Ukraine based on their innovativeness. Specifically, eight clusters were identified, comprising between eight and one region. For instance, the second, fifth, and eighth clusters are formed by Zaporizhzhia, Kyiv City, and Kyiv region, while the seventh

cluster includes Vinnytsia, Zhytomyr, Ivano-Frankivsk, Kirovohrad, Poltava, Ternopil, Cherkasy, and Chernihiv regions. These groupings of regions demonstrate that clusters are being formed that unite areas with similar innovative characteristics, and there is potential for the formation of clusters as project solutions arising from state policy, particularly in conditions of turbulence.

Table 4.3 KNN (K Nearest Neighbors) method

Region	Cluster
Vinnytsia	7
Volyn	4
Dnipropetrovsk	3
Donetsk	1
Zhytomyr	7
Zakarpattia	4
Zaporizhzhia	2
Ivano-Frankivsk	7
Kyiv	8
Kirovohrad	7
Luhansk	4
Lviv	6
Mykolaiv	6
Odesa	6
Poltava	7
Rivne	4
Sumy	1
Ternopil	7
Kharkiv	3
Kherson	4
Khmelnytskyi	4
Cherkasy	7
Chernivtsi	4
Chernihiv	7
Kyiv City	5

The clustering of national economies is based on the synergistic effect and network amplification, whereby the combination of enterprises occurs rationally and is driven by the current needs of these business hubs to unite "from the bottom up" (**Fig. 4.1**).

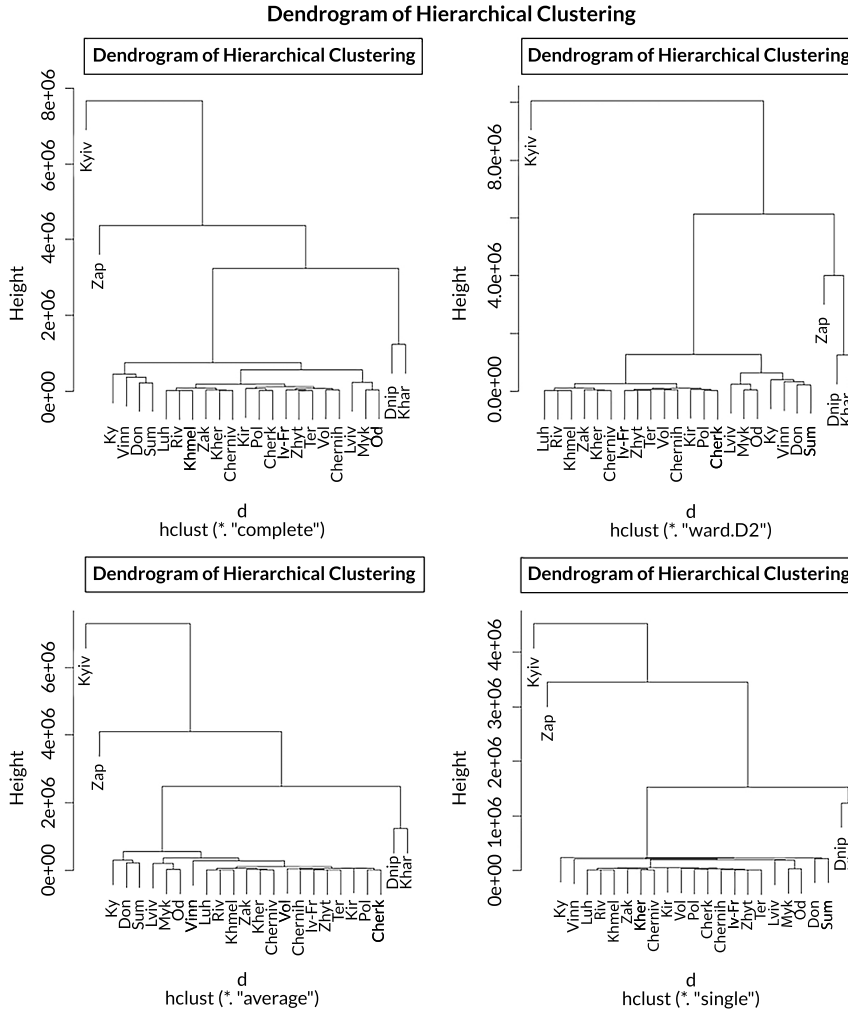

Fig. 4.1 Hierarchical clustering (4 dendrogram variants)

The methodology for researching clustering is quite complex and requires a comprehensive approach. Such research involves distinguishing the analysis of IEs (individual entrepreneurs), which, through a specific macro-project, form associations – clusters that are governed by state authorities. Furthermore,

the methodology for such research should include an analysis of the territory and its potential, culminating in a cluster analysis of the territories of a specific country (regions, areas, etc.).

4.4 Management projects in the macroeconomics of Ukraine amidst turbulence

The shock of financial, economic, and military crises has significantly shifted society from populist priorities to a readiness for economic reforms. However, as society becomes prepared for reforms, it grows increasingly critical of the appropriateness and justification of these reforms. Therefore, to restore public trust in the strategic policies of the state, the effects of reforms must be sufficiently tangible and relatively swift. This should be achieved through a strategic project-based approach to the development and implementation of modernization strategies.

The significance of national project planning increases in the post-crisis period when there is an objective need for a targeted concentration of societal resources on the key objectives of the modernization strategy, prompting the search for adequate contemporary tools for such concentration. Management projects in macroeconomics, when an effective model of their organization is implemented, can satisfy this need.

The project management method, which has gained considerable traction in contemporary corporate management practices, acquires several specific characteristics when elevated to the level of national project planning. In public administration, the coherence of hierarchical structures is incomparably higher, the scale of project implementation is broader, and the degree of interaction among the various structural elements of the public administration system is clearly regulated by normative legal acts. Furthermore, management functions and tasks are typically associated with achieving certain hard-to-measure societal effects, as well as being based on the necessity to balance the political and economic interests of different societal groups. Consequently, within the framework of project management in public administration, modified interpretations of the general principles of project planning typically emerge. These are limited to three primary interpretations of management projects at the macroeconomic level:

1. **Management project as a strategic reform programme.** A management project serves as a strategic reform programme within a specific area. The criteria for positioning such a project are, firstly, the strategic importance of the national tasks set, and secondly, a high level of political control over the implementation of the project.

This type of project design is typical for countries undergoing a certain systemic transformation and establishing new political and economic state structures. Within this framework, a management project, particularly an anti-crisis project, aims to unite the nation under a fundamental idea (goal) based on the values inherent to the nation.

2. **Management project as an intersectoral component of a state programme.** A management project functions as an intersectoral component of a state programme aimed at achieving nationwide goals, ensuring necessary intersectoral coordination. This approach is characteristic of relatively mature states with developed socio-economic systems. The central authority employs the project format to implement "general" and "socially significant" tasks that require the concentration of financial and managerial efforts on strategic directions. In this regard, the boundaries of the management project integrate the efforts of central and regional authorities, the leadership of various departments and sectors, thus facilitating a partnership between the state and business.

3. **Management project as an investment project.** A management project acts as an investment project that combines the efforts of the state, business, and civil society to achieve priority goals and objectives. This vision most fully reflects the classical notion of business project management, which is why the process of national project management is often undertaken not by specific state bodies but by state investment enterprises. In this case, contrary to previous visions, the role of project selection criteria in the activities of such state enterprises rapidly increases, as their operations can have direct political consequences for the state management system overall. The failure of a particular "small" project may directly affect certain social groups within the population, highlighting the flaws in the systemic planning of the country's development.

Under current conditions of global economic instability, driven by both internal and external factors, Ukraine's macroeconomics faces a number of challenges that require effective management and strategic planning. Economic turbulence, particularly due to military conflicts, economic sanctions, the COVID-19 pandemic, and other global factors, presents the state with the task of adapting and implementing innovative management projects capable of stabilizing the economy and ensuring its sustainable development. The turbulent environment can be described as a combination of factors characterized by unpredictable changes that significantly impact the activities of organizations and Ukraine's macroeconomy as a whole.

The main factors of the turbulent environment that have the most significant impact on management projects include:

1. Political instability and military actions. The armed conflict in eastern Ukraine and the full-scale invasion by Russia create constant pressure on the economy.

Defense expenditures, infrastructure destruction, and population migration negatively affect economic development and require the application of new approaches in public management.

2. Inflation and financial instability. Due to military actions, rising energy resource prices, and decreased foreign investments, the inflation rate has significantly increased. This necessitates new management decisions from financial institutions and the National Bank of Ukraine to stabilize the exchange rate and control inflationary processes.

3. Changes in the structure of international trade. The constantly changing conditions of international trade, caused by export and import restrictions due to sanctions and reduced demand for certain types of goods, require the state to actively manage macroeconomic processes to ensure export diversification and support for national producers.

Ukraine currently serves as a classic example of a turbulent environment due to the ongoing war and accompanying economic challenges. Infrastructure reconstruction projects are being executed amidst resource shortages, continuous hostilities, and economic instability. Management teams must respond swiftly to changes in the situation, and the risks involved are of a strategic nature.

Strategies for adapting to a turbulent environment should be based on:

– **implementing agile methodologies.** The use of Agile or Lean approaches allows project teams to quickly adapt to changes by breaking the project into short iterations, each with clear objectives. This enables the reassessment of priorities and the making of adjustments without compromising the overall success of the project;

– **diversification of resources.** To mitigate the risks associated with resource instability, it is essential to develop diversification strategies. This may include engaging alternative suppliers, securing various funding sources, or forming teams comprised of employees from different regions;

– **scenario planning.** To manage risks in an unpredictable environment, it is beneficial to implement scenario planning. This allows for the anticipation of multiple potential scenarios and the development of action plans for each;

– **continuous learning and team development.** A turbulent environment demands high adaptability from project teams, which can only be achieved through ongoing learning and development. Project managers should encourage their teams to acquire new skills and enhance qualifications, enabling them to respond more swiftly to changes.

Management projects in the macroeconomics of Ukraine should focus on mitigating the impact of turbulent factors and ensuring the resilience of the economy. Key strategic directions are outlined in **Table 4.4**.

Table 4.4 Strategic directions for management projects in Ukraine

Direction	Action
Fiscal reforms and cost optimization	In order to overcome economic difficulties, the government is implementing fiscal reforms aimed at reducing the budget deficit and optimizing state expenditures. Focus is placed on directing funds to support sectors that contribute to economic development in wartime, such as defense, energy, and infrastructure
Banking system reform	To stabilize the financial sector and control inflationary processes, the National Bank of Ukraine continues to reform the banking system by tightening requirements for bank liquidity and capital. This enhances the reliability of financial institutions and the stability of the hryvnia in the domestic market
Infrastructure investment	In light of the destruction of infrastructure due to military actions, the Ukrainian government is focusing on the restoration and development of transport, energy, and social infrastructure. Investment projects in this area are a key factor in stabilizing the economy and creating new jobs
Support for small and medium-sized enterprises	Small businesses are the backbone of the national economy, and support for this sector through government loan and subsidy programmes is becoming crucial for ensuring economic stability. Additionally, digitalization programmes are being implemented to enable businesses to adapt to new conditions
Energy independence and environmental transformation	The development of renewable energy sources and the reduction of dependence on energy resource imports are priority tasks. The state is working on expanding domestic energy production, which contributes to economic security and creates a foundation for environmentally sustainable development

Management projects aimed at developing strategic directions for state policy or organizational activities become particularly effective when implemented with consideration of international experience and the involvement of partners from other countries. This approach not only facilitates the exchange of knowledge and best practices but also integrates global standards and innovations.

The project management approach enables a clear structuring of processes, allocation of necessary resources, and achievement of set objectives within specified timeframes. Management projects require meticulous planning, the identification of key performance indicators (KPIs), risk management, and result monitoring. In the context of international cooperation, this approach gains particular significance as it necessitates the alignment of various standards, laws, and regulations, as well as ensuring intercultural communication.

In Ukraine, one vivid example of international collaboration is the implementation of infrastructure projects involving international investors, such as the European Investment Bank or the World Bank. This pertains, in particular, to the modernization of transport infrastructure, road construction, and the development of energy capacities.

Management projects in Ukraine's macroeconomics encompass a wide range of initiatives aimed at supporting economic stability, restoring damaged infrastructure, and developing key sectors of the economy amid martial law and post-war reconstruction (**Table 4.5**).

Table 4.5 Management projects in the macroeconomics of Ukraine

Project	Content
Large construction	A large-scale infrastructure initiative launched in 2020 aimed at modernizing Ukraine's road and social infrastructure. The project involves the construction and reconstruction of roads, bridges, hospitals, schools, and other facilities. Special emphasis is placed on restoring infrastructure after the destruction caused by war
Affordable loans 5–7–9 %	Providing access to financing for small and medium-sized enterprises, stimulating entrepreneurial activity, and preventing bankruptcies
Digitalization of the economy and public services "Diia"	Ukraine is actively implementing digital solutions in macroeconomics, particularly in the context of military actions. The "Diia" platform has become a key tool for delivering government services to citizens and businesses. This project allows for the minimization of bureaucracy, enhancing the transparency of economic processes, and ensuring rapid responses to changes in the environment
Energy Independence Programme "Energy Efficiency"	This initiative aims to reduce Ukraine's energy dependence on imported energy resources, especially in light of the destruction of energy infrastructure. The programme includes measures for modernizing electricity networks, promoting the use of renewable energy sources, and improving energy efficiency in the housing and utilities sector

4.5 Conclusions

The implementation of project management at the macro level should be based on a comprehensive and centralized approach (utilizing elements of the institutional approach), having a legal foundation enshrined in state development strategies and the formulation of standards and methodological documents. These should incorporate systematized theoretical and practical knowledge of project management for effective execution of projects, project programmes, and portfolios within the public sector. They must delineate the procedures for managing projects, project programmes, and portfolios, according to which the planned schedules, volumes, and budgets will be realized. The standard should include a monitoring and control mechanism to ensure the rational utilization of public resources and the positive development of society, clarifying how the processes of project, programme, and portfolio management relate to existing methodologies of strategic planning. The standard is grounded in the PMI PMBOK project management approaches.

It is always challenging to minimize losses, but it is crucial to address the causes of unpredictability and turbulence. Therefore, developers and potential managers of national projects within the Ukrainian economy should leverage existing government initiatives regarding state support; explore global best practices in managing public-private partnership projects; and, importantly, reassess the subjectivity of the Ukrainian business environment towards robust development of small and medium enterprises through self-investment.

The creation of small and medium-sized businesses in Ukraine is a macro-environmental project. Thus, employed individuals become entrepreneurs and work "for themselves". At the state level, it is necessary to create conditions for self-regulation of business, when the business environment forms barriers to entry into the industry for potential competitors. These barriers are the result of a symbiosis of business and state policy, this is a state project that must be implemented.

The conditions for the formation of clusters in Italy have been studied, where small, medium, and micro enterprises joined forces to collectively address pressing needs. Clustered enterprises differ from non-clustered ones mainly in that the latter do not engage in unifying alliances, making their survival more challenging.

The evolution of cluster development in Italy has been tracked, where state-level support for local cluster initiatives is now in place. The Italian government proposes to support cluster businesses at the level of small and medium enterprise structures.

Cluster analysis has shown that the prospects for uniting the regions of Ukraine based on innovation criteria are rather conditional. There are regions that combine several areas, and there are clusters with a mono-forming region. There are differences in such clusters, but business clusters still require further investigation. It is necessary to create conditions in Ukraine for the real unification of entrepreneurs (IEs) to enhance the efficiency of their activities. This should be overseen by a corresponding national project. It must be a macro-project, as its effectiveness is greater than that of creating special (free) economic zones, which are established from above and are not always effective.

Ukraine's experience demonstrates that to form territorial districts as an association of enterprises within a single industry, it is necessary to identify the innovative capabilities of specific areas and establish clusters based on these.

Management projects in the macroeconomics of Ukraine play a key role in supporting economic stability and adapting to contemporary challenges. Infrastructure, investment, and digital projects ensure sustainable development, while support for small and medium businesses, energy efficiency, and the modernization of state institutions create a foundation for economic growth, despite challenging conditions.

References

1. Maylor, H., Turkulainen, V. (2019). The concept of organisational projectification: past, present and beyond? International Journal of Managing Projects in Business, 12 (3), 565–577. https://doi.org/10.1108/ijmpb-09-2018-0202
2. Söderlund, J., Sydow, J. (2019). Projects and institutions: towards understanding their mutual constitution and dynamics. International Journal of Project Management, 37 (2), 259–268. https://doi.org/10.1016/j.ijproman.2019.01.001
3. Jalocha, B., Bogacz-Wojtanowska, E. (2016). The bright side of social economy sector's projectification: a study of successful social enterprises. Project Management Research and Practice, 3, 5043. https://doi.org/10.5130/pmrp.v3i0.5043
4. Wagner, R., Huemann, M., Radujkovic, M. (2021). The influence of project management associations on projectification of society – An institutional perspective. Project Leadership and Society, 2, 100021. https://doi.org/10.1016/j.plas.2021.100021
5. Domeikienė, J. Project management in the public sector: a new threat or an opportunity? Available at: https://eu4pfm.com.ua/interviews/project-management-in-the-public-sector-a-new-threat-or-an-opportunity/
6. Jacobsson, M., Lundin, R. A., Söderholm, A. (2016). Towards a multi-perspective research program on projects and temporary organizations: analyzing the Scandinavian turn and the rethinking effort. International Journal of Managing Projects in Business, 9 (4), 752–766. https://doi.org/10.1108/ijmpb-10-2015-0100
7. Bakker, R. M., DeFillippi, R. J., Schwab, A., Sydow, J. (2016). Temporary Organizing: Promises, Processes, Problems. Organization Studies, 37 (12), 1703–1719. https://doi.org/10.1177/0170840616655982
8. Jensen, A., Thuesen, C., Geraldi, J. (2016). The Projectification of Everything: Projects as a Human Condition. Project Management Journal, 47 (3), 21–34. https://doi.org/10.1177/875697281604700303
9. Henneberry, J., Parris, S. (2013). The embedded developer: using project ecologies to analyse local property development networks. Town Planning Review, 84 (2), 227–250. https://doi.org/10.3828/tpr.2013.13
10. Söderlund, J., Sydow, J. (2019). Projects and institutions: towards understanding their mutual constitution and dynamics. International Journal of Project Management, 37 (2), 259–268. https://doi.org/10.1016/j.ijproman.2019.01.001
11. Packendorff, J., Lindgren, M. (2014). Projectification and its consequences: Narrow and broad conceptualisations. South African Journal of Economic and Management Sciences, 17 (1), 7–21. https://doi.org/10.4102/sajems.v17i1.807

12. Munck af Rosenschöld, J. (2019). Inducing institutional change through projects? Three models of projectified governance. Journal of Environmental Policy & Planning, 21 (4), 333–344. https://doi.org/10.1080/1523908x.2019.1606702
13. Jacobsson, M., Jałocha, B. (2021). Four images of projectification: an integrative review. International Journal of Managing Projects in Business, 14 (7), 1583–1604. https://doi.org/10.1108/ijmpb-12-2020-0381
14. Maylor, H., Brady, T., Cooke-Davies, T., Hodgson, D. (2006). From projectification to programmification. International Journal of Project Management, 24 (8), 663–674. https://doi.org/10.1016/j.ijproman.2006.09.014
15. Maniak, R., Midler, C. (2014). Multiproject lineage management: Bridging project management and design-based innovation strategy. International Journal of Project Management, 32 (7), 1146–1156. https://doi.org/10.1016/j.ijproman.2014.03.006
16. Boltanski, L., Chiapello, È. (2018). The New Spirit of Capitalism. London: Verso.
17. Jensen, A., Thuesen, C., Geraldi, J. (2016). The Projectification of Everything: Projects as a Human Condition. Project Management Journal, 47 (3), 21–34. https://doi.org/10.1177/875697281604700303
18. Lundin, R. A. (2016). Project Society: Paths and Challenges. Project Management Journal, 47 (4), 7–15. https://doi.org/10.1177/875697281604700402
19. Grabher, G., Ibert, O.; Morris, P., Pinto, J., Söderlund, J. (Eds.) (2012). Project ecologies: a contextual view on temporary organizations. The Oxford Handbook of Project Management. Oxford: Oxford University Press, 175–199. https://doi.org/10.1093/oxfordhb/9780199563142.003.0008
20. Scott, R. W.; Smith, K. G., Hitt, M. A. (Eds.) (2005). Institutional theory: contributing to a theoretical research program. Great Minds in Management: The Process of Theory Development. Oxford: Oxford University Press, 460–484. https://doi.org/10.1093/oso/9780199276813.003.0022
21. Sydow, J., Windeler, A. (2020). Temporary organizing and permanent contexts. Current Sociology, 68 (4), 480–498. https://doi.org/10.1177/0011392120907629
22. Scott, W. R. (2012). The institutional environment of global project organizations. Engineering Project Organization Journal, 2 (1-2), 27–35. https://doi.org/10.1080/21573727.2011.634546
23. Zilber, T. B. (2002). Institutionalization as an Interplay Between Actions, Meanings, and Actors: The Case of a Rape Crisis Center in Israel. Academy of Management Journal, 45 (1), 234–254. https://doi.org/10.5465/3069294
24. Cleland, D. I., Bopaya, B. (2015). The Evolution and Maturity of Project Management. Project Management Institute. Pennsylvania, 130.

25. Müller, R., Pemsel, S., Shao, J. (2015). Organizational enablers for project governance and governmentality in project-based organizations. International Journal of Project Management, 33 (4), 839–851. https://doi.org/10.1016/j.ijproman.2014.07.008
26. Dubyna, M., Serdiuk, D. (2023). Ensuring Sustainable Development of Ukraine in the Uncertain and Turbilent Environment. Problems and Prospects of Economics and Management, 4 (36), 9–25. https://doi.org/10.25140/2411-5215-2023-4(36)-9-25
27. Doslidzhennia stanu ta potreb biznesu v umovakh viiny: rezultaty opytuvannia v hrudni 2023 – sichni 2024 roku (2024). Diia.Business. Available at: https://business.diia.gov.ua/analytics/research/stan-ta-potreby-biznesu-v-umovakh-viiny-rezultaty-doslidzhennia-v-sichni-2024
28. Karapetian, E., Kvasovskyi, O. (2014). Henezys ta evoliutsiia kontseptsii promyslovykh klasteriv. Visnyk TNEU, 1, 36–48. Available at: http://visnyk.wunu.edu.ua/images/docs/journal/vtneu_2014_1/5.pdf
29. Svirko, S., Vlasiuk, T., Shevchuk, O., Suprunova, I. (2023). Public-private partnership as a tool for innovative development of urban areas. Economics, Management and Administration, 1 (103), 118–127. https://doi.org/10.26642/ema-2023-1(103)-118-127
30. Yemtsev, V. I. (2012). Klastery yak suchasna forma kvaziintehratsii na mezorivni. Zb. nauk. prats z aktualnykh problem ekonomichnykh nauk, 74–79. Available at: https://dspace.nuft.edu.ua/jspui/bitstream/123456789/9142/1/3.pdf

CHAPTER 5

Universities as regional leaders for sustainable energy and climate EU-harmonized policies

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Abstract

European Green Deal envisages a wide range of goals and milestones to provide a policy framework to integrate innovative, educational, and institutional components of the input from higher educational institutions toward a green transition of their regions and countries. Since, at the initial European Commission level, the role of the university sector was not fully formulated, there's a need to create a new roadmap for their contribution. We foresee the following impact areas from the universities in the green transition of national economies: research and innovation, education, staff and infrastructure management, and public/social impact.

Keywords

University leadership, energy management system, renewable energy, energy monitoring, climate action.

5.1 Introduction

5.1.1 EU green deal and universities

In October 2023, the European University Association released a study, "A Green Deal roadmap for universities" [1]. The roadmap described universities' vital roles and outcomes in the green transition:

1. Research and innovation: universities play a crucial role in conducting research on sustainable technologies, energy solutions, climate change, and

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environmental policies. They develop innovative solutions to address the challenges of the green transition.

2. Education and training: universities provide education and training programs that equip students with the necessary knowledge and skills to address sustainability challenges. These programs include degrees in renewable energy, environmental sciences, sustainable engineering, and sustainable business practices.

3. Policy advocacy and expertise: universities contribute their expertise to policy dialogue and support policymakers in developing effective strategies for the green transition. They provide evidence-based research and analysis to shape sustainability policies at the local, national, and international levels.

4. Collaboration and partnerships: universities collaborate with industry, government agencies, and civic organizations to promote sustainable practices. They create partnerships for joint research projects, knowledge exchange, and implementing sustainable initiatives in various sectors.

5. Campus practices and operations: universities adopt sustainable practices within their campuses, aiming to reduce their carbon footprint, promote renewable energy, improve waste management, and enhance energy efficiency. They serve as living laboratories for testing and implementing green technologies and practices.

6. Community engagement: universities engage with their local communities to raise awareness about sustainability issues and contribute to the transition towards a greener society. They organize public lectures, workshops, and community-based projects to promote sustainable behaviors and empower individuals to take action.

7. Entrepreneurship and start-ups: universities support and foster entrepreneurship in sustainable industries. They provide resources, mentorship, and funding opportunities for students and faculty members to develop innovative start-ups that contribute to the green economy.

These roles and outcomes demonstrate how universities are vital partners in driving the green transition, contributing to a sustainable future for local communities and global society. Being big energy consumers in their home municipalities, universities shall become a working example of ambitious actions aimed at green transition.

5.1.2 Universities as drivers of green transition at the municipal level

Since universities typically are headquartered in relatively big towns and cities, which aligns with the stated approach, they shall contribute differently to municipal

energy and climate plans. More than two-thirds (67 %) of European municipalities have adopted some form of energy and climate planning document [2], such as a sustainable energy action plan, sustainable energy, and climate adaptation plan. Based on this, it is possible to consider the leading role of universities at the municipal level far more active than at the national.

As significant energy consumers in their respective communities within the EU, universities have a distinctive role in the transition towards sustainable energy practices. Here are the critical aspects of their role:

1. Energy efficiency initiatives. Universities can implement energy efficiency measures within their facilities, considering their energy consumption. By adopting energy-saving technologies, optimizing heating and cooling systems, and maintaining efficient lighting, universities can reduce energy consumption and serve as models for sustainable community practices.

2. Collaboration with local energy providers. Universities can collaborate with local energy providers to explore sustainable energy options. By engaging in dialogue with utility companies, universities can encourage the adoption of renewable energy sources, such as solar or wind power, in their towns. This collaboration can drive the transition towards cleaner and more sustainable energy generation and consumption.

3. Research and innovation. Universities can research energy-related topics and develop innovative solutions. They can partner with local businesses, government agencies, and community organizations to address energy challenges within their home towns. Research initiatives can focus on renewable energy integration, energy storage technologies, smart grids, and energy-efficient urban planning.

4. Knowledge dissemination and public outreach. Universities are responsible for sharing their expertise and knowledge with the local community. They can organize workshops, seminars, and public lectures to raise awareness about sustainable energy practices and promote behavioral change. By engaging with local residents, businesses, and policymakers, universities can foster a shared understanding of the benefits of sustainable energy consumption and encourage its implementation beyond their campuses.

5. Collaborative projects with local stakeholders. Universities can initiate collaborative projects with local businesses, communities, and government bodies to promote sustainable energy practices. These projects can involve joint research ventures, pilot programs for renewable energy adoption, or consultations on energy efficiency measures for local infrastructure. By working together, universities and their hometowns can create innovative solutions and drive the transition toward a sustainable energy future.

5.2 University as community leader in energy transition

The global transition to sustainable energy systems requires collective action from all sectors of society. Universities are uniquely positioned to lead this transition as centers of knowledge and innovation. Their activities demonstrate a commitment to reducing their carbon footprint and promoting sustainable energy practices in their home cities. By collaborating with local stakeholders, engaging in research and innovation, and promoting knowledge dissemination, universities are making a significant contribution to the European Union's (EU) energy transition goals and inspiring their communities to use energy more cleanly and sustainably.

Education is a cornerstone of the energy transition. Universities can contribute by developing comprehensive educational programs that address energy literacy and consumption patterns. Understanding these patterns is essential for developing strategies that support the energy transition. By incorporating energy education into their curricula, universities can raise awareness and promote responsible energy behavior.

To solve the abovementioned problems of staffing the industry, IFNTUOG launched a new bachelor's program "Renewable Energy Engineering" in the specialty 152 "Metrology and Information and Measuring Technology". The new educational program, which is consistently and meaningfully aligned with the strategies of the university, Ivano-Frankivsk region and the government of Ukraine, has emerged as a central component of the eco-system that has been formed on the basis of the Department of Energy Management and Technical Diagnostics in recent years. In the **Fig. 5.1**, ecosystem includes the Master's program in Energy Management, which has been implemented since 2016, the New Energy Science Campus (since 2016), the program for training and certification of energy auditors, experience in implementing and ongoing international projects and academic mobility programs for students and teachers with EU universities, and a significant portfolio of completed projects commissioned by Ukrainian enterprises and municipalities.

In the fall of 2019, a draft profile of the educational program was developed and published on the university's website. Within 2 months, almost 30 reviews were received from stakeholders, and most of the substantive comments were considered. The improved program was agreed upon and approved by the established procedure. At the same time, there was a significant number of needs for material and information support for the new educational program. For this purpose, an application was submitted to the USAID Energy Security Project (ESP) grant competition and was supported.

Thanks to the ESP grant support, the latest training equipment, computer hardware, and specialized software were purchased during the 2020/2021 academic year, which successfully complemented the existing material base at the department.

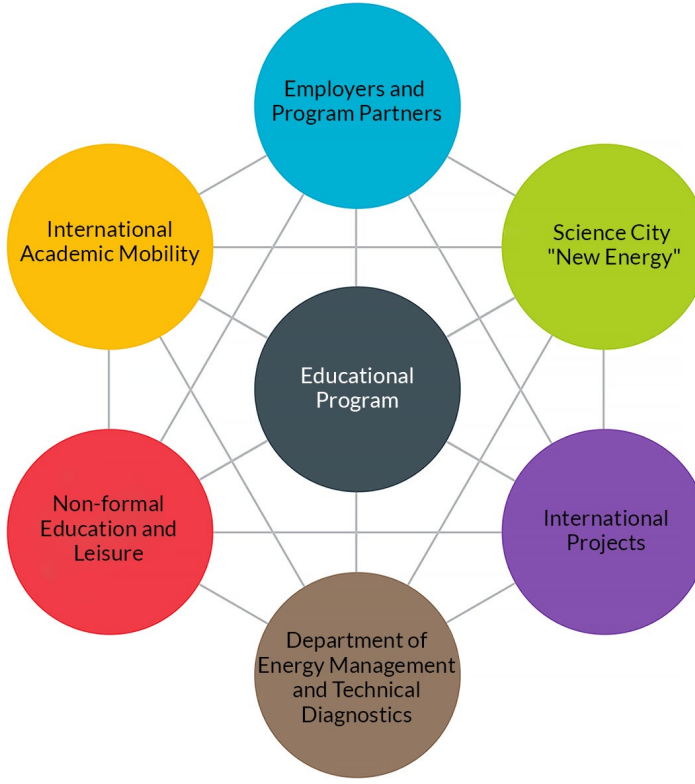

Fig. 5.1 Eco-system of the Renewable Energy Engineering study program

Additionally, external lecturers were engaged to teach specialized courses provided by the educational program. A good example of such involvement is the involvement of V. Sheremeta, Head of the Ukrainian Greek-Catholic Church Bureau of Ecology, to teach a separate module of the Philosophy and Environmental Ethics course.

Its coverage in the media and social networks is equally important for popularizing the new educational program. For this purpose, several videos were filmed,

more than 100 thematic publications were created and disseminated on social networks, and more than 10 appearances in regional media were made.

One factor that hinders the development of energy efficiency and renewable energy in Ukraine is the lack of trained personnel. Specialized companies operating in the energy sector are constantly looking for additional training for their staff. As of the end of 2019, no university in Ukraine trained specialists in the renewable energy sector – there were only "adapted" educational programs that did not meet the industry's requirements and lacked proper technical and methodological support. The efforts of many stakeholders, a solid methodological and technical base, and compliance with the current requirements of the higher education system allowed to introduce an educational program that meets the challenges of the Ukrainian and global labor market.

Integrating an educational program with industry partnerships, international collaborations, and practical experiences is crucial for preparing specialists capable of addressing current and future energy challenges. Universities play a central role in this process by creating an environment that fosters learning, innovation, and engagement with the broader community. The schematic representation underscores the importance of a multifaceted approach to education in driving the energy transition forward.

The outbreak of the war in Ukraine exacerbated existing problems in the energy production and transmission sector. Critical infrastructure was damaged, leading to frequent power outages. In this context, the role of universities becomes even more important. Alumni and current students are contributing to solving these pressing problems, using their experience to find innovative solutions in difficult circumstances.

Universities, as centers of learning and research, can catalyze community energy initiatives by establishing partnerships and promoting the sharing of energy resources. Student initiatives can play a crucial role in bridging the gap between universities and local communities. By engaging students in community projects, universities can educate a new generation of environmentally conscious citizens and contribute to a sustainable future.

In a series of projects mainly co-funded by the EU, the authors showcased an approach to how universities can become local drivers of the energy-green transition in Ivano-Frankivsk, Ukraine. The university played a central role in promoting sustainable energy practices by collaborating with local stakeholders – including government agencies, businesses, and community groups.

The projects involved installing shared photovoltaic facilities, conducting energy literacy workshops, and developing community-driven energy plans. These initiatives reduced the university's carbon footprint and inspired the local community to embrace cleaner energy consumption. Importantly, 100 % of the university's alumni involved in these projects emerged as competent specialists, well-prepared to address their community's energy challenges.

5.2.1 Energy management system at the university as a public institution

The ISO 50001 standard is a powerful tool for organizations to improve energy performance. It has been estimated that the ISO 50001 Energy Management Standard could positively impact 60 % of the world's energy use by providing public and private sector organizations with management strategies to increase energy efficiency, reduce costs, and improve energy performance. Effective energy management is a priority focus because of the potential to save energy and reduce greenhouse gas (GHG) emissions [3].

The structure of ISO 50001:2020 is designed according to other ISO management system standards, ISO 9001:2015 (Quality Management Systems) and ISO 14001:2015 (Environmental Management Systems). Since all three management systems are based on the Plan-Do-Check Act (PDCA) cycle (**Fig. 5.2**), ISO 50001:2020 can be integrated easily into these systems [4].

The ISO 50001:2020 standard is grounded in the Plan-Do-Check-Act (PDCA) cycle, providing a structured approach for continuous improvement in energy performance. In the context of a university's energy management [5], this cycle enables the institution to effectively control energy use, identify opportunities for enhancement, and implement strategies to achieve energy efficiency goals.

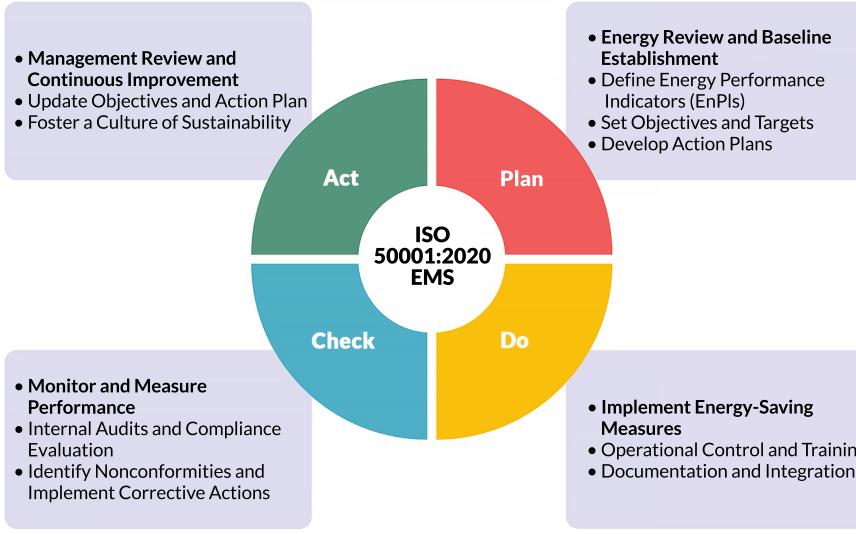

Fig. 5.2 Plan-Do-Check-Act (PDCA) cycle of ISO 50001:2020 for IFNTUOG

In the **planning phase**, the university begins by conducting a comprehensive energy review to analyze current energy consumption across all facilities, including classrooms, laboratories, offices, and dormitories. This review helps establish a baseline against which future improvements can be measured, considering factors like seasonal variations and occupancy rates. The institution then defines energy performance indicators such as energy consumption per square meter or per student, facilitating the monitoring of progress toward energy objectives. Clear and achievable energy objectives and targets are set, aligning with the university's energy policy and sustainability commitments. Detailed action plans outline necessary actions, responsibilities, timelines, and resources to meet these objectives.

During the **implementation phase**, the university puts the planned actions into practice. This may involve executing strategies like retrofitting buildings with energy-efficient lighting, installing solar panels, optimizing heating and cooling systems, and promoting energy-saving practices among students and staff. Operational control ensures daily operations align with energy performance objectives, such as scheduling equipment use during off-peak hours and ensuring equipment is properly maintained for optimal efficiency. Communication and training are essential components, as educating faculty, staff, and students about energy management initiatives fosters a culture of sustainability and encourages active participation. All relevant records and documentation are maintained to support the Energy Management System (EMS) and demonstrate compliance with ISO 50001 requirements.

In the **checking phase**, the university monitors and measures key aspects of operations that determine energy performance. Regular tracking of energy performance indicators and energy consumption data allows assessment of performance against the baseline and objectives. Internal audits are conducted to verify that the EMS conforms to planned arrangements and ISO 50001 requirements, helping identify areas of non-compliance and opportunities for improvement. Compliance with legal and other requirements related to energy use is evaluated, ensuring adherence to local regulations, building codes, and environmental standards. When deviations from expected performance are identified, corrective measures are implemented to address nonconformities.

Finally, in the **action phase**, the university takes steps to continually improve energy performance and the effectiveness of the EMS. Top management reviews the system to assess its suitability, adequacy, and effectiveness, making decisions regarding resource allocation, policy adjustments, and strategic direction. Changes and enhancements identified during reviews or as a result of monitoring and audits are implemented, embracing new technologies and practices that can further reduce energy consumption. Objectives, targets, and action plans are updated based on

performance data and changing circumstances, ensuring the EMS remains dynamic and responsive to evolving energy needs.

By integrating the PDCA cycle into its EMS, a university creates a system that adapts to technological advancements and changing energy demands [6]. For example, if the institution sets a goal to reduce energy consumption in campus buildings by 15 % over the next two years, it would implement energy-saving measures such as installing energy-efficient windows, upgrading to LED lighting, and encouraging energy-conscious behaviors. Progress would be monitored monthly using EnPIs, and strategies would be adjusted based on the findings as needed.

Implementing the PDCA cycle in university energy management offers numerous benefits. It provides a systematic approach to managing energy performance across diverse campus facilities and encourages continuous improvement of energy efficiency measures. Engaging the entire campus community fosters a culture of sustainability, while compliance with regulatory requirements can qualify the university for grants and recognition programs. Additionally, optimizing resource use leads to significant cost savings, allowing the institution to allocate funds to other critical areas such as research and education.Building upon the principles of the ISO 50001 standard and the Plan-Do-Check-Act (PDCA) cycle, scientists at Ivano-Frankivsk National Technical University of Oil and Gas (IFNTUOG) have developed and prepared an Energy Management System (EnMS) for certification. This initiative demonstrates the university's dedication to enhancing energy efficiency, reducing operational costs, and contributing to environmental sustainability.

The development process involved creating a comprehensive set of documents aligned with the national standard DSTU ISO 50001 requirements. University scientists meticulously prepared key documents, including the implementation order of the EMS, which formalizes the initiation and scope of the energy management system within the institution. They established regulations for the working group on the EMS, defining the roles and responsibilities of the team overseeing its implementation and maintenance.

An integral part of the documentation is the Energy Policy, outlining the university's commitment to energy efficiency and setting strategic objectives and guiding principles for energy management. Additionally, they prepared a questionnaire for the management system certification body, providing essential information required for the certification assessment. Procedures for documentation management were established to ensure consistency and accessibility of all EMS-related documents.

The team also developed protocols for internal audits and corrective and preventive actions to facilitate regular assessments and continuous system improvement. Guidelines for record management were specified to maintain and safeguard

records pertinent to energy performance and EMS activities. General guidelines offering overarching instructions for effective energy management within the university context were included to support the implementation process.

To establish a baseline for energy consumption, a methodology for calculating the basic level of consumption of fuel and energy resources was created. This provided a systematic approach to tracking consumption patterns and identifying areas for improvement. An in-depth analysis of energy consumption was conducted to pinpoint significant energy uses and uncover opportunities for enhancement.

Upon completion, the university's leadership reviewed and approved these documents, ensuring they met the specific conditions and requirements of IFNTUOG. The formal approval of the Energy Policy and accompanying regulatory documentation signifies a strong institutional commitment to energy efficiency and adherence to DSTU ISO 50001 standards.

As a result, Ivano-Frankivsk National Technical University of Oil and Gas has developed a comprehensive Energy Policy that underscores the institution's commitment to energy efficiency and sustainability. This policy serves as a guiding framework for all energy-related activities within the university, reflecting a dedication to reducing environmental impact and promoting responsible energy use.

A central focus of the Energy Policy is the reduction of fuel and energy consumption, aiming to minimize unnecessary costs and promote the rational use of resources. The university actively seeks to enhance energy efficiency by implementing energy-saving measures, ensuring that every aspect of its operations contributes to this goal.

Compliance with Ukraine's current legislation, international agreements, and established standards in the field of energy conservation and efficiency is a fundamental aspect of the policy. By adhering to these regulations, IFNTUOG aligns its practices with both national and international expectations, fostering a culture of accountability and excellence in energy management.

The Energy Policy emphasizes establishing and continuously analyzing energy goals, objectives, and programs designed for their implementation. Regular monitoring and analysis of energy efficiency indicators enable the university to track progress, identify areas for improvement, and adjust strategies accordingly. This dynamic approach ensures that energy performance is maintained and consistently enhanced over time.

Transparency and the availability of information regarding activities in energy efficiency are also key components of the policy. IFNTUOG is committed to providing the necessary resources to achieve its energy objectives, ensuring that all stakeholders are informed and engaged in the process. Raising awareness and motivation

among staff about energy efficiency and the functioning of the EnMS is essential. By fostering an environment where employees are knowledgeable and proactive, the university enhances the effectiveness of its energy initiatives.

With over a decade of experience in energy efficiency and the rational use of energy resources, IFNTUOG has leveraged this expertise to develop and prepare for certification in an energy management system. The adoption of the ISO 50001 standard has been instrumental in this endeavor. Recognized as a powerful tool for organizations to improve energy performance, ISO 50001 provides a structured framework that enables the university to systematically manage and reduce energy consumption.

By embracing the ISO 50001 standard, IFNTUOG improves its energy performance and sets a benchmark for other institutions. The university's efforts demonstrate how public institutions can lead by example in the global pursuit of sustainability and energy efficiency. Through dedicated policy, strategic planning, and active engagement of its community, IFNTUOG continues to contribute significantly to the energy transition, both within Ukraine and in the broader international context.

5.2.2 Demonstration installations on renewable energy sources

Renewable energy installations, particularly solar power systems, are increasingly pivotal in the global energy mix. According to the International Energy Agency (IEA) [7], solar energy is projected to become the world's second-largest renewable energy source after hydropower by the end of this decade. Solar power plants (SPPs) are expected to become the most significant energy source in Europe by 2025. This rapid expansion can be attributed to the steady decline in the cost of generating power from SPPs. Over the past ten years, global prices of solar panels have decreased dramatically, while their efficiency has nearly doubled. These technological advancements have made electricity generated from SPPs commercially attractive for businesses.

Businesses are adopting SPP projects through several prevalent approaches. One method involves generating electricity and selling it to the grid at a special "green" tariff, incentivizing renewable energy production. Another strategy is generating energy for the company's own consumption, reducing dependence on external energy sources, and lowering operational costs. Additionally, a combined mode of operation is often employed, where businesses both consume the generated energy and sell any excess back to the grid. This hybrid approach allows for the optimization of energy use and the maximization of financial benefits.

As for installing SPPs for operation under the "green" tariff, due to its significant reduction and the situation that has arisen with delays in payments from the state for the generated energy, such projects are becoming less attractive for investment. Unlike working under the "green" tariff, when installing an SPP for its consumption, the enterprise can replace part of the electricity from the grid with electricity from the SPP.

According to the International Finance Corporation (IFC), Ukraine has a vast potential for developing the solar energy self-consumption segment. Experts predict that by 2030, the potential for the installation of solar power plants (SPPs) for self-consumption by enterprises in Ukraine will be from 2 to 3 GW, and the required investment volume for the implementation of these projects will be from 1.5 to 2 billion USD [8].

The simplicity of installation also helps to minimize capital costs. In most cases, SPPs do not require the allocation of particular additional space – they are installed on the roofs of industrial buildings or empty land areas on the enterprise's territory. Another factor in reducing the cost side is that there is no need to connect to the network and obtain many permits. As a result, the quick installation and ease of registration allow the solar power plant to be operated in just a few months. The operating costs of SPPs are minimal compared to other renewable energy sources. SPP equipment is reliable and durable (the service life of photovoltaic panels is 25 years or more, inverters – up to 10 years), requiring minimal maintenance [9].

The university has embraced these developments by installing demonstration units of renewable energy sources on campus. These installations serve multiple purposes: they contribute to the university's energy needs, provide hands-on learning opportunities for students, and act as tangible examples of sustainable practices for the community. By integrating renewable energy technologies into its infrastructure, the university reduces its carbon footprint and positions itself as a leader in promoting renewable energy adoption.

Solar PV systems for self-consumption are designed to meet the energy needs of a business or institution during the day. The difference is automatically taken from the centralized electrical grid if not enough solar energy is generated. The main economic benefit of such systems is the savings on electricity costs that the energy supplier would otherwise incur. In this case, the business or institution's operation cycle is essential. The ideal scenario is when peak energy demand coincides with the daily activity of the sun. In this case, such systems can be installed in offices, factories, warehouses, supermarkets, car washes, schools, government agencies, and other facilities where stable consumption occurs during the day. In **Fig. 5.3**, the blue line represents the generation of the solar PV system, and the orange line represents the enterprise's energy consumption. As can be seen, the solar PV system can meet the enterprise's energy needs during the day, with only a tiny amount of energy being drawn from the grid.

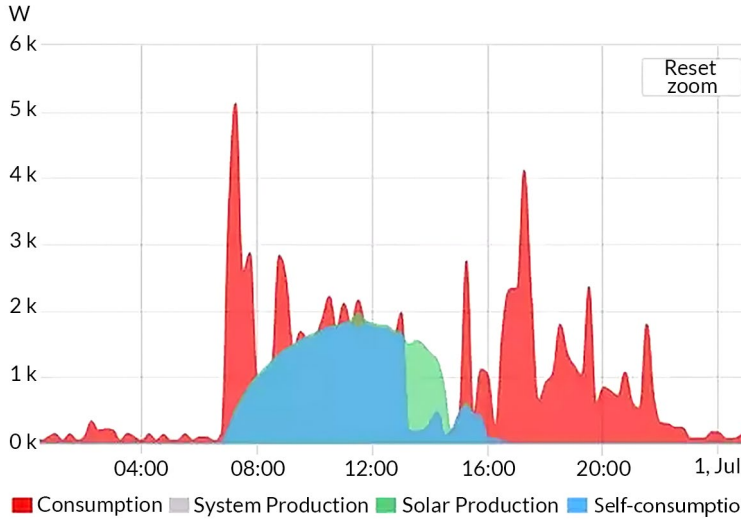

Fig. 5.3 Solar PV system coverage of daily energy consumption at an enterprise
Source: [10]

It should be noted that decentralization of electricity supply is a strategically important direction, as reducing electricity consumption from traditional energy sources by switching to alternative energy sources installed near the consumer can potentially lead to the unloading of electrical networks of distribution system operators, reducing losses in them.

A demonstration solar power plant was installed and commissioned to demonstrate the operation of a solar power plant (SPP) designed to compensate for its own electricity consumption and demonstrate the capabilities of renewable (solar) energy equipment for energy saving.

The assembled SPP is in a publicly accessible place – the laboratory of the physical foundations of renewable energy sources of the Department of Energy Management and Technical Diagnostics of IFNTUOG. Structurally, the SPP is built according to the grid scheme and consists of a solar panel array, a grid inverter, and a smart meter through which it is connected to the electrical network. For the implementation of the SPP according to the structural diagram shown in **Fig. 5.4**, a grid inverter and a smart meter from the Fronius company were selected [11].

As noted above, the demonstration solar power plant (SPP) equipment is located in the laboratory of the physical foundations of renewable energy sources of the Department of Energy Management and Technical Diagnostics (EMandTD)

of IFNTUOG. This includes a grid inverter (with a capacity of 3 kW), a DC switchgear with protection and switching devices, and an AC switchgear to connect to the electrical network and the corresponding energy consumption accounting (**Fig. 5.4**).

The array of photovoltaic panels with a total capacity of 3420 W (the capacity of the array is chosen higher than the capacity of the grid inverter to compensate for the decrease in the efficiency of photovoltaic panels during heating), which consists of 12 photovoltaic panels, is located on the roof of an adjacent single-story building, accessible for inspection. The DC voltage from the array of photovoltaic batteries is supplied to the grid inverter via an overhead line (**Fig. 5.5**).

The display and demonstration of the operation of the demonstration SPP are carried out both on the screen of the grid inverter and using the Fronius Solar web application (**Fig. 5.6**).

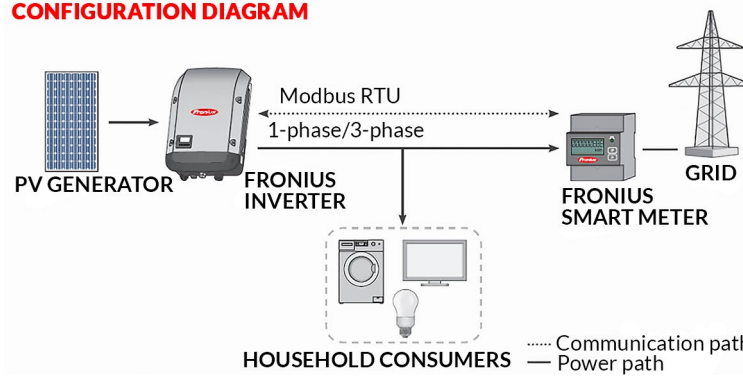

Fig. 5.4 Structural diagram of a solar power plant
Source: [11]

Fig. 5.5 Grid inverter, DC and AC switchgear, and solar panel array installed at the demonstration grid-connected solar power plant

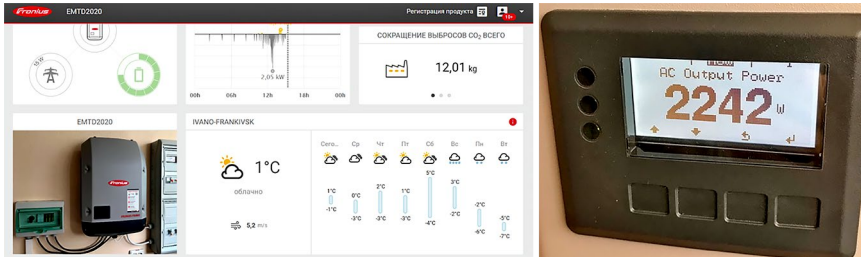

Fig. 5.6 View of demonstration photovoltaic station in application of Fronius Solar web

In addition to the Fronius smart meter, located in the AC switchgear, energy monitors are used to monitor electricity consumption and the operation of the SPP in compensation mode. For direct measurement of total consumption, the D103 smart-MAIC energy monitor with current shunt transformers is used to measure generation from the SPP. To determine the consumption of electrical energy from the primary consumers after the switchgear, which is the electric boiler and the lighting system of the common areas of the department, universal D105 smart-MAIC energy monitors are used that are connected to the telemetry pulse outputs of electromechanical electric meters located in the switchgear. A page was created in the web application of the energy monitoring system for the university building to display the operation of the demonstration SPP (**Fig. 5.7**).

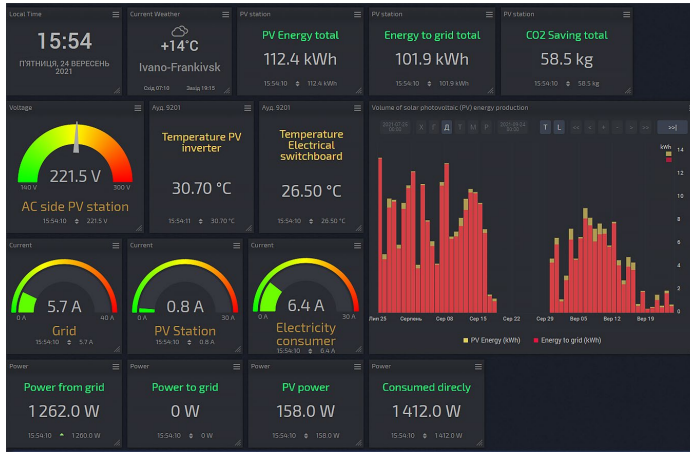

Fig. 5.7 Dashboard of the demonstration photovoltaic station for energy monitoring at the university building at the application

5.2.3 Energy consumption monitoring system

Continuous monitoring of heat, electricity, and water consumption in public buildings is fundamental to effective energy management and conservation efforts. By obtaining hourly data on energy usage for individual consumers and specific areas within buildings, organizations can gain a precise understanding of actual energy needs. This granular insight enables energy-supplying organizations to plan and distribute energy more efficiently, aligning supply with demand and reducing wastage.

Implementing advanced metering systems and energy management software allows for real-time tracking and analysis of consumption patterns. This information can highlight areas of excessive use, identify inefficiencies in building systems, and uncover opportunities for energy-saving measures. For instance, if certain zones within a building consistently show higher energy consumption, targeted interventions such as upgrading insulation, optimizing HVAC systems, or promoting energy-conscious behaviors among occupants can be employed.

Moreover, continuous monitoring supports predictive maintenance by signaling when equipment is operating sub-optimally or nearing failure, thereby preventing energy losses and reducing downtime. It also facilitates compliance with energy regulations and certifications by providing documented evidence of consumption and efficiency measures.

In essence, the availability of detailed consumption data empowers both energy providers and building managers to make informed decisions that enhance energy efficiency, reduce operational costs, and contribute to environmental sustainability. By focusing on areas with high energy usage, organizations can implement strategic improvements that yield significant long-term benefits.

Advancing energy efficiency within public buildings requires innovative solutions that address the unique challenges these structures present. Recognizing this, the university has embarked on developing a specialized information and measurement system (IMS) for monitoring energy resource consumption. The primary aim is to implement a pilot version of this IMS in a university building, laying the groundwork for broader application across the campus and potentially serving as a model for other public institutions.

Globally, numerous solutions exist for energy monitoring in buildings [12]. However, public buildings like universities often encompass large areas with a multitude of rooms and facilities, resulting in a significant number of measurement points for various energy parameters and microclimate conditions. This complexity necessitates an IMS that is not only effective but also simple to implement and cost-efficient.

Key considerations include:

– integration with existing systems: the IMS must seamlessly integrate with current metering devices to avoid redundant infrastructure costs;

– user-friendly interface: visualization and data storage should be accessible and easily configurable without requiring specialized technical skills, enabling facility managers and other stakeholders to interact with the system effectively;

– flexibility and scalability: the system should be adaptable to accommodate future expansions or technological advancements, ensuring long-term viability.

In Ukraine, existing approaches to energy monitoring in public buildings are often limited. They primarily involve the implementation of energy management systems that rely heavily on manual data collection [13]. Such methods lack the capability to provide detailed hourly or daily consumption data, restricting the ability to perform real-time analysis or respond promptly to inefficiencies. This manual approach also increases the likelihood of errors and data gaps, hindering accurate monitoring and decision-making.

Continuous monitoring of heat, electricity, and water consumption is fundamental to effective energy management. Having access to hourly energy consumption data for individual consumers and specific points within buildings enables a granular understanding of actual energy needs. This detailed information is crucial for:

– optimizing energy distribution: collaborating with energy-supplying organizations to plan appropriate energy distribution based on real consumption patterns;

– identifying inefficiencies: detecting areas with unusually high energy consumption to target interventions and improve overall energy efficiency;

– enhancing decision-making: providing data-driven insights that support operational decisions, such as adjusting heating schedules or implementing energy-saving measures.

Given these needs, developing an automated IMS for monitoring and managing energy supply has become an urgent task. The proposed system aims to:

– provide real-time data: offer continuous, automated monitoring of energy consumption and microclimate parameters, facilitating timely responses to any anomalies or inefficiencies;

– support operational management: enable the management of energy supply systems based on operational decisions derived from real-time data analysis;

– improve energy efficiency: contribute to reducing energy consumption and operational costs by identifying and addressing inefficiencies promptly.

The development process involves selecting appropriate hardware and software components that meet the university's requirements. This includes:

– sensors and meters: deploying devices that accurately measure various energy parameters and environmental conditions;

– data acquisition systems: implementing robust systems to collect and transmit data reliably from multiple points across the building;

– communication networks: establishing secure and efficient communication protocols to ensure seamless data flow between devices and central systems;

– data management platforms: utilizing platforms that allow for easy visualization, analysis, and storage of collected data.

Implementing such an IMS enhances operational efficiency and aligns with the university's commitment to sustainability and environmental stewardship. It provides several additional benefits:

– educational opportunities. Serves as a practical tool for students and researchers to engage with real-world energy management technologies, fostering innovation and expertise in the field;

– community leadership. Positions the university as a leader in sustainable practices, setting an example for other institutions and contributing to broader societal shifts toward energy efficiency;

– compliance with regulations. Helps meet legal and policy requirements related to energy use, potentially qualifying the university for grants, incentives, or recognition programs.

Moreover, the IMS can facilitate advanced functionalities such as predictive maintenance and energy forecasting. The system can predict potential equipment failures or maintenance needs by analyzing historical data and consumption patterns, preventing downtime and additional costs. Energy forecasting allows the university to anticipate future energy demands, enabling better budgeting and resource allocation.

Based on the requirements in [14], an Information and Measurement System (IMS) for monitoring energy consumption was built. Authors within the framework of the EU-funded project NET4SENERGY conducted a thorough study to find the most optimal solution for creating an IMS for energy monitoring of a university building that meets the abovementioned requirements [15]. Smart devices of the Ukrainian company smart-MAIC were chosen to build the monitoring system [16].

The development and pilot implementation of an advanced Information and Measurement System for energy monitoring are currently underway at the Department of Energy Management and Technical Diagnostics (EMandTD) of Ivano-Frankivsk National Technical University of Oil and Gas. The EMandTD department occupies approximately one-third of educational building No. 9, encompassing two floors and incorporating various autonomous electric heating systems. This complex energy infrastructure presents an ideal environment for modeling the IMS, facilitating its potential replication across other university buildings and public institutions.

The architecture of the pilot IMS is illustrated in **Fig. 5.8**. The system is designed to capture high-resolution data on electrical and thermal energy consumption and cold and hot water usage within the university building. Additionally, it continuously monitors key microclimate parameters in each classroom, including air temperature, relative humidity, and carbon dioxide (CO_2) concentration. An external meteorological module complements the system by recording outdoor environmental conditions such as ambient temperature, humidity, and atmospheric pressure trends.

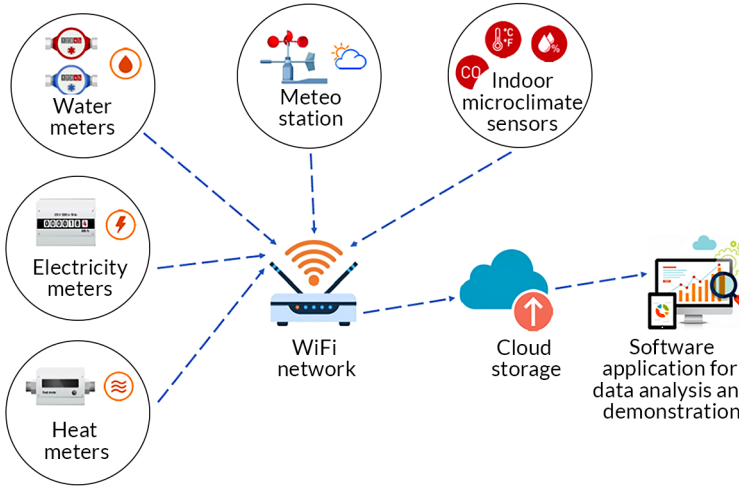

Fig. 5.8 Structure of the pilot information-measurement system for energy monitoring of the university building

The IMS employs a network of interconnected sensors and metering devices based on the smart-MAIC product line. These devices are engineered to monitor events, conditions, and processes, and include:

– electricity meters: both single-phase and three-phase electricity meters are equipped with ring or plug-in current transformers. These devices measure voltage and current parameters, facilitating the calculation of power consumption with high precision;

– pulse counters: devices with temperature sensors and analog inputs can record consumption data for utilities such as water and gas through pulse signals from standard utility meters;

– environmental sensors: devices measuring microclimate parameters contribute to indoor environmental quality assessments (IEQ).

All devices conform to the DIN-rail casing standard EN 60715:2017, allowing for seamless installation within existing electrical panels. This modularity ensures ease of integration and scalability, which is critical for expansive facilities like university buildings.

The IMS utilizes a combination of wired and wireless communication protocols for data acquisition and transmission. Measurement devices are connected via Modbus RTU over RS-485 communication lines, a robust industrial standard for serial communication in energy monitoring systems. Data collected from the devices are aggregated by a central data logger equipped with Internet connectivity, which transmits the data to a cloud-based server using secure MQTT (Message Queuing Telemetry Transport) protocols. This approach ensures reliable and efficient data transmission, even in environments with variable network connectivity.

In the classrooms, the IMS focuses on tracking microclimate parameters to optimize energy usage while maintaining occupant comfort. The universal smart-MAIC D105 data logger is the central hub for environmental sensors, connecting temperature-humidity and CO_2 sensors.

Temperature and humidity sensors. The AM2302 digital sensors (also known as DHT22) measure temperature and relative humidity. These sensors employ capacitive humidity sensing and thermistor temperature sensing technologies, providing temperature measurements in the range of −40 °C to +80 °C with an accuracy of ±0.5 °C, and relative humidity measurements from 0 % to 99.9 % with an accuracy of ±2 %. These sensors' high accuracy and reliability are critical for precise environmental monitoring.

Carbon dioxide sensors. The MH-Z41A infrared CO_2 sensor is used to measure indoor CO_2 concentrations, ranging from 0 to 5000 ppm with an accuracy of ±50 ppm. This non-dispersive infrared (NDIR) sensor operates based on the absorption of infrared light by CO_2 molecules, offering high accuracy and stability. Monitoring CO_2 levels is essential for assessing indoor air quality and ensuring adequate ventilation, which can impact both occupant health and cognitive performance.

To measure electricity consumption, particularly in classrooms equipped with electric heating, the smart-MAIC D103 energy monitor is deployed. This device connects to the three-phase power supply, measuring voltage and current through ring-type current transformers with a nominal rating of 100 A. The smart-MAIC D103 measures active and reactive power, power factor, and energy consumption with a relative error within 0 %, adhering to Class 1 accuracy standards as defined by IEC 62053-21. Accurate measurement of electrical parameters is crucial for identifying energy-saving opportunities and verifying the effectiveness of implemented energy efficiency measures.

Collected data are transmitted to a cloud-based data management system, where they are stored, processed, and made accessible for real-time analysis. The cloud infrastructure leverages scalable storage solutions and computational resources to handle the large volume of IMS-generated data.

The smart-MAIC Dashboard web application is the user interface for data visualization and analysis. This application aggregates data for specific classrooms or monitored areas, providing customizable dashboards where users can configure widgets, graphs, and tables to suit their analytical needs. Advanced data analytics features allow for trend analysis, anomaly detection, and performance benchmarking against predefined energy efficiency targets.

An example of the dashboard interface for a university classroom is depicted in **Fig. 5.9**. The dashboard displays real-time and historical data on energy consumption, environmental conditions, and utility usage, enabling facility managers to make informed decisions regarding energy management strategies.

The pilot implementation of the IMS at IFNTUOG provides a comprehensive platform for monitoring and analyzing energy consumption and environmental parameters at a granular level. By leveraging high-resolution data, the university can:

– identify energy inefficiencies. Detailed monitoring allows for detecting unusual energy consumption patterns, such as excessive heating or cooling, equipment malfunctions, or suboptimal operating schedules;

– optimize HVAC operations. Real-time microclimate data support the implementation of demand-controlled ventilation and temperature regulation, adjusting HVAC operations based on occupancy and indoor environmental quality requirements;

– enhance occupant comfort and health. Maintaining optimal indoor environmental conditions contributes to occupant comfort, well-being, and productivity. Monitoring CO_2 levels and other indoor air quality parameters enables timely interventions to improve ventilation when necessary;

– support predictive maintenance. Analysis of energy consumption trends and equipment performance can inform predictive maintenance programs, reducing downtime and extending the lifespan of assets;

– inform policy and investment decisions. Data-driven insights support strategic planning and investment in energy efficiency measures, renewable energy integration, and infrastructure upgrades.

The IMS is a valuable educational tool for students and faculty within the EMandTD department and beyond. It provides hands-on experience with state-of-the-art energy monitoring technologies, data analytics, and IoT systems, enriching the curriculum and fostering research in energy management, sustainability, and smart building technologies.

Students can engage in projects that involve:

– data analysis and modeling: applying statistical and machine learning techniques to analyze energy and environmental data, develop predictive models, and identify optimization opportunities;

– system integration and development: designing and implementing enhancements to the IMS, such as integrating additional sensors, developing control algorithms, or exploring new communication protocols;

– interdisciplinary research: collaborating across disciplines to study the interactions between building systems, occupant behavior, and energy consumption, contributing to the broader field of building science.

Fig. 5.9 An example of an information panel for a segment of the information and measurement system for energy monitoring in a university classroom

The modular design and standardized components of the IMS facilitate its scalability and replicability across other buildings within the university and in public buildings by analogy. By demonstrating the system's effectiveness in a pilot setting, IFNTUOG can develop guidelines and best practices for wider deployment, contributing to energy efficiency improvements at a larger scale.

This system is engineered to collect real-time data from a network of devices strategically installed throughout the building. These devices include sensors and meters that monitor various energy parameters such as electricity consumption, thermal energy usage, water consumption, and microclimate conditions like temperature and humidity.

Data acquired from these devices are transmitted to a cloud-based storage infrastructure, enabling instantaneous access for viewing and analysis. The utilization of cloud computing not only ensures scalability and flexibility but also facilitates remote monitoring capabilities. This approach allows for aggregating vast amounts of data without the constraints of on-premises storage limitations.

The cloud-hosted platform supports the smart-MAIC Dashboard web application, an interactive interface for data visualization and analysis. This application consolidates information for specific classrooms or other monitored spaces, providing comprehensive insights into energy consumption patterns. Advanced analytical tools within the dashboard enable further examination of the data, supporting the identification of inefficiencies and the development of targeted energy-saving strategies.

Users can customize their dashboards by configuring widgets, graphs, and tables according to their requirements. This personalization enhances the user experience and ensures that stakeholders can focus on the most pertinent data relevant to their roles. The intuitive dashboard design reduces the need for specialized technical skills, promoting broader engagement among facility managers, administrative staff, and researchers.

An information panel for a university classroom's energy monitoring system illustrates the real-time visualization of energy consumption metrics and environmental conditions within the space. By providing granular data at the room level, the system enables precise monitoring and management of energy use, contributing to energy efficiency and sustainability objectives.

The information panel (**Fig. 5.9**) shows the current values of temperature, humidity, and carbon dioxide concentration in the room and voltage, current, and consumed power for each phase of the power line. It is essential to analyze energy consumption, the thermal inertia of the building, and the efficiency of the heating, air conditioning, and ventilation system to track changes in the controlled parameters over time. The smart-MAIC Dashboard web application can build various graphical

dependencies with different time granularity (minute, hour, day, week, month, year) and varying types of graphical trend display (line, area, bar chart). Additionally, the user can configure the required data output in a table, particularly for detailing consumption and costs, by setting the price for the energy carrier or hot/cold water, which the monitoring system tracks. For further analysis, for example, in the Excel environment (as a standard software tool for energy management tasks), the data aggregated in the table are exported in CSV format.

To assess the electrical energy consumption by the entire building or its part, the smart-MAIC D103 energy monitor is also used with the appropriate current transformers. The smart-MAIC device line uses current transformers from 100 A to 2000 A, which allows to control the load in a building up to 1.5 MW.

5.2.4 Sustainable energy and climate action planning at the university level

To establish a robust foundation for advancing the green transition within the university setting and to align with local municipal policies, the development and adoption of Sustainable Energy and Climate Action Plans (SECAPs) have been implemented. The SECAP serves as a comprehensive roadmap for the university, aiming to achieve its institutional commitments on climate change mitigation. It considers the sustainable development policies of Ivano-Frankivsk National Technical University of Oil and Gas (IFNTUOG), European initiatives to reduce greenhouse gas emissions, and the university's goals to improve energy efficiency. These commitments include a targeted reduction of greenhouse gas emissions by at least 40 % by 2030 and the development of strategies for climate change mitigation and adaptation, as endorsed by the Covenant of Mayors.

The SECAP for the university encompasses several critical components designed to systematically address energy consumption and emissions. It begins with a declaration of milestones for reducing energy consumption and CO_2 emissions and increasing the share of renewable energy sources in the university's energy mix. This sets clear, measurable goals aligning with national and international climate objectives, providing a strategic direction for the university's sustainability efforts.

An outline of the campus facilities is provided, offering detailed descriptions of building envelopes, infrastructure condition, heating areas, and other relevant aspects. This comprehensive overview identifies key areas where energy efficiency improvements can be made. By understanding the current state of facilities, the university can prioritize actions that will significantly reduce energy consumption and emissions.

An in-depth analysis of heating losses is conducted based on the energy audit results, offering enhancements recommendations. Energy auditing is crucial in identifying inefficiencies in heating systems, insulation quality, and overall thermal performance of campus buildings. Implementing the recommendations from these audits can lead to substantial reductions in energy waste and operational costs, contributing to the university's sustainability goals.

Calculations estimating greenhouse gas emissions are derived from meticulous energy balance spreadsheets, enabling accurate emissions and energy use tracking. This data-driven approach facilitates benchmarking progress over time, allowing the university to assess the effectiveness of implemented measures and adjust strategies as necessary. It also ensures transparency and accountability in reporting emissions reductions to stakeholders and regulatory bodies.

The operational strategy outlined in the SECAP focuses on implementing energy efficiency measures, establishing robust energy monitoring systems, and increasing the use of renewable energy sources such as solar, wind, or biomass. The university enhances its energy administration practices and improves environmental reporting to maintain transparency and encourage continuous improvement. By adopting advanced monitoring technologies and management practices, the university can optimize energy use, detect anomalies, and engage in proactive maintenance, further driving efficiency gains.

A detailed description of planned measures to be implemented is provided, accompanied by estimates of the return on investments (ROI) for each proposed initiative. This economic analysis ensures that the planned actions are both environmentally beneficial and financially viable, promoting sustainable development in a holistic sense. By demonstrating favorable ROI, the university can justify investments in energy projects to stakeholders and secure funding or financing as needed.

An implementation plan with specific details outlines the steps necessary to achieve these goals, including timelines, responsible parties, and resource allocations. This plan is a practical guide for university administration, faculty, and staff, ensuring coordinated efforts across all departments. It emphasizes the importance of stakeholder engagement, recognizing that the participation of the entire university community is essential for the successful execution of the SECAP.

The development of the SECAP at IFNTUOG exemplifies how universities can effectively align their sustainability efforts with both local and European climate objectives. By integrating comprehensive planning, energy auditing, and strategic investments, the university positions itself as a leader in reducing greenhouse gas emissions and advancing the energy transition at the institutional level. This approach contributes to global climate goals and enhances the university's operational

efficiency, reduces energy costs, and fosters a culture of sustainability among students, faculty, and the broader community.

An example of the developed SECAP for Ivano-Frankivsk National Technical University of Oil and Gas can be found [18]. This document is a model for other educational institutions seeking to implement similar strategies. By sharing best practices and lessons learned, IFNTUOG contributes to disseminating effective energy management and climate action planning methods in the higher education sector.

Moreover, the SECAP initiative at the university level demonstrates the critical role that educational institutions play in combating climate change. Universities are not only centers of learning and research but also significant consumers of energy and resources. By adopting comprehensive action plans like the SECAP, universities can significantly reduce their environmental footprint, inspire students and staff to engage in sustainable practices and contribute to developing innovative solutions to global energy challenges. This proactive approach underscores the importance of integrating sustainability into all aspects of university operations, from infrastructure and resource management to education and community engagement.

The commitment to reducing greenhouse gas emissions by at least 40% by 2030 is a significant undertaking that requires concerted effort across multiple domains. It involves upgrading infrastructure to more energy-efficient systems, increasing the use of renewable energy, and promoting behavioral changes among the university community to support energy conservation. The SECAP provides a structured framework for these efforts, ensuring that they are strategic, coordinated, and effective.

The Sustainable Energy and Climate Action Plan (SECAP) is a roadmap for the university aimed at achieving its institutional commitments on climate change mitigation, taking into account the sustainable development policy of IFNTUOG, the European initiatives to reduce greenhouse gas emissions, as well as the university's goals to improve energy efficiency. These commitments include reducing greenhouse gas emissions by at least 40 % by 2030 and developing an approach to climate change mitigation and adaptation (the Covenant of Mayors).

SECAP for the university shall, in general, contain the following:

1. Declaration on milestones for energy consumption and CO_2 emission reduction, share of renewables.

2. Outline of campus with a description of facilities, a brief description of building envelope condition, heating area, etc.

3. Analysis of heating losses based on results of energy auditing with recommendations (optional).

4. Calculations of estimates of greenhouse gas emissions based on energy balance spreadsheets.

5. Operational strategy focused on energy efficiency measures, energy monitoring, use of renewable energy sources, energy administration, and environmental reporting.

6. Description of planned measures to be implemented with estimates on returns of investments for those proposed.

7. Implementation plan with a specific detailing.

An example of the developed SECAP of Ivano-Frankivsk National Technical University of Oil and Gas may be found [17].

5.3 Conclusions

This paper has outlined a comprehensive approach demonstrating the pivotal role universities can play as regional leaders in implementing sustainable energy and climate policies harmonized with European Union standards. Through a tri-directional strategy piloted at Ivano-Frankivsk National Technical University of Oil and Gas, the study showcases the integration of a demonstration solar power station, the development of an Information and Measurement System for energy consumption and indoor climate monitoring, and the institutional efforts embodied in the university's Sustainable Energy and Climate Action Plan.

The demonstration solar power plant at IFNTUOG represents a significant advancement in the university's energy infrastructure. By generating electricity from renewable sources, the plant reduces the university's reliance on traditional fossil fuels and contributes to lowering its carbon footprint. This initiative serves the university's energy needs and acts as a tangible example of renewable energy implementation, inspiring students, staff, and the broader community to embrace sustainable practices.

The pilot information and measurement system for energy monitoring is another critical component of the university's strategy. By collecting high-resolution data on energy consumption and indoor environmental conditions across university buildings, the IMS enables the identification of areas where energy efficiency improvements are most needed. This data-driven approach facilitates informed decision-making, allowing for targeted interventions that optimize energy use, reduce operational costs, and enhance occupant comfort. The IMS also provides an educational platform for students and researchers to engage with cutting-edge energy management technologies.

The development of a Sustainable Energy and Climate Action Plan marks the university's institutional commitment to contributing toward the green transition at the municipal level. The SECAP outlines clear objectives, strategies, and implementation

plans to reduce greenhouse gas emissions, improve energy efficiency, and integrate renewable energy sources. By aligning with local policies and European initiatives such as the Covenant of Mayors and the EU Green Deal, IFNTUOG positions itself as a leader in sustainability efforts within the higher education sector.

Moreover, these initiatives exemplify how universities can catalyze regional adoption of EU-harmonized sustainable energy and climate policies. IFNTUOG's efforts advance its sustainability goals and contribute to Ukraine's alignment with EU environmental and energy standards. Ukraine's commitment to harmonizing its sustainable energy policies with the EU is crucial to its broader European integration strategy. This alignment is driven by the need to comply with EU regulations, access funding opportunities, and participate actively in the EU's ambitious climate and energy frameworks, such as the European Green Deal and the Fit for 55 packages. By adopting practices and standards consistent with these EU directives – such as implementing the ISO 50001 Energy Management System and developing the SECAP in line with the Covenant of Mayors – IFNTUOG not only advances its own sustainability goals but also supports Ukraine's broader ambitions to integrate with the European community. This harmonization facilitates collaboration and access to funding opportunities and supports Ukraine's efforts to enhance its energy security and environmental sustainability in line with European standards.

The successful implementation of these projects demonstrates IFNTUOG's dedication to energy efficiency and environmental stewardship. As a leader in the field of energy efficiency in Ukraine, the university's initiatives serve as a testament to its commitment to reducing environmental impact and fostering a culture of sustainability. These efforts benefit the university and contribute to broader societal goals of combating climate change and promoting sustainable development and climate EU-harmonized policies.

The tripartite approach detailed in this paper-combining renewable energy deployment, advanced energy monitoring systems, and comprehensive strategic planning-provides a replicable model for other public buildings and educational institutions in Ukraine and beyond. The integration of these elements showcases how universities can effectively lead by example, driving the adoption of sustainable practices at the municipal and national levels. In light of the EU Green Deal and global climate objectives, other European higher education institutions may adopt similar strategies to advance the energy transition.

In conclusion, universities are uniquely positioned to lead regional efforts in the energy transition by integrating EU-harmonized sustainable energy and climate policies into their operations and communities. Being a valuable part of their local community, they act as a demonstrator and working examples for the promotion

of sustainable energy and climate actions in line with respective municipal policies. By leveraging their resources, expertise, and influence, they can implement practical solutions that reduce emissions, enhance energy efficiency, and educate future generations. The initiatives undertaken by IFNTUOG highlight the profound impact that higher education institutions can have in shaping a sustainable future, reinforcing the imperative for continued efforts and collaboration in this critical endeavor. The successful implementation of the proposed triplicate approach shall lead to adopting similar projects at other public buildings in Ukraine. Other European higher education institutions may consider it given the EU Green Deal.

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References

1. A Green Deal roadmap for universities (2023). Report. Available at: https://eua.eu/resources/publications/1078:a-green-deal-roadmap-for-universities.html
2. Climate change (2021). Report summary. European Union. Available at: https://climate.ec.europa.eu/system/files/2021-07/report_summary_2021_en.pdf
3. Win the Energy Challenge with ISO 50001 (2011). ISO (International Organization for Standardization). Geneva: ISO Central Secretariat.
4. The ISO Survey-2012 (2013). ISO (International Organization for Standardization). Geneva: ISO Central Secretariat. Available at: http://www.iso.org/iso/home/standards/certification/iso-survey.htm
5. ISO 50001 Energy Management Systems – Requirements with Guidance for Use (2011). ISO (International Organization for Standardization). Geneva: ISO Central Secretariat.
6. Dobes, V. (2013). New tool for promotion of energy management and cleaner production on no cure, no pay basis. Journal of Cleaner Production, 39, 255–264. https://doi.org/10.1016/j.jclepro.2012.08.007
7. Renewables 2020 Analysis and forecast to 2025 (Solar PV) (2020). International Energy Agency. Available at: https://www.iea.org/reports/renewables-2020#overview

8. Pershyi spilnyi z IFC vebinar na temu "Soniachni elektrostantsii dlia vlasnoho spozhyvannia dlia ukrainskykh pidpryiemstv" (2021). UKRGASBANK. Available at: https://www.ukrgasbank.com/eco/webinar_ifc
9. Chomu vse bilshe ukrainskykh kompanii investuiut u soniachni elektrostantsii dlia vlasnoho spozhyvannia (2021). Informatsiyne ahentstvo "Interfaks-Ukrayina". Available at: https://ua.interfax.com.ua/news/blog/740411.html
10. Rogers, S. (2016). Solar Immersion – Maximise your solar power self consumption. Gold Coast Solar Power Solutions. Available at: https://gold-coast-solar-power-solutions.com.au/posts/solar-immersion/ Last accessed: 18.10.2024
11. Export limitation? No problem. Choose the Fronius solution for Limited or zero feed-in situations. Fronius International. Available at: https://www.fronius.com/~/downloads/Solar%20Energy/Flyer/SE_FLY_Export_Limitation_Solution_EN_UK.pdf
12. Mataloto, B., Calé, D., Carimo, K., Ferreira, J. C., Resende, R. (2021). 3D IoT System for Environmental and Energy Consumption Monitoring System. Sustainability, 13 (3), 1495. https://doi.org/10.3390/su13031495
13. Nguyen, V. K., Zhang, W. E., Mahmood, A. (2021). Semi-supervised Intrusive Appliance Load Monitoring in Smart Energy Monitoring System. ACM Transactions on Sensor Networks, 17 (3), 1–20. https://doi.org/10.1145/3448415
14. Guide on monitoring of building energy efficiency (2015). USAID. Municipal energy reform in Ukraine. Kyiv. Available at: https://pdf.usaid.gov/pdf_docs/PA00MD8N.pdf
15. Rybitskyi, I., Karpash, M., Yavorskyi, A., Tsykh, V. (2021). Indoor climate and energy monitoring system at educational institutions. Building Smart Communities for the Future: SMART solutions for energy. Technical University of Košice, 69–76.
16. Smart-MAIC. Smart meters for any consumption. Available at: https://smart-maic.com/en/
17. Sustainable energy and climate action plan for 2021–2030 (2021). IFNTUOG. Available at: https://nung.edu.ua/sites/default/files/2021-12/SECAP-eng.pdf

CHAPTER 6

Digital transformation of the national economy in the context of information environment development in Ukraine

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Abstract

This study is dedicated to defining the conceptual foundations of digital transformation in economic systems and the specifics of digital economy development in Ukraine amid an evolving information environment. It is substantiated that the integration of modern information technologies and digital innovations across all economic sectors lays the groundwork for establishing a new type of economic environment where information becomes a key resource. The study demonstrates that the technological-singularity vector of development, which reflects the increasing importance of information as a critically important productive resource, is the conceptual foundation for the digital transformation of the national economic system. An analysis was conducted on the intensity of digital transformation in the economies of European Union member countries and Ukraine. Based on the obtained data, it is shown that digitalization is a critical condition for global economic competitiveness and stability. This trend emphasizes the importance of investing in the development of information and communication technologies, infrastructure, and digital innovations as key drivers of further economic growth. An analysis of gross value-added formation across types of economic activities in Ukraine reveals an increasing share in sectors fundamental to the digital transformation of the national economy, particularly in the information and telecommunications sectors. The study proves that the digital sector also serves as an essential tool for reducing the shadow economy and corruption risks. The importance of information security in the context of digital economy development is highlighted. The study outlines prospects for the digital transformation of Ukraine's economy amid growing risks and threats in cyberspace.

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Keywords
Digitalization, economic system, digital economy, information asymmetry, information security, sectoral structure of the economy, IT sector, business, shadow economy, corruption risks.

6.1 Introduction

Current trends in the development of the information environment are closely linked to the gradual establishment of the digital economy, which defines the vector of economic growth for leading countries around the world. The digital economy has become a key direction of strategic development, contributing to the formation of a digital society and the integration of security aspects into information and economic processes at all levels of management – from macro to micro levels. This approach necessitates the modernization of management systems and the implementation of qualitatively new methods for monitoring and analyzing economic processes to ensure stable growth.

The digital economy is based on the utilization of digital data as a primary production resource, which enhances the efficiency, productivity, and competitiveness of goods and services. The use of data as a resource factor transforms the core processes of economic activity, enabling the creation of new types of services and improving the quality of life for the population. Information and communication technologies, along with artificial intelligence, have become the main drivers of economic development, facilitating the transition to a knowledge economy and increasing the adaptability of society to new conditions.

Digital transformation of the economy encompasses not only the implementation of digital technologies but also changes in the approaches to utilizing information resources across all sectors of activity. From the social sphere to industry and the financial sector, digitalization fosters profound changes in the structure of economic relations and creates prerequisites for building a society with a new quality of life, where technology serves as the foundation for socio-economic development.

The integration of digital tools into the economy enables countries to strengthen their positions amid globalization, ensuring sustainable development and enhancing competitive advantages in the global market.

In light of the above, the relevance of studying the processes of digital transformation of the national economy in the context of the development of the information environment in Ukraine is undeniable.

6.2 Conceptual framework for the digital transformation of economic systems

Digitalization encompasses all spheres of economic activity, significantly impacting both the global economy and national economic systems [1]. The effects of implementing information and communication technologies (ICT) at the macro level are manifested through the creation of added value for economic sectors and social spheres, while at the micro level, it results in innovative products and services with enhanced profitability and quality [2]. The introduction of digital technologies not only accelerates the process of developing ideas until the finished product reaches the market but also ensures increased economic efficiency and sustainable competitive advantages for the country on the international stage.

Moreover, digitalization serves not only as a tool for achieving national economic interests but also as a powerful factor in strengthening the economic security of the state. It can create new opportunities for economic development and ensure an adequate level of protection for the country's economic resources. However, digitalization also brings new challenges and threats, such as cybercrime and cyberattacks, which are characterized by rapid growth in contemporary conditions [3]. Their negative impact on economic indicators, infrastructure, and social security aspects is becoming increasingly significant, leading to considerable financial losses in the global economy.

Amid the intensifying processes of digitalization, significant transformational changes have occurred in the structure of the economy and productive forces. Information, which traditionally served as one of the key resources in economic systems, has now evolved into a fundamental productive force, reshaping the way economic activities are conducted and driving innovation across various sectors. In contemporary conditions, information holds a status equal to that of primary factors of production – land, labor, and capital – highlighting its critical importance in fostering new economic opportunities and enhancing productivity. This shift emphasizes the evolving role of information, not merely as a supportive element but as a primary driver of economic growth and competitiveness. In this context, the ability to effectively gather, analyze, and utilize information becomes a key determinant of success in the modern economy.

From an economic perspective, information functions as a dominant production factor that encompasses a wide array of functions beyond simple data exchange. It comprises a complex mix of data, knowledge, and insights that are essential for understanding and managing economic processes. This includes the production, distribution, exchange, and consumption of both tangible and intangible goods. Economic

agents – ranging from small businesses to large corporations – rely on information not only to navigate market dynamics but also to make strategic decisions that optimize production processes, enhance efficiency, and secure competitive advantages.

The ability to harness information effectively allows firms to respond rapidly to changes in market conditions, consumer preferences, and technological advancements. Furthermore, the role of information is crucial in facilitating innovation, as it enables businesses to identify trends, anticipate challenges, and develop new products and services tailored to the evolving needs of the market. In this way, information serves as a catalyst for innovation, driving the development of novel solutions that can lead to increased profitability and market share. The universality of information is evident in its capacity to function simultaneously as both a means and an object of labor. This duality makes information an integral component of every production process, permeating all aspects of resource management and business operations. By integrating information into decision-making processes, organizations can enhance their operational efficiency and improve overall performance [4].

Moreover, the advent of digital technologies has further amplified the significance of information. The proliferation of big data, artificial intelligence, and machine learning enables businesses to analyze vast amounts of information swiftly, leading to more accurate forecasts and informed strategic planning. As a result, companies that can leverage information effectively gain a significant edge over their competitors, positioning themselves as leaders in their respective industries.

In summary, the transformation of information from a mere resource to a pivotal productive force reflects the broader shifts in the economic landscape driven by digitalization. As economies continue to evolve, the ability to effectively manage and utilize information will be paramount for achieving sustainable growth, fostering innovation, and maintaining competitiveness in an increasingly interconnected global marketplace.

The modern economic system, dependent on technological development, increasingly relies on information resources that allow for the rapid processing of large volumes of data, enabling the forecasting of market trends and adaptation to changes in market conditions. Technological progress and the development of integrated information solutions create opportunities for building economic models where information serves as a foundation for strategic management, accelerating the innovation process, and enhancing the overall efficiency of production systems. This requires continuous improvement of information support tools to ensure the relevance, accessibility, and usefulness of information resources.

Information, as an economic factor, possesses unique properties that distinguish it from traditional resources such as labor, land, and capital. It combines

characteristics of both scarcity and abundance, limitation and inexhaustibility, which makes it particularly significant in the context of the modern market [5, 6]. The scarcity of information is determined by its significance and utility to specific categories of consumers; for individual economic entities, possessing certain information can be crucial, providing them with competitive advantages. At the same time, information has the potential for widespread dissemination due to digital technologies, which ensure its accessibility to a broad range of users.

A distinctive property of information lies in its inexhaustibility during repeated use: unlike traditional resources, information does not lose its essence or volume when transmitted or exchanged. It is not subject to physical wear; however, it can lose its economic value if it becomes less relevant, obsolete, or no longer applicable due to changes in market conditions when certain data can no longer be effectively utilized. Therefore, information requires constant updating to remain a valuable resource, and its relevance depends on changes in the external environment and the ability of economic agents to adapt it to new conditions.

Overall, the significance of information in the modern economy is important not only because of its properties as a resource but also due to its strategic role in supporting economic development, achieving efficiency in production systems, and forming competitive advantages for business entities [7, 8].

The increasing significance of information in economic processes has contributed to the development of a new stream of economic theory that focuses on studying the phenomenon of information inequality, or "asymmetric information", and its impact on the functioning of economic systems. This direction contrasts with traditional neoclassical theory, which assumed that economic agents, having access to complete information, are capable of making rational decisions that ensure maximum efficiency in the functioning of the economy [9, 10]. Research within the theory of "asymmetric information", conducted by scholars such as G. Akerlof, M. Spence and J. Stiglitz [11–14], has demonstrated that under modern conditions, economic agents possess varying levels of awareness regarding market conditions, which can lead to significant deviations from optimal behavior and even hinder the development of the economic system.

The increasing significance of information in economic processes has contributed to the development of a new stream of economic theory that focuses on studying the phenomenon of information inequality, or "asymmetric information", and its impact on the functioning of economic systems. This direction stands in contrast to traditional neoclassical theory, which posited that economic agents, having access to complete information, are capable of making rational decisions that ensure maximum efficiency in economic functioning.

Research within the framework of the "asymmetric information" theory, conducted by scholars such as G. Akerlof, M. Spence, and J. Stiglitz, has demonstrated that, under contemporary conditions, economic agents possess varying levels of awareness regarding market conditions, which can lead to significant deviations from optimal behavior and even hinder the development of the economic system.

The founders of the theory of information asymmetry have developed models of market equilibrium that account for different access to information and emphasize the importance of information in ensuring the sustainable functioning of various markets – from the agricultural sector to financial institutions. These models have shown that economic efficiency largely depends on the level of awareness among economic agents: insufficient or distorted information leads to disruptions in market mechanisms, and asymmetry among participants in economic relations becomes one of the causes of low productivity and the absence of equilibrium in the market.

Researchers argue that by implementing mechanisms that reduce information inequality, it is possible to significantly enhance market self-regulation, which underscores the importance of government intervention [15] in ensuring the availability and accuracy of information. Addressing information asymmetry can lead to improved trust among market participants. When consumers and producers have reliable access to information, it encourages informed decision-making, reducing the likelihood of market failures and promoting a healthier economic climate. This is particularly crucial in sectors where trust is paramount, such as finance and healthcare, where misinformation can have dire consequences. The exploration of information asymmetry not only enriches our understanding of economic behavior but also underscores the vital need for robust information management strategies. By prioritizing the reduction of information inequality, policymakers can create a more equitable and efficient economic landscape, driving sustainable growth and improving overall welfare in society.

In this context, establishing effective information flows that reflect the transfer and exchange of data between economic entities is extremely important. The circulation of information within the economic system creates an information exchange that directly impacts the level of information asymmetry. This issue highlights the necessity of implementing mechanisms to ensure the reliability, accessibility, and integrity of information resources, as well as to protect the information environment from potential risks and threats [16, 17]. Information asymmetry can be reduced through accessible channels for information exchange, which is a task for government policy aimed at supporting the effectiveness of market processes by creating transparent and reliable conditions for communication within the economic system [18].

The integration of modern information technologies and digital innovations into all sectors of the economy lays the foundation for the creation of a new type

of economic environment where information becomes a key resource [19]. This shapes the information environment as an organic component of the economic system, in which production, distribution, and exchange processes increasingly rely on quick access to data, technological solutions, and analytics. This approach leads to the formation of a new structure of the national economy, focused on utilizing knowledge and digital resources to enhance competitiveness and resilience. In the context of the growing importance of information, it serves as a primary factor of production that ensures the dynamism of economic processes and facilitates the transition to a knowledge economy, where innovations and digital solutions become the basis for economic development [20].

The conceptual vision of the national economic system is increasingly based on the techno-singularity vector of its development, reflecting the growing importance of information as a critically important production resource. This not only contributes to an increased share of the information and communication technology sector in GDP but also fosters the formation of a global information space that ensures effective interaction among economic entities at the international level. Information serves as the foundation for developing strategic, tactical, and operational goals for economic development, implementing them at all levels – from macro and meso levels to micro and nano levels.

6.3 Development of the information environment and formation of the digital economy in Ukraine

The digital information environment is a crucial factor in forming competitive advantages, contributing to the innovative development of economic systems in various countries. Currently, the digital economy accounts for a significant share of global GDP – estimated to be between 15.5 % and 17.5 %. Notably, nearly 40 % of the added value generated by the global information and communication technology sector comes from leading economies, such as the USA and China. It is expected that by 2030, the share of the digital economy in the overall GDP of the world's largest economies will reach 50–60 % [21, 22].

The rapid growth of digital economy indicators demonstrates the dynamics of a global transition to an innovative economic model. Specifically, in 2018, the share of global GDP created by digitalized enterprises was valued at 13.5 trillion USD. It is projected that by the end of 2023, this figure could quadruple, reaching approximately 53.3 trillion USD, which would account for over half of the nominal volume of global GDP. This indicates significant changes in the economic environment, where

digitalization is becoming not only an important tool for enhancing business efficiency but also a critical condition for global economic competitiveness and stability [23, 24].

This trend emphasizes the importance of investing in the development of information and communication technologies, infrastructure, and digital innovations as key factors for further economic growth (**Fig. 6.1**).

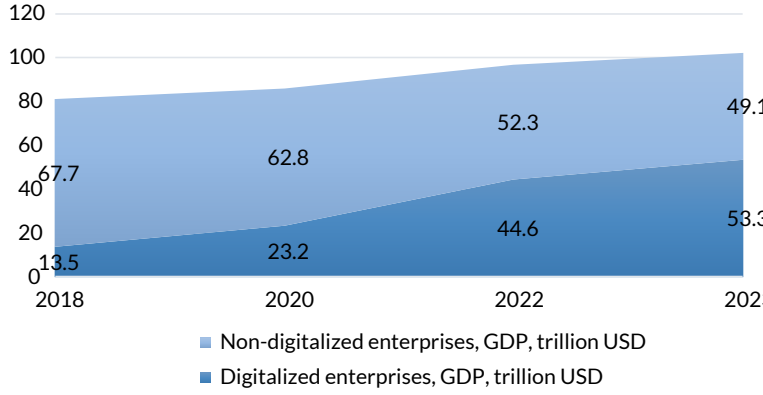

Fig. 6.1 Volume of products from digitalized and non-digitalized enterprises in global GDP
Source: compiled by the authors based on data [23]

The International Digital Economy and Society Index (I-DESI) is one of the key indicators for assessing the level of digital economy development on the international stage. It is based on an analysis of digital performance indicators for EU member countries and an additional 19 countries worldwide, including Australia, Israel, Japan, the United States, the United Kingdom, South Korea, Canada, Turkey, and others [25]. This index allows tracking countries' progress in digitalization and identifying key areas for digital economy development.

According to the I-DESI results for 2022, five EU countries ranked among the top ten leaders, taking leading positions in the rating. In this context, Denmark became the most digitally developed country in the EU, confirming its leadership as indicated by the internal DESI score for 2021. Among non-EU countries, Iceland topped the ranking, showing high levels of digital readiness and performance. Overall, the average I-DESI scores remain higher for some countries outside the EU, indicating increased global competition in the field of digital economy.

The I-DESI ranking reflects not only the level of digital infrastructure development but also shows how effectively countries implement digital technologies to improve citizens' quality of life, support economic growth, and enhance

competitiveness in the international market. The index serves as an important benchmark for policy development in the field of digital transformation, promoting the exchange of best practices among countries.

At the European Union level, the Digital Economy and Society Index (DESI) is calculated [26], serving as one of the primary tools for assessing digital transformation and competitiveness among EU member states. DESI is a composite index that combines various indicators of digital performance, including the level of digital infrastructure development, access to high-speed internet, digital skills of the population, the degree of digital technology integration in business, and the development of e-government services. This enables not only a comparative analysis of digital readiness across EU countries but also the monitoring of digital economy progress at both national and EU-wide levels.

DESI also provides data that allow for an assessment of the strengths and weaknesses of EU member states in digital transformation, identifying areas that require additional investment or reform. For instance, countries with a high level of infrastructure might need to improve the digital skills of their population, while countries that already have a high level of digital competencies among citizens may focus on expanding e-government services. This facilitates the development of national digital transformation strategies aimed at achieving the EU's long-term goals of enhancing its global competitiveness and ensuring sustainable economic growth through innovative technologies [27].

Fig. 6.2 illustrates the progress of EU member states in the digitalization of the economy and society over the past five years. For each country it shows the relationship between DESI scores for 2017 (horizontal axis) and the average annual growth rate of this index from 2017 to 2022 (vertical axis). Similar to the classical theory of economic growth, a convergence phenomenon can be observed: countries with lower initial levels of digital development exhibit higher growth rates, as represented on the left side of the chart.

The graph clearly illustrates the overall convergence trend among EU countries between 2017 and 2022. The blue line on the graph represents the predicted convergence model, indicating the expected growth rates of countries based on their initial scores. Countries located above the blue line showed growth that exceeded the expected values according to the convergence model, highlighting their substantial progress in the digital sector. Conversely, countries below this line experienced growth lower than the predicted rates, which may indicate a lag in digitalization compared to average expectations.

This analysis not only demonstrates the intensity of digital transformation in individual countries but also reveals the general dynamics that contribute to the con-

vergence of EU member states in the field of digital development, ensuring more equitable opportunities for further economic growth within the European Union.

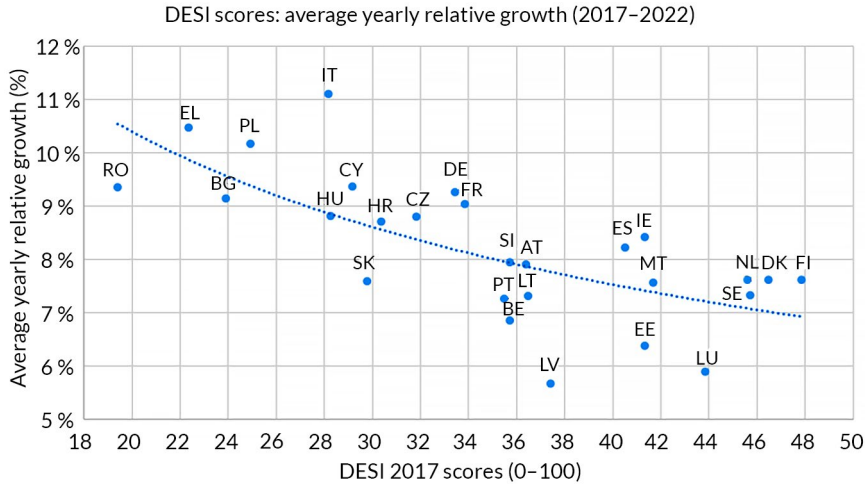

Fig. 6.2 Digital economy and society index – member states' relative progress in the period 2017–2022
Source: [26]

Given current trends in global development, it is important to note that developed countries have a significant advantage over developing countries in terms of cybersecurity and digital economy indicators. This observation is supported by correlational studies that demonstrate that the security of digital systems, as well as the transparency of digital actors, particularly in the context of data use, play a crucial role in the diffusion of technology in society [28]. For example, e-government, which relies on effective interaction between the state and citizens, requires a high level of trust and information security.

In this context, addressing cybersecurity issues becomes not only important, but also necessary to facilitate the active use of e-participation resources. E-participation is an important component of the democratic process, as it provides citizens with the opportunity to participate in decision-making, which, in turn, increases the level of social awareness and activity [29]. Thus, the successful implementation of e-services directly depends on the state of cybersecurity, which emphasizes the importance of integrating security aspects into all stages of digitalization [30, 31].

In Ukraine, unfortunately, there is a significant shortage of models that could adequately assess the economic impact of information and communication technologies (ICT) on various sectors of the national economy. For example, 2018 data show that the total consumption of ICT equipment and services in Ukraine amounted to approximately 1.5 billion USD, which is significantly lower than in Poland, where it amounted to 6.5 billion USD [32]. This difference in consumption indicates that Ukraine is lagging behind in terms of digitalization, which may be due to a number of factors, including insufficient investment activity, limited access to the latest technologies, and insufficient training.

This low level of consumption of ICT products and services also indicates limited opportunities for the country's modernization, innovation and competitiveness. In the context of the global economy, where digital technologies are becoming the basis for development, Ukraine needs to take urgent measures to increase the consumption of ICT products.

Given the goal of reaching a GDP of 1 trillion USD by 2030, Ukraine needs to significantly increase its consumption of ICT products [33, 34]. This can be realized, in particular, through large-scale national projects in the field of digital transformation, which will include infrastructure development, investment in new technologies, and training of personnel capable of using these technologies effectively. Only by focusing on ICT development will Ukraine be able to increase its productivity, competitiveness, and sustainability in light of the current challenges facing the country's economy (**Table 6.1**).

Table 6.1 Projected indicators of economic digitalization in Ukraine

Indicator	Year							
	2023	2024	2025	2026	2027	2028	2029	2030
Domestic market (ICT consumption), billion USD	3.0	4.5	6.0	8.0	10.0	12.0	14.0	16.0
Growth rate of ICT consumption, %	–	150.0	133.3	133.3	125.0	120.0	116.7	114.3
GDP growth rate due to economic digitalization, %	2.0	3.5	4.5	6.0	7.5	9.0	11.0	14.0
Share of the digital economy in total GDP, %	5.0	8.0	11.0	15.0	20.0	28.0	40.0	52.0

Source: summarized by the authors based on data [20, 35]

In the event of a positive scenario for the development of the digital economy, the share of the digital economy in the overall GDP will demonstrate a steady growth

trend (**Fig. 6.3**), reflecting the successful adaptation of Ukraine's national economy to the new conditions of the global digital environment. This transformation will not only enhance the competitiveness of the national economy but also contribute to overall economic growth and improve the quality of life for the population.

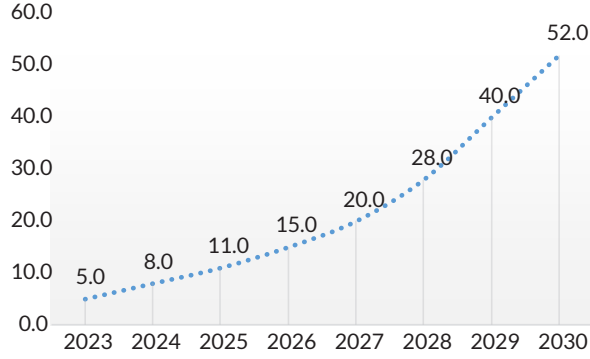

Fig. 6.3 Projected share of the digital economy in total GDP, %
Source: compiled by the authors based on data [20]

In the modern context of economic development, information has become a key asset that shapes a new paradigm in the functioning of national economies. The informational nature of the national economy reflects significant changes in the ways of conducting business based on knowledge and emphasizes the importance of generating, processing, and effectively utilizing information to ensure competitiveness, enhance the productivity of economic entities, and ensure their financial security [36]. A key role in the informational transformation of the economy is played by the development of artificial intelligence (AI). AI enables the automation of processes for processing and analyzing large volumes of data, which, in turn, allows businesses to make informed decisions more quickly and adapt to changes in the market environment [37]. The use of machine learning algorithms and data analytics helps companies uncover hidden patterns, forecast consumer behavior, and optimize their offerings, thereby enhancing their competitiveness.

Thus, in the rapidly changing global environment, information is regarded not only as a commodity but also as a critically important economic resource. This creates added value not only at the macro level, where it shapes the overall economic potential of the country, but also at the micro level, where each specific product or service can gain increased value through the use of cutting-edge technologies and digital innovations [38].

Therefore, studying the sectoral structure of Ukraine's national economy, particularly the formation of added value in different sectors, is extremely relevant. This allows for the identification of which industries are most sensitive to the implementation of digital technologies, as well as the discovery of potential reserves for improving efficiency and productivity. According to data from the State Statistics Service of Ukraine [39], a detailed analysis can be conducted that will enable important conclusions to be drawn about the relationship between information technologies and added value in various sectors of the economy.

Analyzing the dynamics of added value formation across sectors will enable to assess not only the effectiveness of their operations but also to understand how changes in the information environment impact economic development. Sectors that actively utilize information and communication technologies may demonstrate higher rates of added value growth, indicating significant potential for development [40, 41].

An important aspect of this analysis is considering not only production indicators but also the impact of information technologies on other factors such as innovation, competitiveness, and the adaptive capacity of enterprises. This allows for the formulation of a comprehensive picture that reflects the complex interactions between information, knowledge, and economic outcomes.

Therefore, studying the formation of added value within the sectoral structure of the Ukrainian economy is a crucial step in determining its development strategy in the context of digitalization. It provides the opportunity to evaluate the current state as well as outline prospects for further growth and development of the national economy, which is becoming increasingly dependent on the effective use of information resources. Examining the data presented in **Fig. 6.4–6.7** will allow for a comprehensive analysis and informed conclusions regarding the observed trends in various sectors of Ukraine's economy.

Structure of gross added value by types of economic activity in 2010 is shown in **Fig. 6.4**.

According to the presented results, in 2010 the largest contributions to the formation of gross added value in Ukraine's national economy came from the following types of economic activity: wholesale and retail trade, which accounted for 16.4 % of the total volume; manufacturing industry, which contributed 14.8 %; and transportation, warehousing, postal and courier services, which made up 8.8 %. At the same time, the information and communications sector contributed 3.4 % to the overall structure of gross added value.

Structure of gross added value by types of economic activity in 2015 is shown in **Fig. 6.5**.

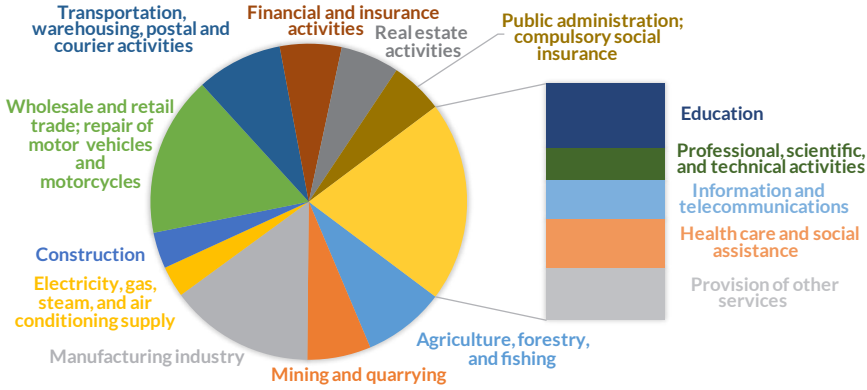

Fig. 6.4 Structure of gross added value by types of economic activity (2010, in current prices)
Source: constructed by the authors based on data [42]

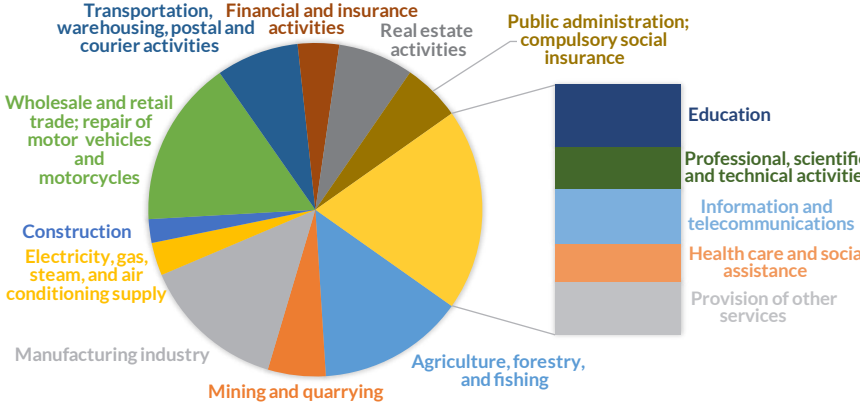

Fig. 6.5 Structure of gross added value by types of economic activity (2015, in current prices)
Source: constructed by the authors based on data [42]

Over the five years – from 2010 to 2015, there has been a significant change in the share of industries in the national economy within the structure of gross added value. In particular, wholesale and retail trade, which accounted for 16.4 % in 2010, decreased to 16.2 %, while the manufacturing industry saw its contribution drop from 14.8 % to 14.0 %. These decreases indicate certain changes in the economic dynamics of the country and may result from the adaptation of enterprises to new market conditions, as well as the influence of external factors.

At the same time, the contribution of agriculture, forestry, and fishing noticeably increased, rising from 8.4 % to 14.2 %. This can be attributed to the growing demand for agricultural products, particularly in the context of global market globalization, as well as an increase in investments in the agricultural sector. The growth of this sector indicates its potential for further development, especially regarding food security and sustainable development.

Equally important is the positive trend in the information and communications sector, whose contribution to gross added value was 4.3 %. This reflects the increasing significance of information technologies in various areas of the economy, highlighting the trend toward digitalization and the implementation of innovations.

Structure of gross added value by types of economic activity in 2020 is shown in **Fig. 6.6**.

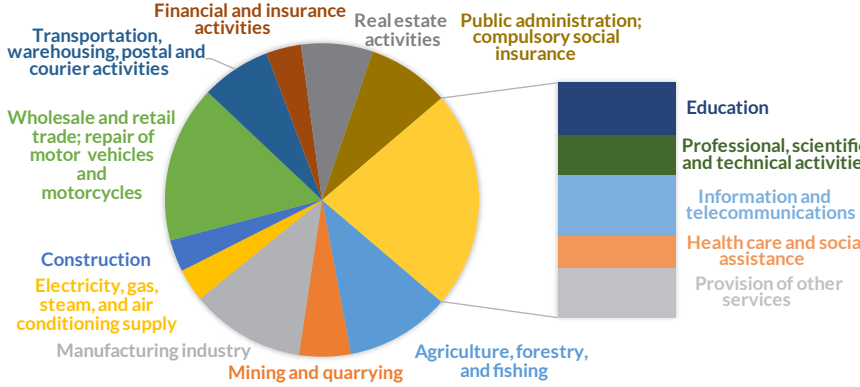

Fig. 6.6 Structure of gross added value by types of economic activity (2020, in current prices)
Source: constructed by the authors based on data [42]

In 2020, another important trend emerged: the contribution of intangible capital to the formation of added value exceeded that of tangible capital. This indicates a paradigm shift in economic development, where intellectual property, brands, and technologies are becoming key assets for enterprises. The contribution of the wholesale and retail trade sector continues to lead, maintaining a share of 16.2 % in the structure of gross added value.

There is also a noticeable increase in the share of public administration, which reached 8.5 % compared to 5.6 % in 2015. This indicates a growing role of the state in economic processes and the importance of public administration in ensuring economic efficiency. All of this suggests that the modern economy of Ukraine

is undergoing structural changes that require the adaptation of development strategies to maximize the potential of sectors in light of new challenges and opportunities [43].

These changes in the structure of gross added value in Ukraine reflect the impact of new government initiatives aimed at stimulating the digitalization of the economy, which began to be implemented in 2019. The launch of the EU program "EU4Digital: Support for the Digital Economy and Society in the Eastern Partnership" has been an important step in extending the benefits of the European Union's Single Digital Market to Ukraine and other Eastern Partnership countries [44, 45]. This program aims to stimulate economic growth, create new jobs, improve the quality of life for citizens, and support businesses through the implementation of modern digital solutions.

The state has proven to be a key consumer and active user of innovations, recognizing digital transformation as a priority of national policy. The cultivation of a digital culture and the promotion of education in high-tech fields contribute to the upskilling of the workforce and the creation of a favorable environment for innovation. Important aspects include the implementation of infrastructure projects that ensure access to modern technologies for the population, such as connecting 90 % of Ukrainians to 4G mobile coverage, which significantly improves communication and access to information resources [46].

In addition, a number of digital transformation projects have been initiated and implemented, which are already actively being adopted in various sectors of the economy. For example, the "Prozorro" and "e-Health" systems have become key tools for enhancing transparency in public procurement and improving the quality of medical services, respectively, since 2020. The official launch of the "Diia" state services portal has provided citizens with convenient access to a variety of administrative services, which, in turn, contributes to reducing bureaucracy and increasing the efficiency of public administration [47].

These initiatives not only increase the level of digitalization in Ukraine but also contribute to the formation of a modern economy where information and communication technologies become the foundation for the development of various industries [48]. As a result, the country's economy gains new opportunities for innovative growth, which will undoubtedly have a positive impact on its competitiveness on the global stage.

Structure of gross added value by types of economic activity in 2022 is shown in **Fig. 6.7**.

The specifics of the presented results are undoubtedly related to the war of the Russian Federation against Ukraine, which has significantly affected the structure

of gross value added. In 2022, the largest share in this structure was occupied by the public administration and defense sector, accounting for 24 %. This figure is primarily due to the necessity of funding salaries for military personnel, which has become a priority for the state under martial law.

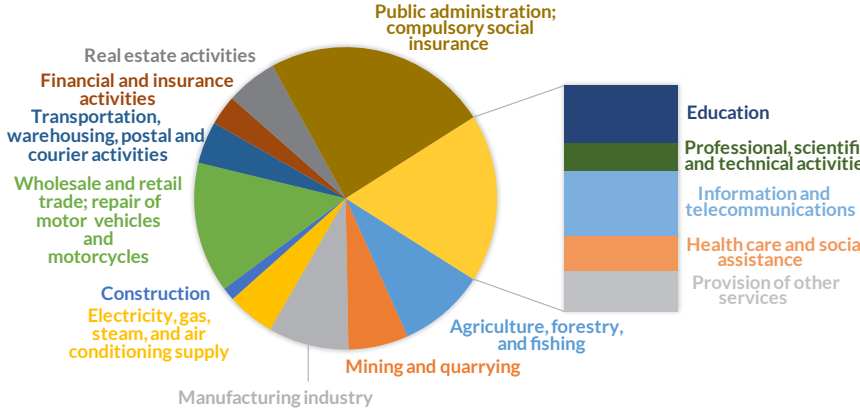

Fig. 6.7 Structure of gross added value by types of economic activity (2022, in current prices)
Source: constructed by the authors based on data [42]

The agriculture, forestry, and fishing sector also had a noticeable presence in the structure of gross value added, comprising 9.3 %. Although this figure is relatively high compared to similar indicators in European Union countries, it indicates a structural imbalance, as low-value-added products continue to dominate the agricultural sector. With significant competitive advantages in the agricultural field, Ukraine must focus on increasing the added value of products produced in this sector to achieve sustainable economic growth.

An analysis of real estate operations indicates that this sector does not function as a growth driver for the national economy. Despite its potential, it does not demonstrate a significant contribution to the formation of gross value added. In contrast, the information and telecommunications sector, which belongs to the innovation sector, shows steady growth in the structure of gross value added. This indicates that information and communication technologies (ICT) play an increasingly important role in shaping an economy oriented towards knowledge and innovation [49].

According to the analysis conducted, there is a noticeable increase in the share of sectors that form the foundation of a post-industrial economy and serve as the basis for the development of a digital economy. This indicates a transformation of

the national economy towards greater innovation and digitalization. The transition to a post-industrial society requires strategic resource management aimed at ensuring sustainable development through increased productivity, innovation, and the integration of digital technologies into all areas of economic activity. These changes are critically important for the recovery and further development of Ukraine's economy in the face of contemporary challenges.

Despite the full-scale war, the IT sector in Ukraine has become the only industry demonstrating positive export dynamics. Specifically, in 2022 the export revenue from IT services increased by 5.85 %, reaching 7.3 billion USD. This exceeds the figures from the previous year by 406 million USD, indicating the resilience and adaptability of the IT sector amid war and economic instability [50].

The dynamics of changes in IT exports in Ukraine during 2021–2022 underscore the importance of this sector for the national economy. This trend may be attributed to several factors, including the growing demand for Ukrainian IT services in the international market, the high quality of the services provided, and the availability of skilled personnel. The information technology sector, thanks to its flexibility, has managed to quickly adapt to new conditions, continuing to execute projects for foreign clients despite internal challenges.

It is worth noting that the IT sector not only provides stable export income but also plays a crucial role in modernizing other sectors of the economy, contributing to their digitalization and increased efficiency [51]. The trends in the development of IT exports, presented in **Fig. 6.8, 6.9**, demonstrate how this sector, even in times of war, remains a driver of economic growth and innovation in Ukraine. In the long term, supporting and developing the IT sector may become critically important for the recovery of the national economy and its integration into the global market.

As shown in the graph illustrating the quarterly dynamics of exports, the peak of IT activity was recorded just before the Russian invasion in the fourth quarter of 2021, when exports reached 2.1 billion USD. Since then, the average volumes of computer service exports have gradually decreased to 1.7 billion USD, reflecting approximately a 20 % decline in quarterly export revenue in the IT sector.

Although the sector's share in the total exports of goods and services from Ukraine has increased from 8.8 % to 13.4 % over the year and a half of war (**Fig. 6.9**), the current role of the IT sector as a driver of export growth is far from the optimistic expectations that were formed prior to the conflict.

The resilience of the digital sector in times of crisis is an important factor that determines not only the economy's operational response to challenges but also its potential for recovery. The digital economy, in particular, has the capacity to become a key factor in the resilience of the national economy and a reliable source of tax

revenues, as it demonstrates less dependence on physical assets compared to traditional sectors such as industry or agriculture.

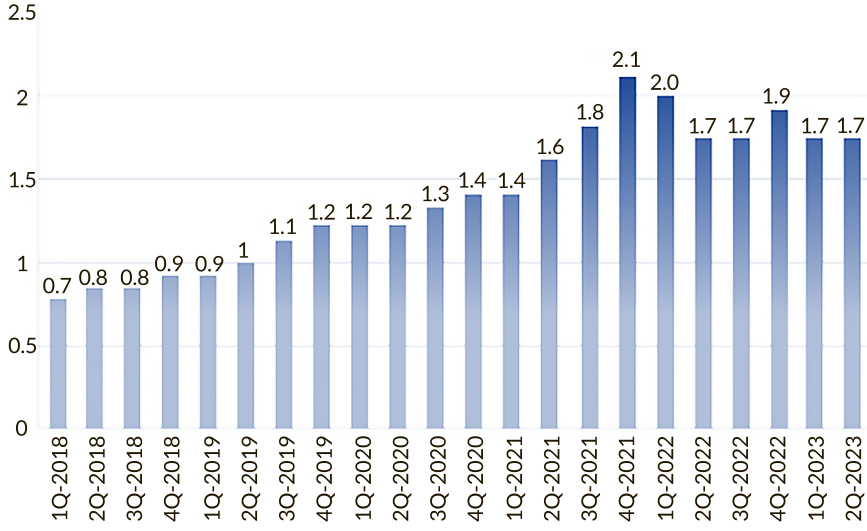

Fig. 6.8 Quarterly dynamics of IT service exports from Ukraine, billion USD
Source: [42, 52, 53]

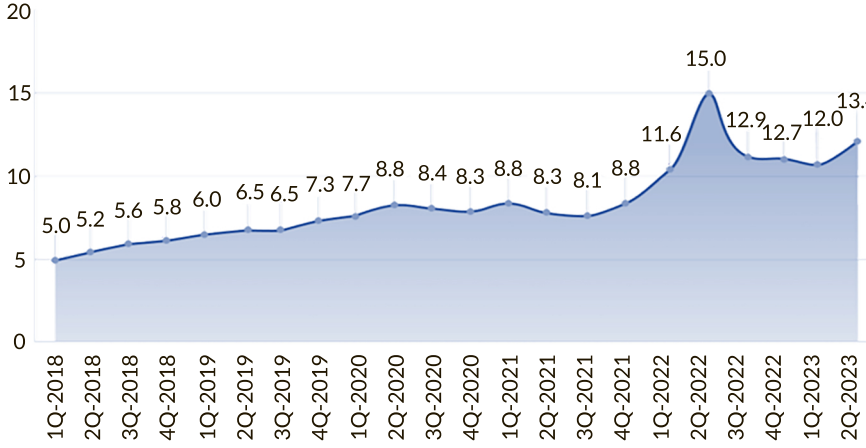

Fig. 6.9 Share of the IT sector in the structure of goods and services exports from Ukraine, %
Source: [42, 52, 53]

The strategic importance of the IT sector for the national economy is also confirmed by the regression analysis of the relationship between Ukraine's GDP and the share of IT sector in GDP (**Fig. 6.10**).

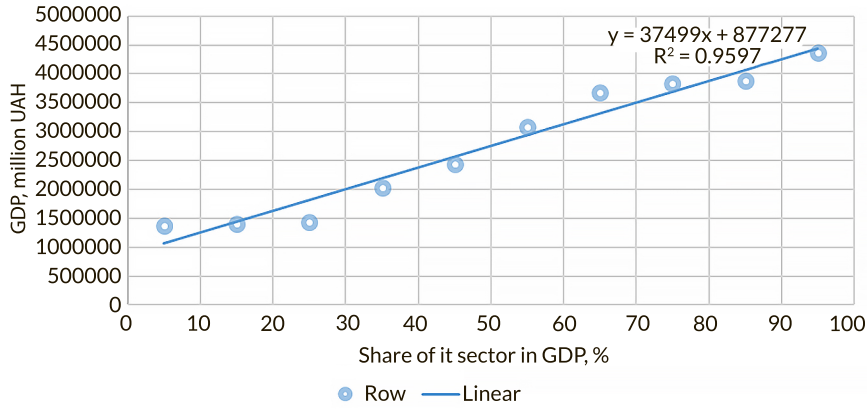

Fig. 6.10 Relationship between Ukraine's GDP and the share of IT sector in GDP
Source: constructed by the authors based on data [42]

The value of the coefficient of determination R^2=0.9597 indicates the high adequacy of the model for analyzing this relationship. The correlation coefficient r=0.846 indicates a strong positive relationship between the share of IT sector in GDP and the overall GDP. This suggests that an increase in the share of IT sector will ensure the growth of the country's economy. The high values of these coefficients confirm the importance of the IT sector for economic development. Given global digitalization trends, investments in the IT sector can serve as a key driver of Ukraine's economic growth in the long term.

In crisis conditions, information technologies become essential for increasing the efficiency and flexibility of economic processes. The development of the IT sector not only contributes to the creation of new jobs but also stimulates innovations in other industries by implementing digital technologies that allow for production optimization, cost reduction, and improved product quality.

In addition, digital solutions can play an important role in the distribution of international aid provided to Ukraine in connection with the war and in monitoring its use. The utilization of technologies such as blockchain or e-governance platforms can reduce corruption risks by ensuring transparency and accountability in budgetary expenditures [54]. Through digitalization, citizens gain access to

information about government decisions, budgets, and expenditures in real time, which contributes to the demystification of government activities and allows society to monitor the actions of officials. The simplification of administrative procedures through digital solutions also reduces opportunities for corruption that often arise in complex bureaucratic systems. The automation of processes minimizes the human factor, which is one of the most vulnerable points for the emergence of corrupt schemes, such as bribery or nepotism. For instance, the use of online platforms for submitting tax declarations, registering businesses, and conducting public procurements eliminates the need for personal meetings, which could be exploited for corrupt agreements.

Furthermore, digital solutions enable the use of data analytics to monitor the activities of government bodies. This creates the possibility of detecting anomalies and patterns that may indicate corruption. The application of predictive analytics, for example, can reveal unusual expenditures or inefficiencies that would warrant further investigations.

E-government platforms provide citizens with direct access to public services, such as permits, licenses, and social services. This reduces dependence on intermediaries who may abuse their positions to gain corrupt benefits. Direct interaction between the government and society fosters a culture of integrity and trust. Additionally, digitalization may include feedback mechanisms that allow citizens to anonymously report cases of corruption or inefficiency. This encourages active citizen participation in governance and ensures a sense of security for those who voice their concerns.

Finally, the implementation of digital solutions in accordance with international standards can enhance the country's authority on the international stage and attract foreign investment. Investors generally prefer governments that demonstrate a commitment to transparency and anti-corruption measures. Therefore, the digitalization of public administration not only optimizes processes but also fundamentally changes the relationship between the government and citizens. By promoting transparency and accountability, it reduces opportunities for corruption and fosters a more reliable and efficient governance system. This transformation is essential for ensuring effective management of the national economy and sustainable societal development.

Thus, the digital economy not only ensures resilience in crisis conditions but can also serve as a foundation for the transformation of the national economy, creating new opportunities for growth and development. In the face of the ongoing challenges posed by the war, it is precisely information technology that can become a catalyst for recovery and stability in the future.

6.4 Prospects for digital transformation of Ukraine's economy amid deepening risks and cyber threats

Despite the challenges posed by the war, Ukraine is actively developing its digital economy, aiming to integrate into the European Union's Single Digital Market. This process involves removing barriers and establishing common rules for online services in the areas of digital marketing, telecommunications, and e-commerce, as well as enhancing the level of cybersecurity for networks and information systems. According to estimates from leading domestic economists, integration into the EU's Single Digital Market could lead to a GDP growth of up to 12 % for Ukraine, with the export of goods to EU member states increasing by up to 17 % and services by up to 12.2 % [55, 56]. Thus, Ukraine's accession to the EU markets would not only facilitate the eurointegration processes but also bring significant economic advantages, enhancing the competitiveness and innovative potential of the national economy.

However, in the current context of digitalizing the national economy, information can sometimes take on a dangerous significance, as the emergence of new technologies brings about increased risks of information and hybrid threats. This is manifested in the ability of information not only to foster development but also to become a tool for destabilization, particularly during information attacks that can lead to the disorganization of government systems, the collapse of financial structures, technological disasters, and even the outbreak of armed conflicts [57]. For example, the military aggression of the Russian Federation against Ukraine is accompanied by a large-scale information war, which causes significant harm to the national economy and society, often comparable in scale to the damage from combat actions.

In the context of armed confrontation and external aggression, the national economy requires a clear operational strategy based on the principles of information security. This necessitates the creation and maintenance of an information infrastructure capable of withstanding external information attacks and ensuring the continuous operation of key economic and governmental institutions. A critical task becomes the integration of information protection systems into all areas of economic management, which contributes not only to ensuring stability but also to forming a resilient economic system capable of adapting to new challenges.

Consequently, an important condition for successful digital transformation is the provision of cybersecurity at all levels, from government bodies to the private sector. This includes implementing modern information protection systems, training personnel in the fundamentals of cyber hygiene, and developing a national cybersecurity strategy that meets international standards. It is also necessary to develop infrastructure to support digital technologies. This includes expanding access to

high-speed internet, developing e-government platforms, and investing in cutting-edge technologies such as artificial intelligence, blockchain, and big data [58]. These technologies can help optimize business processes and enhance the effectiveness of government management.

Furthermore, the digital transformation of Ukraine's national economy should be accompanied by the active involvement of all participants in the process, including the government, businesses, and society. This will create conditions for forming a culture of digitalization, where information technologies are used to enhance transparency, accountability, and trust among all parties.

On the other hand, Ukraine should take into account international experience and adapt best practices in the fields of digitalization and cybersecurity. Cooperation with international organizations, such as NATO, the European Union, and other entities, can help strengthen national security and improve the country's technological base.

Thus, the digital transformation of Ukraine's economy has enormous potential for creating new opportunities for growth and development; however, it requires a systematic approach to ensuring cybersecurity and effectively managing risks. Only through a comprehensive resolution of these issues can we hope for a successful integration of Ukraine into the global digital economy.

6.5 Conclusions

Given that digitalization processes are a key factor in the development of the national economy in current conditions, this section substantiates the conceptual foundations of the digital transformation of economic systems and the features of forming a digital economy in Ukraine. In Ukraine, as in many other countries, digitalization has become not only a catalyst for economic growth but also a crucial factor in enhancing the resilience of the national economy to crises. Observed correlations between the level of digital sector development and the economy's ability to withstand external and internal challenges indicate the high adaptability and efficiency of digital solutions. These solutions ensure economic flexibility, enabling companies to quickly switch to remote work, automate processes, and minimize dependency on physical assets, which is especially valuable during periods of instability.

The conducted research demonstrates current trends and dynamics in the development of the information environment both in Ukraine and globally, highlighting the deep penetration of digital technologies into various sectors of economic activity and their contribution to GDP formation. Analysis of the formation of gross value

added by types of economic activity from 2010 to 2022 confirms that the advent of Industry 4.0 and the adoption of Industry 5.0 principles have fundamentally changed the structure of the national economy. Growth has been observed in sectors that constitute the foundation of a post-industrial economy and are the basis for digital economic development, particularly in the information and telecommunications sectors.

It has been proven that the digital sector also plays an essential role as a tool in reducing the shadow economy and corruption risks. The use of digital platforms and solutions, such as electronic document management, state registries, and expenditure monitoring platforms, significantly limits opportunities for shadow operations, making economic activities more transparent and accountable. The effective integration of digital solutions in public administration and the corporate sector contributes to increased trust in government institutions and fosters a culture of transparency.

It is substantiated that despite the significant advantages of digitalization, Ukraine's national information environment faces new security challenges driven by the active development of technologies and the growing threats in cyberspace. Traditional threats, such as industrial espionage, commercial secrets leaks, and unintentional disclosure of confidential information, are intensified by new types of cyber risks. Improvements in information systems and their expanded accessibility make them potential targets for cyber-attacks, which can have serious consequences for the economy and national security. Specifically, cyber-attacks aimed at disrupting the integrity of databases can lead to the loss of critical data, reduced trust in government structures, and undermining economic stability. This underscores the need for a comprehensive cybersecurity strategy that will include not only protective technological solutions but also the development of early warning systems, increased public awareness, and constant threat monitoring.

Thus, digital transformation requires an approach that simultaneously encompasses economic, informational, and security components to minimize risks and ensure long-term stability. This approach enables not only the strengthening of economic resilience but also creates opportunities to enhance Ukraine's competitiveness on the international stage, where maintaining high cybersecurity standards becomes one of the key factors for integration into global digital markets.

References

1. Lee, C., Lim, C. (2021). From technological development to social advance: A review of Industry 4.0 through machine learning. Technological Forecasting and Social Change, 167, 120653. https://doi.org/10.1016/j.techfore.2021.120653

2. Onyshchenko, V., Onyshchenko, S., Verhal, K., Buriak, A.; Onyshchenko, V., Mammadova, G., Sivitska, S., Gasimov, A. (Eds.) (2023). The Energy Efficiency of the Digital Economy. Proceedings of the 4th International Conference on Building Innovations. ICBI 2022. Cham: Springer, 299, 761–767. https://doi.org/10.1007/978-3-031-17385-1_64
3. Krasnobayev, V., Yanko, A., Hlushko, A. (2023). Information Security of the National Economy Based on an Effective Data Control Method. Journal of International Commerce, Economics and Policy, 14 (3). https://doi.org/10.1142/s1793993323500217
4. Bezruchko, D. S. (2012). Kliuchovi osoblyvosti informatsii yak ekonomichnoi katehorii. Effective Economy, 12. Available at: http://www.economy.nayka.com.ua/?op=1&z=1630
5. Kovalenko, Yu. O. (2011). Informatsiinyi resurs u konteksti teorii faktoriv vyrobnytstva. Ekonomika promyslovosti, 4, 148–152.
6. Terekhov, V. I., Odihaillo, B. M. (2018). (2018). Role information factors in shaping advantages in competitive markets. "Scientific Notes of the University "KROK", 4, 36–44. https://doi.org/10.31732/2663-2209-2018-52-36-44
7. Svistun, L., Glushko, A., Shtepenko, K. (2018). Organizational Aspects of Development Projects Implementation at the Real Estate Market in Ukraine. International Journal of Engineering & Technology, 7 (3.2), 447–452. https://doi.org/10.14419/ijet.v7i3.2.14569
8. Song, Y., Du, C., Du, P., Liu, R., Lu, Z. (2024). Digital transformation and corporate environmental performance: Evidence from Chinese listed companies. Technological Forecasting and Social Change, 201, 123159. https://doi.org/10.1016/j.techfore.2023.123159
9. Buzhal, Yu. M.; Rozputenko, I. (Ed.) (2004). Informatsiina ekonomika. Rol informatsii u formuvanni rynkovoi ekonomiky. Kyiv: K.I.S., 34–57.
10. Onyshchenko, S., Yanko, A., Hlushko, A., Maslii, O., Skryl, V., Onyshchenko, V., Mammadova, G., Sivitska, S., Gasimov, A. (Eds.) (2023). The Mechanism of Information Security of the National Economy in Cyberspace. Proceedings of the 4th International Conference on Building Innovations. Lecture Notes in Civil Engineering Vol. 299. Cham: Springer, 791–803. https://doi.org/10.1007/978-3-031-17385-1_67
11. Akerlof, G. A. (1970). The Market for "Lemons": Quality Uncertainty and the Market Mechanism. Quarterly Journal of Economics, 84 (3), 488–500. https://doi.org/10.2307/1879431
12. Akerlof, G. (1976). The Economics of Caste and of the Rat Race and Other Woeful Tales. The Quarterly Journal of Economics, 90 (4), 599–617. https://doi.org/10.2307/1885324

13. Spence, M. (1974). Market Signaling: Informational Transfer in Hiring and Related Processes. Cambridge: Harvard University Press, 221.
14. Stiglitz, J. E. (1979). Equilibrium in Product Markets with Imperfect Information. The American Economic Review, 69 (2), 339–345.
15. Glushko, A. D. (2013). Directions of Efficiency of State Regulatory Policy in Ukraine. World Applied Sciences Journal, 27 (4), 448–453.
16. Onyshchenko, S., Yanko, A., Hlushko, A., Maslii, O., Cherviak, A. (2023). Cybersecurity and Improvement of the Information Security System. Journal of the Balkan Tribological Association, 29 (5), 818–835. Available at: https://scibulcom.net/en/article/L8nV7It2dVTBPX09mzWB
17. Slayton, R. (2020). Governing Uncertainty or Uncertain Governance? Information Security and the Challenge of Cutting Ties. Science, Technology, & Human Values, 46 (1), 81–111. https://doi.org/10.1177/0162243919901159
18. Wiktor, J. W., Sanak-Kosmowska, K. (2021). Information Asymmetry in Online Advertising. Routledge, 230. Available at: https://www.routledge.com/Information-Asymmetry-in-Online-Advertising/Wiktor-Sanak-Kosmowska/p/book/9780367680824
19. Onyshchenko, V., Yehorycheva, S., Maslii, O., Yurkiv, N. (2021). Impact of Innovation and Digital Technologies on the Financial Security of the State. Proceedings of the 3rd International Conference on Building Innovations, 749–759. https://doi.org/10.1007/978-3-030-85043-2_69
20. Amelin, A., Fishchuk, V., Lavryk, Ya., Yurchak, O., Cherniev, Ye., Matiushko, V. (2019). Ukraine 2030E – A Country with a Developed Digital Economy. Available at: https://strategy.uifuture.org/kraina-z-rozvinutoyu-cifrovoyu-ekonomikoyu.html
21. Onyshchenko, S., Skryl, V., Hlushko, A., Maslii, O. (2023). Inclusive Development Index. Proceedings of the 4th International Conference on Building Innovations, 779–790. https://doi.org/10.1007/978-3-031-17385-1_66
22. Revenko, D., Romanenkov, Y., Polozova, T., Lebedchenko, V., Molchanova, K. (2024). The impact of digitalization on the economic growth of the European Union: an empirical study. Eastern-European Journal of Enterprise Technologies, 3 (13 (129)), 46–56. https://doi.org/10.15587/1729-4061.2024.304256
23. Boots – Worldwide. Statista. Available at: https://www.statista.com/outlook/cmo/footwear/textile-other-footwear/europe
24. Onyshchenko, S., Bilko, S., Yanko, A., Sivitska, S. (2023). Business Information Security. Proceedings of the 4th International Conference on Building Innovations, 769–778. https://doi.org/10.1007/978-3-031-17385-1_65

25. European Commission. International Digital Economy and Society Index 2022 – Executive Summary (2022). European Commission. Available at: https://nqa.gov.ua/news/indeks-cifrovoi-ekonomiki-2022-zvit-evropejskoi-komisii/
26. Digital Economy and Society Index (DESI) (2022). European Commission. Available at: https://digital-strategy.ec.europa.eu/en/policies/desi
27. Krasnobayev, V., Yanko, A., Hlushko, A., Kruk, O., Kruk, O., Gakh, V. (2023). Cyberspace protection system based on the data comparison method. Economic and cyber security. Kharkiv: PC TECHNOLOGY CENTER, 3–29. https://doi.org/10.15587/978-617-7319-98-5.ch1
28. Onyshchenko, V., Onyshchenko, S., Maslii, O., Maksymenko, A. (2023). Systematization of Threats to Financial Security of Individual, Society, Business and the State in Terms of the Pandemic. Proceedings of the 4th International Conference on Building Innovations, 749–760. https://doi.org/10.1007/978-3-031-17385-1_63
29. Kutsenko, O. (2023). Elektronna demokratiia v Ukraini: cuchasnyi stan ta perspektyvy rozvytku. U-Plan. Available at: https://uplan.org.ua/elektronna-demokratiia-v-ukraini-cuchasnyi-stan-ta-perspektyvy-rozvytku/
30. Verhelst, A., Wouters, J. (2020). Filling Global Governance Gaps in Cybersecurity: International and European Legal Perspectives. International Organisations Research Journal, 15 (2), 141–172. https://doi.org/10.17323/1996-7845-2020-02-07
31. Onyshchenko, S., Yanko, A., Hlushko, A., Maslii, O. (2023). Economic cybersecurity of business in Ukraine: strategic directions and implementation mechanism. Economic and cyber security. Kharkiv: PC TECHNOLOGY CENTER, 30–58. doi: https://doi.org/10.15587/978-617-7319-98-5.ch2
32. Pidhaina, Y. (2018). Pishly na proryv: ukrainskyi IT-rynok zrostaie shvydshe za svitovyi. Mind. Available at: https://mind.ua/publications/20189963-pishli-na-proriv-ukrayinskij-it-rinok-zrostae-shvidshe-za-svitovij
33. Natsionalna ekonomichna stratehiia 2030. Available at: https://nes2030.org.ua/
34. Tsyfrovizatsiia – odyn z holovnykh vektoriv rozvytku ekonomiky u nastupni 10 rokiv (2020). Ministerstvo tsyfrovoi transformatsii Ukrainy. Available at: https://thedigital.gov.ua/news/tsifrovizatsiya-odin-z-golovnikh-vektoriv-rozvitku-ekonomiki-u-nastupni-10-rokiv
35. Skrypin, V. (2022). Infohrafika: ukrainska IT-haluz za 2021 rik – v tsyfrakh. ITC. Available at: https://itc.ua/news/infografika-ukrayinska-it-galuz-za-2021-rik-v-czifrah/
36. Onyshchenko, S., Maslii, O., Kivshyk, O., Cherviak, A. (2023). The impact of the insurance market on the financial security of Ukraine. Financial and Credit

Activity Problems of Theory and Practice, 1 (48), 268–281. https://doi.org/10.55643/fcaptp.1.48.2023.3976
37. Shefer, O., Laktionov, O., Pents, V., Hlushko, A., Kuchuk, N. (2024). Practical principles of integrating artificial intelligence into the technology of regional security predicting. Advanced Information Systems, 8 (1), 86–93. https://doi.org/10.20998/2522-9052.2024.1.11
38. Zhang, X., Wang, Y. (2022). Research on the Influence of Digital Technology and Policy Restrictions on the Development of Digital Service Trade. Sustainability, 14 (16), 10420. https://doi.org/10.3390/su141610420
39. State Statistics Service of Ukraine. Available at: https://stat.gov.ua/
40. Sun, J. (2020). From digital economy to digital trade: Connotation, characteristics, rules and influence. Int. Econ. Trade Explor., 36, 87–98.
41. Liu, C., Yan, M., Zhang, M. (2024). Digital Economy, Green Innovation and Urban-Rural Income Gap – Analysis Based on Prefecture-Level City Panel Data of China. Journal of Advanced Computational Intelligence and Intelligent Informatics, 28 (4), 845–853. https://doi.org/10.20965/jaciii.2024.p0845
42. Ekonomichna statystyka / Natsionalni rakhunky. Derzhavna sluzhba statystyky Ukrainy. Available at: https://www.ukrstat.gov.ua/operativ/menu/menu_u/nac_r.htm
43. Onyshchenko, S. V., Masliy, O. A., Buriak, A. A. (2023). Threats and Risks of Ecological and Economic Security of Ukraine in the Conditions of War. 17th International Conference Monitoring of Geological Processes and Ecological Condition of the Environment, 1–5. https://doi.org/10.3997/2214-4609.2023520072
44. The EU4Digital Initiative. Available at: https://eufordigital.eu/uk/discover-eu/the-eu4digital-initiative/
45. Ekonomichni perevahy vid intehratsii v Yedynyi tsyfrovyi rynok YeS: nazvani realni tsyfry (2020). Ministerstvo tsyfrovoi transformatsii Ukrainy. Available at: https://thedigital.gov.ua/news/ekonomichni-perevagi-vid-integratsii-v-ediniy-tsifroviy-rinok-es-nazvani-realni-tsifri
46. How 4G Developed in Ukraine: Kyivstar Statistics for Five Years (2023). American chamberof commerce Ukraine. Available at: https://chamber.ua/ua/news/yak-rozvyvavsia-4g-v-ukraini-statystyka-kyivstar-za-p-iat-rokiv/
47. Mintsyfry zapustylo portal derzhavnykh posluh Diia (2020). Ministerstvo tsyfrovoi transformatsii Ukrainy. Available at: https://thedigital.gov.ua/news/mintsifri-zapustilo-portal-derzhavnikh-poslug-diya
48. Zhao, T., Zhang, Z., Liang, S. K. (2019). Digital Economy, Entrepreneurial Activity and High-Quality Development: Empirical Evidence from Chinese Cities. J. of Management World, 36 (10), 65–76.

49. Bahrini, R., Qaffas, A. A. (2019). Impact of Information and Communication Technology on Economic Growth: Evidence from Developing Countries. Economies, 7 (1), 21. https://doi.org/10.3390/economies7010021
50. Export of Services in 2022: IT Share Reaches a Record 45% (2023). Lviv IT Cluster. Available at: https://itcluster.lviv.ua/eksport-poslug-u-2022-chastka-it-stanovyt-rekordni-45/
51. Jiang, M., Jia, P. (2022). Does the level of digitalized service drive the global export of digital service trade? Evidence from global perspective. Telematics and Informatics, 72. https://doi.org/10.1016/j.tele.2022.101853
52. National Bank of Ukraine. Available at: https://bank.gov.ua/ua/statistic
53. YouControl.Market. Available at: https://youcontrol.market/
54. Onyshchenko, S., Hlushko, A., Kivshyk, O., Sokolov, A. (2021). The shadow economy as a threat to the economic security of the state. Economics of Development, 20 (4), 24–30. https://doi.org/10.57111/econ.20(4).2021.24-30
55. Ukraine continues to integrate into the EU single market: new opportunities for digital development (2023). Government portal. Available at: https://www.kmu.gov.ua/news/ukraina-prodovzhuie-intehruvatysia-v-iedynyi-rynok-ies-novi-mozhlyvosti-rozvytku-tsyfrovykh-tekhnolohii
56. Efekt tsyfrovoi synerhii. Yaki perspektyvy dlia rozvytku IT-sektoru ta startap-industrii vidkryvaie ochikuvanyi vstup Ukrainy do YeS (2023). EUKraina Voice. Available at: https://forbes.ua/innovations/efekt-tsifrovoi-sinergii-yaki-perspektivi-dlya-rozvitku-it-sektoru-ta-startap-industrii-vidkrivae-ochikuvaniy-vstup-ukraini-do-es-29082023-15636
57. Implementation Guide for for Small- and Medium-Sized Enterprises (SMEs) (2017). CIS Controls. Available at: https://www.cisecurity.org/-/media/project/cisecurity/cisecurity/data/media/files/uploads/2017/09/CIS-Controls-Guide-for-SMEs.pdf
58. Onyshchenko, S., Yanko, A., Hlushko, A. (2023). Improving the efficiency of diagnosing errors in computer devices for processing economic data functioning in the class of residuals. Eastern-European Journal of Enterprise Technologies, 5 (4 (125)), 63–73. https://doi.org/10.15587/1729-4061.2023.289185

CHAPTER 7

Information and digital technology trends in the green economy

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Abstract

Information and digital green tech encompass many technological practices, all geared towards safeguarding the environment. Green tech addresses a climate change by reducing greenhouse gas emissions and promoting a circular economy from harnessing renewable energy and eco-friendly transportation to revolutionizing agriculture.

The aim of the research paper is to highlight the role of information and digital technology trends in the green economy.

The digital transition towards a greener future prioritizes sustainability through resource optimization, waste reduction, and recycling. Digital green IT refers to adopting environmentally sustainable computing practices, striving to curtail energy usage, mitigating the technology sector's impact on global emissions, and combatting climate change.

Practical implications of the research are represented in green tech innovation clusters, digital technology trends in the green economy and a case study of digital technologies' effect on the energy efficiency in Ukraine during the Russian-Ukrainian war.

The paper has been developed through a systematic methodology, centered on a desk research, surveys, and empirical analysis while formulating hypotheses, testing them for visualizing research results to identify, short-list, and validate economy trends in green architecture and Sustainable Development Goals (SDGs) of Ukraine under conditions of instability due to the information and digital green tech of Ukraine under conditions of war.

Keywords

Technology, digital, information, green economy, trends, Sustainable Development Goals.

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7.1 Introduction

In recent decades, one of the main trends in the development of green economy has been the penetration of information and digital technologies into various spheres of human activity. Informatization has become an important factor in the increasing labor productivity and improving the quality of life that the changes are considered to be the beginning of a new era of green economic development which is characterized by the term "digital or information economy". The relevance of the paper is driven by two stable and large-scale trends as: the need of global economic transformation in accordance with the concept of sustainable development and green economy; the deployment of the fourth industrial revolution, the main target of which is information and digital technologies.

Europe is a leading player in green innovations, venture capital, deployment of net-zero digital technologies and sustainable products. According to the European Commission, it has a strong starting point – a green industry with a track record as a proven trend-setter and standard-setter, with growing levels of digitalization. Manufacturing high quality and green innovative products that are used across the world, the European Green Deal sets in stone green transition ambitions, including climate targets towards net-zero by 2050. The Fit for 55 package provides a concrete plan to put the European economy firmly on track, with the REPowerEU Plan accelerating the move away from fossil fuels. Alongside the Circular Economy Action Plan, this sets the framework for the transformation of the EU's industry for the net-zero age [1].

According to the European Commission, in the next few years, the economic shape of the net-zero age will be firmly set. New markets will have been created, breakthrough clean digital technologies will have been innovated, developed, and brought to market. The International Energy Agency estimates that the global market for key mass-manufactured clean energy technologies will be worth around 650 billion USD a year by 2030. The United States' Inflation Reduction Act will mobilize over 360 billion USD by 2032. Japan's green transformation plans aim to increase up to 20 trillion JPY (approximately 140 billion EUR) – through green transition bonds. India has put forward the Production Linked Incentive Scheme to enhance competitiveness in sectors like solar photovoltaics and batteries [2].

The UK, Canada and many others have also put forward their investment plans in clean tech technologies. Europe is committed working with all of those partners for the greater good. However, the trade and competition on net-zero industry must be fair. More fundamentally, China's subsidies have long been twice as high as those in the EU, relative to GDP. This has distorted the market and ensured that the manufacturing of a number of net-zero digital and green technologies is currently dominated by

China, which has made subsidizing clean tech innovation and manufacturing a priority of its Five-Year Plan. China's pipeline of announced investments in clean technologies exceeds 280 billion USD [3]. Europe needs a new Green Deal Industrial Plan that will form part of the European Green Deal, which set us on the path to climate neutrality, and will enable Europe to lead the way globally in the net-zero industrial age.

7.2 Literature review

Many studies and scientific papers of leading research institutes and scholars are dedicated to determining problems, prospects, and consequences from integrating digital transformation and opportunities for sustainable development and green economy.

Analysis of scientific publications of E. Barbier, R. Berger, H.-J. Chang, J. Davis, T. Edgar, J. Porter, J. Bernaden, M. Sarli shows that the green industry belongs to modern strategies for the digital development of an intellectual society, characteristic of technologically advanced countries with the high investment, innovation potential and close integration of digital transformation. According to the scholars, the main driver of progress green and digital transformations are technical and technological innovations that involve the transformation of material production assets, and thus significant investments and the involvement of highly qualified specialized labor for research and development [4, 5], the creation of pilot sites [6], the introduction of effective developments into mass production, and ultimately large-scale reengineering of business processes [7].

According to C. N. Ciocoiu, digital economy and green economy are the most important subjects on the environmental policy agenda. Both are paradigms that have become prominent in the separate worlds of ITC policy and sustainable development. The integration between them leads to new paradigms and creates opportunities for sustainable development, also for economic recovery in the context of recent crises [8]. The authors consider that now it is essential to provide evidence of how a greener economy can offer direct economic benefits of information and digital technology trends to national economies and the majority of their citizens.

A. Strzelecki, B. Kolny and M. Kucia consider that green living issues that arise as a result of smart home use in the context of sustainability consumption, at a time when smart homes are being built that can improve the management of electricity, water, gas consumption, and when their use offers the opportunity to raise awareness of caring for health and achieving wellbeing [9]. The scholars highlight that the significant positive influence of smart homes on sustainable consumption behaviors,

underscoring their potential in driving the digital economy towards sustainability goals lies in their contribution to the understanding of how digital technologies.

The results of P. Tamasiga, H. Onyeaka and E. H. Ouassou illustrate an increasing trend in the research attention towards the green FinTech concept and its relationship with the green economic growth, climate change, and greening rules and standards. A deep inspection indicates that future research trajectories are oriented into five different mainstreams: technology and instruments in digital finance; regulation, policies, and green FinTech; climate risk mitigation through Fintech; Fintech and environmental quality; green finance and climate change mitigation. Based on these research directions, an integrated framework was conceptualized that aims to deliver green economic growth using Fintech as a vehicle of transition especially for African countries [10]. The authors fully support the idea that the emergence of new transformational technology, known as the fourth industrial revolution, has crucially opened a new window to green economic growth. The transition to low carbon, green economy, and green sustainability has gained momentum simultaneously in developed and developing countries.

T. Altenburg, A. Pegels, M. B. Gutierrez, C. Brandi, H. Fuhrmann-Riebel, F. J. Fung, D. Malerba, B. Never, A. Stamm, R. Strohmaier and U. Volz sustain that a development policy should promote inclusive green finance (IGF) through market-shaping policies, such as an enabling regulatory framework for the development of digital IGF services and customer protection in digital payment services. It should also build policymakers' capacity in developing IGF policies and regulation. Support in the area of sustainable, circular consumption should focus on eco-design, and repair and reuse systems. This will need new collaborations with actors shaping systems of consumption and production, for instance with supermarkets or the regulators of eco-design guidelines [11]. The authors suppose that governments should support a green industrial policy and enlarge a policy space in trade rules by promoting technology foresight agencies, coordinating platforms for industry upgrading, and policy think tanks, and working towards reforms of the trading system.

Svitlana Bila underlies that one of the most essential tasks for current economics and researchers of systems and processes of organization future maintenance of world production is to determine the main strategic priorities of social production digitalization. Digital technologies radically change all spheres of a social life, including business and managerial processes at all levels. 21st century witnessed establishing digital economy, smart economy, circular economy, green economy and other various arrangements of social production which are based on digital technologies [12]. The authors consider that green economy consequences of radical structural reformation of all spheres in national and world economy in the 21st century, undoubtedly, will be stipulated with the processes of green production digitalization.

It will require further systemic and fundamental scientific studies on this complicated and multi hierarchical process.

L. Qin, G. Aziz, M. Wasim Hussan, A. Qadee and S. Sarwar examine the influence of Fintech innovations on environment, by using multiple angles. However, they formulate the advanced green environmental index by utilizing the environmental, economic, resources and financial indicators. In recent years, the progress in Fintech has emerged a significant source to decline the energy which turns to enhance the environmental quality. Fintech has confirmed the significant and positive relationship with green environmental index [13]. Scholars consider that three subcategories of Fintech, financial breadth, financial depth, and financial digitalization, have positive influence to promote the green environmental index.

At the same time, M. Sadiq, C. Paramaiah, R. Joseph, Z. Dong, A. M. Nawaz and N. Khajimuratov revealed that green finance as a mediator enhances while natural resource volatility as a mediator deteriorates climate sustainability. Furthermore, industrial structure and environmental regulations also shed inverse impacts on environmental quality. Government interventions play a crucial role in the betterment of climate quality. It is also observed that Fintech-associated carbon emission intensity varies with higher-order quartiles [14].

The conceptual study of Y. Li, R. Sun and Y. Rao provides a framework for digital technologies that can significantly improve green total factor productivity. Their results of the analysis show that there is heterogeneity in the driving effect of digital technology development on green total factor productivity, but this heterogeneity is mainly in the magnitude of the impact. At the subregional level, digital technology development has a greater impact on green total factor productivity in coastal or southern regions.

At the external environment level, digital technology development has a greater impact on green total factor productivity in regions with smaller economies, less external economic dependence, and less government fiscal intervention. According to Y. Li, R. Sun and Y. Rao the capital accumulation has moderating effect in the process of digital technology affecting green total factor productivity which will inhibit the improvement of digital technology development on green total factor productivity [15]. In authors' opinion, it is necessary to encourage the development of this technology by local conditions, formulate differentiated development policies by regional development levels, drive industrialization with digital industrialization, and drive the digitalization of industries in surrounding areas promoting green economic trends.

The paper has been developed through a systematic methodology, centered on desk research, surveys, and empirical analysis, graphical methods while formulating hypotheses, testing them for visualizing research results to identify, short-list, and validate digital green economy trends. This methodology consists of three main steps as:

scan, analyze, and recommend. The success and reliability of any trends report hinge upon developing and implementing a well-defined and thorough methodology, which ensures accuracy, credibility, and actionable insights for informed decision-making.

The following methods are used in the study as monographic, while studying the literature and analyzing previous studies. It should be noted that the paper includes scientific works of Ukrainian and foreign researchers; systemic, while clarifying the categorical apparatus and analyzing the concept of green economy trends in order to identify the key aspects and characteristics in the context of information and digital technologies; induction and deduction for a better understanding of the research results.

In the "scan" step the authors perform a research by identifying and reviewing the relevant data sources, including policy reports of the European Commission, technology and economic trend reports, research articles, relevant think tank publications, databases and thought leadership from recognized multilateral bodies, to identify an exhaustive list of digital green economy trends. The scholars subsequently conduct surveys with international subject-matter experts and global digital economy leaders to substantiate the secondary research findings.

In the "analyze" step the authors perform a qualitative evaluation framework, formulated with the support of leading global experts, to short-list the identified digital green economy trends, employing four criteria: impact, risk, disruption, and scalability. The result list of trends is validated through several figures. In the "recommend" step the authors synthesizes insights gained from the "analyze" step and provide actionable suggestions and guidance, in respect to the green IT trends shortlisted. These include insights on critical challenges, enablers, implications, and recommendations for relevant stakeholders across the digital green economy.

7.3 Digital technologies and green tech innovation clusters

A climate change and environmental degradation are an existential threat to the entire world. This requires global measures to both prevent it and adapt to changes where their consequences are unavoidable. The Green Deal is a response to these challenges that is considered inseparable from the simultaneous digital transition.

According to the European Commission, the starting point for the Green Deal Industrial Plan is the need to massively increase the digital technological development, manufacturing production and installation of net-zero products and energy supply in the next decade, and the value added of an EU-wide approach to meet this challenge together [2]. This is made more difficult by the global competition for raw materials and skilled personnel.

The Plan aims to address this dichotomy by focusing on the areas where Europe can make the biggest difference. It also seeks to avert the risk of replacing its reliance on Russian fossil fuels with other strategic dependencies that could impede our access to key technologies and inputs for the green transition, through a mix of diversification and own development and production. The Plan will complement ongoing efforts to transform industry under the European Green Deal and the EU Industrial strategy, in particular the Circular Economy Action Plan. Modernizing and decarbonizing energy-intensive industries also remains a top priority, as does ensuring job transitions and quality job creation through training and education [2].

As part of the Green Deal Industrial Plan, the Commission proposes to put forward a Net-Zero Industry Act to underpin industrial manufacturing of key digital technologies in the EU. The act would provide a simplified regulatory framework for production capacity of products that are key to meet our climate neutrality goals, such as: batteries, windmills, heat pumps, solar, electrolysers, carbon capture and storage technologies.

Taking technology neutrality as a starting point, the Act would build on an assessment of strategic importance and identified needs of manufacturing investment in different types of net-zero digital products. Those technologies may go beyond the strategic net-zero technologies that will be eligible for the specific type of support available under the State aid Temporary Crisis and Transition Framework.

European standards can help to promote the roll-out of clean and digital technologies. In particular for new industrial value chains, anticipating and developing high-quality European standards could provide EU industries an important competitive advantage – including at global level. They could demonstrate "marketability" and attract investment in firms that adhere to them. European standards would allow EU industries to scale up green technologies across the single market – that is very important for start-ups and SMEs.

V. Vishnevsky, O. Harkushenko, M. Zanizdra and S. Kniaziev suppose that at the global level, the introduction of state-of-the-art digital technologies has a generally positive relationship with the state of environment: the higher the level of digitalization, the more environment friendly national economies, and other things being equal. The scholars have found that the environmental performance of digitalization depends on the level of manufacturing technologies and the overall economic development. In the clusters of less developed countries, including Ukraine that has significant problems in industry and innovation, the spread of digital technologies has less positive impact on the environment than in the clusters of more advanced economies. Therefore, the long-term positive effects of digitalization for Ukraine are not obvious, while the negative ones may have serious negative consequences [16].

To minimize the environmental risks of digitalization processes in Ukraine, it is necessary to develop a national academic program for comprehensive assessment of effects of various aspects (abiotic, biotic, anthropogenic) of digital technologies on environment, as well as to harmonize economic digitalization programs with the overall strategy for innovation-driven national manufacture.

As for digital technologies' effect on energy efficiency in Ukraine, it is possible to include the following applications as: smart transport, and virtual goods, followed by smart buildings, smart energy, smart production and virtual mobility (**Table 7.1**). Other less frequently assessed domains are smart agriculture, smart water, or waste management.

Table 7.1 Digital technologies' effect on energy efficiency in Ukraine

Application	Use cases
Smart transport	Route optimization, traffic flow management
Smart production	Automation of production processes
Smart energy	Smart metering, demand side management, distributed power generation
Smart buildings	Smart heating, smart lighting
Virtual goods	E-books, online newspapers, music and video streaming
Virtual mobility	Video conferencing, e-commerce, e-health, distance learning, remote maintenance

Source: compiled by the authors [17]

In our opinion, Ukraine's implementation of the Green Deal is an important component of European integration. The European Commission determines that Ukraine's reconstruction should be in line with the green and digital agenda. The National Economic Strategy of Ukraine until 2030 envisages synchronization with the Green Deal. Existing environmental problems have become even more acute due to the war (over 200 billion USD in environmental damage). At the same time, the ICT sector needs its own green transformation. Its carbon footprint in the EU is estimated at about 4 %, with a tendency to grow to 8–10 %. Achieving climate neutrality and circularity of ICTs involves, among other things, more energy-efficient data centers and electronic communication networks, fully circular eco-design of ICT equipment, enhanced environmental measures during network deployment, and transparency of the sector's environmental impact.

Driven by the rising awareness of climate change, advancements in enabling technologies, and stricter regulatory mandates by governments, investments in

Green Tech have surged, propelling rapid growth in the green tech market. In our opinion, green tech innovations should include four main clusters (**Fig. 7.1**), such as:

1) green mobility;
2) green information technology;
3) green architecture;
4) carbon capture and storage technologies.

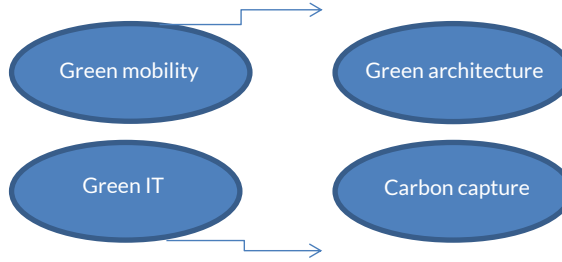

Fig. 7.1 Green tech innovation clusters
Source: compiled by the authors [18]

A green mobility involves utilizing transportation technologies like electric vehicles, hybrids, and vehicles running on alternative fuels, all designed to minimize their environmental impact. As battery and charging technology progresses, electric vehicles are becoming increasingly affordable and convenient for daily use. Conversely, electric vehicles are the incubator for battery technologies.

In Ukraine the rising adoption of these technologies especially after the war has the potential to decrease greenhouse gas emissions, encourage sustainable energy consumption, enhance air quality, and reduce reliance on fossil fuels. According to the IEA, 2023, electric vehicle sales globally surged from approximately 1 Mn to exceeding 10 Mn from 2017 to 2022, showcasing exponential growth [19].

According to the DCO, green IT refers to adopting environmentally sustainable computing practices, striving to curtail energy usage, mitigating the technology sector's impact on global emissions, and combatting climate change. Green IT involves various measures, such as: energy-efficient hardware, data centers, server virtualization, IoT-powered monitoring systems, and e-waste disposal. For instance, Meta's Lulea, Sweden, data center utilizes freezing external air to naturally cool down the digital infrastructure while the server generated hot air is circulated. Axial fan walls are employed to maintain consistent temperatures [18].

Green architecture integrates eco-friendly and resource-efficient practices, prioritizing building design, construction, operation, and maintenance to minimize

environmental impact. With a focus on environmental responsibility and resource efficiency, green architecture also considers the life cycle of a building, from planning and design to construction, operation, maintenance, renovation, and demolition. Renewable energy sources include solar panels, efficient insulation, passive heating and cooling techniques. For instance, Apple's corporate headquarters, "Apple Park" in Cupertino, California, spans 175 acres and operates entirely on renewable energy, primarily sourced from an on-site low-carbon central plant. The site also boasts extensive solar installations, with a significant portion of the solar roof dedicated to electricity generation [20].

According to the DCO, carbon capture and storage (CCS) involves capturing carbon dioxide emissions from industrial activities or burning fossil fuels in power generation. This technique prevents the release of carbon dioxide into the atmosphere, curbing its contribution to global warming. Different technologies are used for CCS, including direct air capture and mobile air capture, where carbon dioxide is either recycled or securely stored where it cannot escape, offering a significant method for cutting emissions and addressing the challenge of global warming [21]. For instance, ExxonMobil's Shute Creek Gas Processing Plant in Wyoming, USA, operates as a CCS facility. It captures around 365 Mn cubic feet of carbon dioxide daily, utilized in oil recovery efforts across multiple oil fields [22]. To sum up, digital technology trends in the green economy are as follows (**Fig. 7.2**).

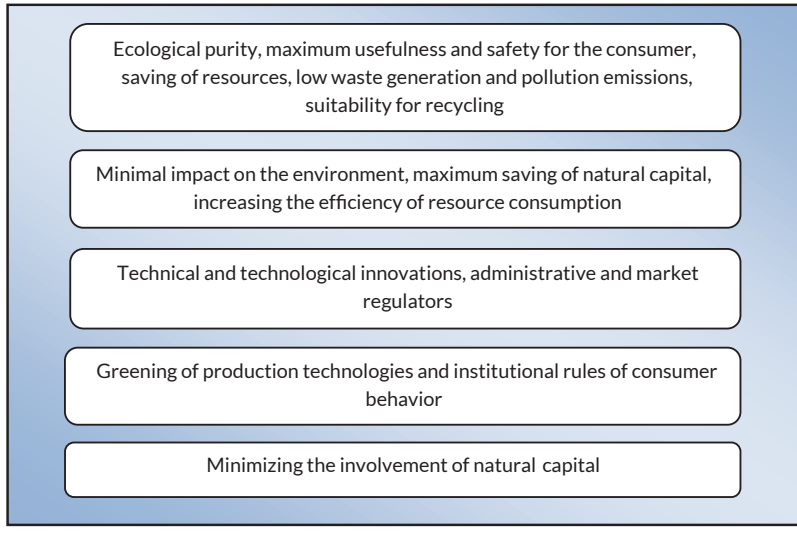

Fig. 7.2 Digital technology trends in the green economy

Green technologies offer a number of benefits, including: reducing greenhouse gas emissions, which are a major cause of climate change. They can help to improve energy efficiency, which can save the energy and reduce air, water and soil pollution.

7.4 Green architecture and sustainable development goals of Ukraine under conditions of instability

The large-scale war has exposed the challenges and issues of Ukraine's development that are in the focus of the UN's 2030 Agenda for Sustainable Development: demographic decline, poverty, various forms of violence, mental and psychological disorders of civilians and military personnel, the growth of refugees, ineffective justice, loss of biodiversity, and environmental damage.

Being a part of the 2030 Agenda for Sustainable Development, it is important for Ukraine to comply with all 17 SDGs, but some of them should be the basis of green policies and initiatives, namely 7 "Affordable and clean energy" in combination with 15 "Protection and restoration of terrestrial ecosystems", 11 "Sustainable development of cities and communities", in particular through 13 "Action on climate change", and 14 "Conservation of marine resources" [23].

The energy and industry are sectors most responsible for GHG emissions due to the high carbon intensity of energy resources and fossil fuels. Implementing Goal 7 through the large-scale deployment of renewable energy generation and energy efficiency is currently the most effective tool to ensure a relatively rapid and safe reduction of emissions. The war between Ukraine and the Russian Federation has demonstrated that no energy in a country means any life. The consequences that Ukraine has experienced from its long-term energy import dependence on Russia, including the first blackout in the country's history, make building energy independence and self-sufficiency based on the renewable energy a critical component of national security [24].

Despite the fact that before Russia's large-scale invasion of Ukraine, the country has already made some progress in the development of renewable energy (according to the NEURC, as of December 31, 2021, the installed capacity of the sector reached 8450.8 MW, excluding small distributed generation, which amounted to only about 14,3 % of the total capacity of Ukraine's energy system), the national energy system was still a post-Soviet legacy, with baseload power provided by low-carbon nuclear power plants and carbon-intensive thermal power plants that are deteriorating.

The damaged thermal power plants across Ukraine, the destroyed "Kakhovka" HPP, and the nuclear blackmail of the country have created an opportunity for the government to make a real transition to a green, energy-efficient, innovative,

smart, environmentally and human-friendly, and distributed energy system based on renewable energy. Given that green recovery involves, Goal 7 "Affordable and clean energy" was strategically justified, and would become economically viable with low financing rates after the end of Russia's military aggression (**Fig. 7.3**).

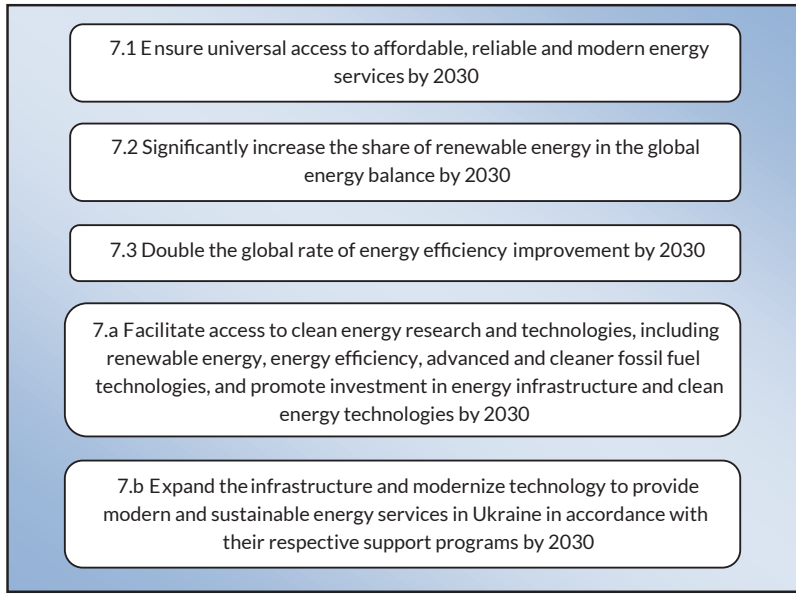

Fig. 7.3 Targets and indicators of SDG 7 "Affordable and clean energy" in Ukraine
Source: compiled by the authors based on [24]

Among the program measures aimed at solving the problems of the innovation sphere in Ukraine, the Strategy for the Development of the Innovation Sphere calls for a review of the priority directions of science and technology development in order to bring them closer to the directions defined in developed countries based on current global technological trends.

The Strategy for Innovative Activity Development until 2030 does not highlight low-carbon sectors and technologies as one of the priority directions, but refers to the Low Emission Development Strategy until 2050 as one of the approximately 40 strategic sectoral documents related to innovation development in various fields [25]. At the same time, attention should be paid to the status of this document, which is supported and approved by the protocol decision of the Cabinet of

Ministers of Ukraine on July 18, 2018 [26], but it is not available in the databases of the official documents of Ukrainian government bodies. There is also a resolution of the Verkhovna Rada (Parliament) dated November 5, 2021, No. 1870-IX, which, inter alia, instructs the Cabinet of Ministers of Ukraine to develop and submit to the Verkhovna Rada of Ukraine a draft Law of Ukraine on the Low Emission Development Strategy of Ukraine until 2050 [27].

SDG 11 "Sustainable development of cities and communities" is aimed at improving approaches to urban planning, management and development of cities and communities, taking into account the principles of inclusiveness, safety and sustainability, as well as preventing possible risks of deterioration in the quality of life of the population [28].

On February 28, 2024, more than 140 representatives of local governments of Ukraine, military administrations, and civil society organizations took part in a meeting of the professional network on municipal infrastructure restoration. The purpose of the meeting was to analyze and clarify current issues and opportunities for the restoration of municipal infrastructure after the war. The event brought together specialists in the field of recovery, including heads and deputy heads of villages, towns, and cities, heads of structural units of executive bodies of local councils, and representatives of NGOs in Ukraine.

In our opinion, achieving Goal 11 in business is possible after the war in Ukraine through: implementing a policy of resource efficiency and risk reduction at the company's operational level; an active participation in the processes of developing city or community development strategies with a special focus on opportunities for innovative and sustainable solutions; investing in the sustainable infrastructure of the local community (low-carbon transport, energy efficient buildings); cooperation with local governments to jointly develop and implement solutions aimed at minimizing the negative environmental impact associated with the company's operations (**Fig. 7.4**).

A climate change is a very real crisis of our time, which leads to various kinds of natural disasters or catastrophes, such as: floods, droughts, hurricanes, tornadoes, dust storms, uncontrolled forest and peatland fires, earthquakes, etc. The key cause of such crises is the gradual increase in the earth's temperature caused by high levels of GHG emissions due to human activity [29]. Given that climate change is global in nature, and Ukraine is interested in overcoming its consequences and maintaining a safe temperature for health, the alignment of investment decisions with SDG 3 (**Fig. 7.5**). On May 30, 2024 the Cabinet of Ministers of Ukraine approved the Strategy for the Formation and Implementation of the State Policy in the Field of Climate Change in Ukraine up to 2035 and the Operational Action Plan in Ukraine for its Implementation during 2024–2026 [30].

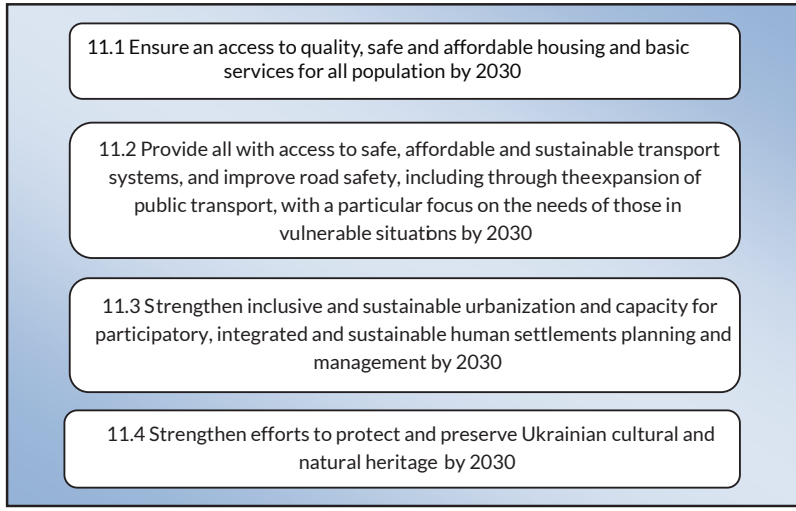

Fig. 7.4 Targets and indicators of SDG 11 "Sustainable development of cities and communities" in Ukraine
Source: compiled by the authors based [28]

Fig. 7.5 Targets and indicators of SDG 13 "Action on climate change" in Ukraine
Source: compiled by the authors based on [29]

On October 8, 2024, the Verkhovna Rada of Ukraine adopted the Law of Ukraine "On the Basic Principles of the State Climate Policy" in the second reading and as a whole by a majority of 284 votes of the people's deputies of Ukraine [31]. This Law was aimed at defining the legal and organizational framework of the state climate policy aimed at ensuring low-carbon and sustainable development of Ukraine, achieving climate neutrality, mitigating the effects of climate change and adapting to it, fulfilling Ukraine's international commitments in the field of climate change, improving the national system of inventory of anthropogenic greenhouse gas emissions by sources and removals by sinks, ensuring the functioning of the national monitoring system, and evaluation of achieving the goals of the state climate policy and forecasting in the field of climate change.

In order to encourage Ukraine to restore and preserve the ecosystem, separate Goals 14 "Protecting and Restoring Underwater Ecosystems" and 15 "Protecting and Restoring Terrestrial Ecosystems" were used, which directly addressed the conservation of "all living things" on land and in water. Sustainable forest management, combating desertification, halting and preventing soil degradation and biodiversity loss were all subject to the above goals and a prerequisite for sustainable recovery [32]. Healthy ecosystems and biodiversity were a source of food, water, medicine, shelter, and other material goods. In addition to the fact that human activity has already significantly altered most ecosystems on land, war crimes committed by Russia on the territory of Ukraine against flora and fauna led to ecocide in the country. Therefore, in the context of Ukraine's green recovery, these Goals have a broader goal: both to protect the national ecosystem from the potential effects of climate change and human activity and to recover from the direct and indirect damage that the ecosystem of all of Ukraine, including the Crimean Peninsula [33].

In January 2023, the Ministry of Environmental Protection and Natural Resources of Ukraine estimated the damage caused by the war to the environment at 46 billion USD. On June 6, 2023, with the Russian army's blowing up of the dam at Ukraine's largest hydroelectric power plant "Kakhovka", which became a large-scale ecocide of all living things both on land and in water, and large-scale pollution of water resources, these losses increased significantly [34]. In view of this, Ukraine's the green recovery should take into account the sustainable use of terrestrial and inland freshwater ecosystems, including forests, wetlands, and mountains. It should not lead to deforestation, but rather promote the restoration of degraded forests and reforestation. It should promote the creation of nature conservation eco-parks for animals, provide the reasonable management of fisheries and water bodies, and introduce water purification systems (**Fig. 7.6**).

The environmental restoration, like decarbonization, is a global necessity and will be possible with international loans in Ukraine. Therefore, the coherence of

investment decisions with SDG 15 is another important condition that Ukraine should take into account [35]. Despite the fact that, according to the Voluntary National Review of Ukraine's implementation of the SDGs for 2020 before the war, Ukraine was still gradually making progress in achieving 15 of the 17 Sustainable Development Goals, with the greatest success declared in poverty reduction, goals such as 13 "Climate Change Measures" and 15 "Protection and Restoration of Terrestrial Ecosystems" were out of the government's attention and showed a negative development trend [35]. It is worth noting that this assessment would be different, given the adoption of the Strategy for Environmental Security and Climate Change Adaptation after the war (**Fig. 7.7**).

According to the World Wildlife Fund, at least 812 protected areas of Ukraine covering 0.9 million hectares were affected by the full-scale Russian invasion of Ukraine. 2.9 million hectares of the Emerald Network were under threat of destruction. There were 17 wetlands of international importance with unique biodiversity at risk. 514 nature reserve sites covering 0.8 million hectares remained occupied [36].

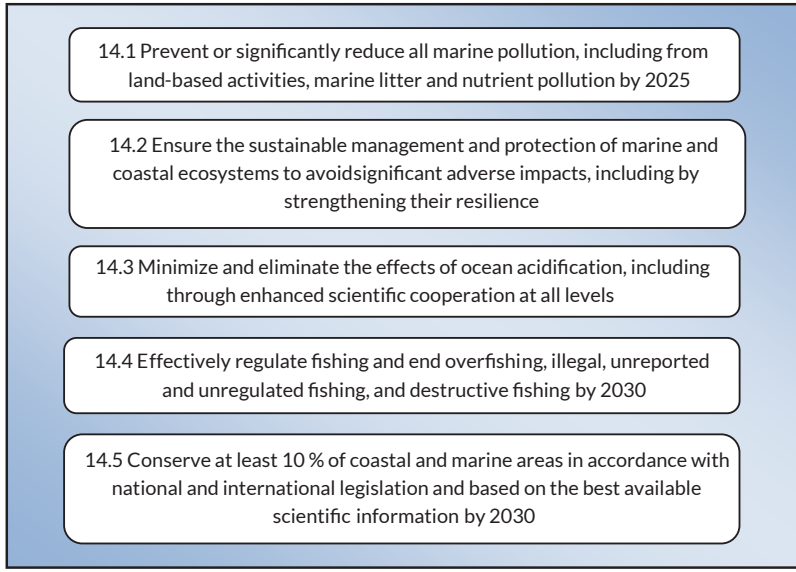

Fig. 7.6 Targets and indicators of SDG 14 "Protection and restoration of terrestrial ecosystems" in Ukraine
Source: compiled by the authors based on [34]

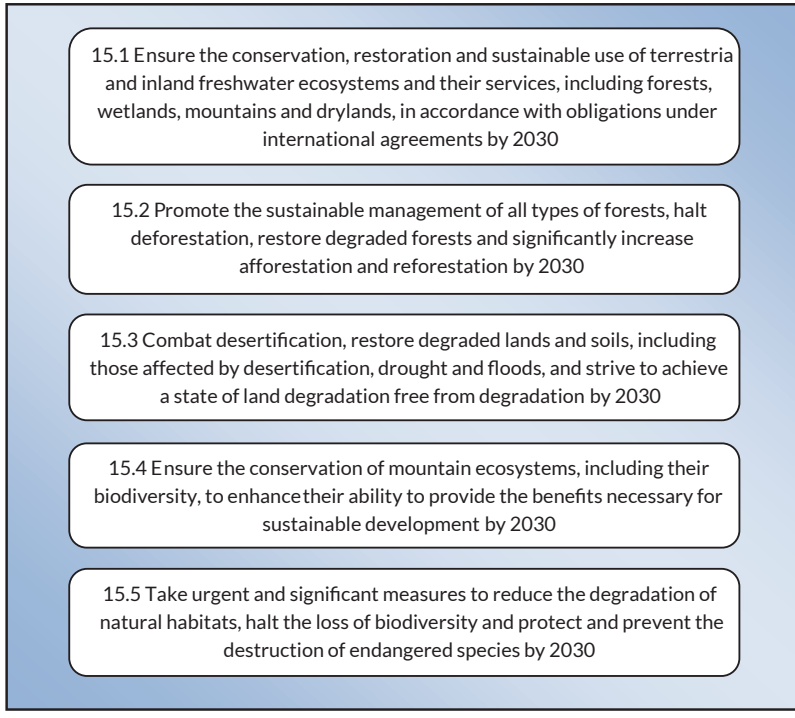

Fig. 7.7 Targets and indicators of SDG 15 "Conservation of marine resources" in Ukraine
Source: compiled by the authors based on [32]

In authors' opinion, to restore forestry, Ukraine needs to plant large artificial forests. However, due to the challenges posed by climate change, foresters must implement technologies that increase forest adaptation and help preserve continuous forest cover. The Forestry Strategy of Ukraine, which is designed for the period up to 2035, should provide for natural resource management in the context of climate change.

In order to integrate into the EU, Ukraine committed itself to create a water management plan. This document should include steps that Ukraine plans to take to solve the problem individually for each river basin or reservoir. Researchers believe that nature-based solutions can become a necessary innovative tool for preserving Ukraine's water resources. Nature-based solutions aim to protect, effectively manage and restore natural ecosystems, respond effectively and flexibly

to societal challenges, and create benefits for people and biodiversity. Farming in restored marshes is a promising natural solution for Ukraine which can contribute to ecological balance.

Due to Russia's large-scale war against Ukraine, the government was given the opportunity to build a new, green and sustainable economy, with a focus on social inclusion and environmentally friendly policies. The roadmap for rebuilding should be based on the synergy of the social and environmental dimensions of the UN SDGs. The alignment of Ukraine's recovery after the war with the SDGs is a condition for the allocation or mobilization of funds for this recovery by a financial institution of any type and scale. The government of Ukraine should place particular emphasis on ensuring that its recovery policy is aligned with the SDGs, and domestic businesses seeking international financial support should consider incorporating SDG principles into their corporate governance policies and follow relevant guidelines when planning and designing projects [37].

7.5 Information and digital green tech of Ukraine under conditions of war

The full-scale war, which has been going on for almost three years, caused enormous damage to Ukraine's economy and a huge humanitarian crisis. It would be worse if Ukraine did not digitize despite all the difficulties and obstacles. The whole world was watching and adopting Ukrainian experience in digitalization and Green Tech innovation clusters' development. The war showed that e-governance and digital services remained not only relevant but also an effective tool of public and green administration. Digitalization was the best example of the resilience and capacity of the Ukrainian state.

The Diia Business online platform received many prestigious international awards and honors during the war. It provided roving one's identity, applying for assistance, sharing a car registration certificate, paying taxes, and obtaining necessary certificates were just a small part of the services available, which were already used by more than 20 million Ukrainians. Diia portal offered 100+ government services, and the mobile application offers 14 documents and 30+ services [38].

On the Internet, Ukrainians could find many useful opportunities to develop their own business in information and digital green tech. Ukrainians who were engaged in green entrepreneurship or were just planning to start their own business could find it useful to know: how to prepare for starting green business, where to study [39], to get an advice, and financial support for business from the state or international programs, how to find investors and partners, more about programs for women's

green entrepreneurship, bank support programs for different types of business and how to use government online services for green tech innovation clusters of Ukraine during the war.

"Kyiv Digital" was another platform of how information technology and innovation helped to ensure sustainability and move forward, providing significant benefits and value to users. Started as a public transport fare app at the very beginning, it grew into a super-powerful platform in three years, offering almost everything people needed to live in the capital: air raid and power outage notifications, utility, fare and parking payments, traffic, registration at the ASC, petitions and polls. Despite the war, Ukraine did not only manage to maintain its digital services but also expanded them significantly. The country adapted to new challenges with innovative solutions that were being actively studied by even the most digitally advanced EU countries, such as Estonia, Denmark, and Sweden.

O. Lytvyn, A. Onyshchenko and O. Ostapenko found that the challenges of implementing new technologies into business include the absence of a unified regulatory framework, high costs associated with transitioning to digital platforms, and resistance from traditional players. These challenges can be addressed by creating clear regulations, providing financial support to companies transitioning to digital technologies, and fostering partnerships between innovative startups and large financial institutions for collaborative development and implementation of technological solutions [40].

I. Maksymenko, A. Akimov and S. Markova suppose that in the context of Russia's full-scale invasion of Ukraine, digital transformations in Ukraine 2023 were aimed at expanding digital opportunities to achieve the resilience of the national economy. In particular, this included Ukraine's integration into the EU's Digital Single Market, building digital infrastructure, attracting investment, creating a register of damage caused by Russia's aggression against Ukraine, etc. In Ukraine, significant attention was paid to digitalization not only at the national but also at the regional level. Thus, digital projects relevant to martial law were implemented in a number of regions using various sources of funding [41].

The full-scale war confirmed that Ukraine's future lied in green tech innovations. Ukraine had the potential to become the country with the largest number of green startups per one million people. Stimulating the development of the startup ecosystem in 2022, the Ministry of Digital Transformation of Ukraine supported existing green tech projects and implemented new ones. It launched the American venture fund Blue&Yellow Heritage Fund together with the company ff Venture Capital. It was focused on Ukrainian enterprises and startups. The fund managed to raise 50 million USD. Plug&Play Tech Center was one of the first investors in the international payment system PayPal.

An important role was also played by the Innovation Development Fund, which was transferred to the Ministry of Digital Transformation. Due to its work, the state became the largest investor in the country. The Fund invested more than 6 million USD in more than 250 startups in Ukraine and Eastern Europe. And the winners of the pitching rose more than 40 million USD in investments on their own. The Fund was going to change its focus to developing military-tech projects to strengthen Ukraine's defense capabilities [42].

Ukraine had to encourage green tech innovation clusters to stay at the forefront of the technological progress. Supporting research and development in the field of the latest technologies, including military and digital, was the key to maintaining a competitive advantage. In the world of digital technologies, where everything was changing at an incredible speed, this was the only way to stay on top. Ukraine needed an innovative ecosystem and investments in key technology sectors, such as: artificial intelligence, cybersecurity, military and green technologies. Supporting at all levels and the creating of a favorable environment for green startups and technology companies would be crucial for the development of innovation and entrepreneurship, attracting investment, economic growth and increasing the global competitiveness of Ukraine.

O. Lytvyn, V. Kudin, A. Onyshchenko, M. Nikolaiev and N. Chaplynska suggest that being a part of sustainable development, post-war companies should increase their activities in the field of renewable energy and ecology, as well as support environmental projects in any way possible, thus contributing to the achievement of the 6, 7 and 13 Global Goals for Sustainable Development, which the United Nations has set for 2015 [43]. Ukrainian companies should be aware of their environmental impact and strive to reduce it by developing their sustainability orientation, including sustainable business and sustainable management. According to the scholars, this once again proves that the path of sustainable development is inevitable for Ukraine. It is possible to believe that the concept of social responsibility should reflect rationality in the, as a rule, conflicting expectations of the entire set of interested parties, be based on the principles of continuous and long-term development of business entities, with the aim of obtaining competitive advantages [44].

The development of green tech innovation clusters was not only about improving Ukraine's position in global innovation rankings, which could help to increase international investments, but also about creating new jobs and engaging women more actively. This would be of great importance in overcoming the demographic crisis caused by the war. In addition, supporting startups and businesses would ensure a diverse and inclusive green economic recovery.

7.6 Conclusions

In conclusion, green IT involves various measures, such as: energy-efficient hardware, data centers, server virtualization, IoT-powered monitoring systems, and e-waste disposal. At the same time, digital technologies also ensure a nature positive transition to the green economy that includes climate resilience and the protection of biodiversity. Adopting green technologies is essential to improve well-being and health, offering benefits like clean air, water, soil, energy-efficient buildings, affordable and healthy food, and creating future-proof jobs for a resilient green industry transition. As a candidate country for EU membership, Ukraine must adopt a number of norms, standards and commitments, as well as pursue a Green Policy, which will focus on the sustainable use of resources. Ukraine needs to develop a collective vision of the harmonious coexistence of humans and nature that are based on the use of ecosystems to combat climate change, preserve biodiversity and promote community development after the war.

References

1. Communication: A Green Deal Industrial Plan for the Net-Zero (2023). European commission. Available at: https://commission.europa.eu/document/41514677-9598-4d89-a572-abe21cb037f4_en
2. 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 A Green Deal Industrial Plan for the Net-Zero Age. COM/2023/62 final (2023). Document 52023DC0062. European Commission, Brussels. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023DC0062
3. Effekte der chinesischen Subven-tionspolitik auf Deutschland (2023). Eine vbw Studie, erstellt von der Prognos AG. VBW. Available at: https://www.vbw-bayern.de/Redaktion/Frei-zugaengliche-Medien/Abteilungen-GS/Au%C3%9Fenwirtschaft/2021/20230112_vbw_Prognos_Studie_Subventionen-China.pdf
4. Barbier, E. (2011). The policy challenges for green economy and sustainable economic development. Natural Resources Forum, 35 (3), 233–245. https://doi.org/10.1111/j.1477-8947.2011.01397.x
5. Berger, R. (2017). Think act beyond mainstream. Win the customer in B2B sales. Available at: https://www.rolandberger.com/publications/publication_pdf/roland_berger_win_the_customer_in_b2b_sales.pdf

6. Chang, H.-J. (2006). Industrial policy in East Asia: Lessons for Europe, EIB Papers. European Investment Bank (EIB). Luxembourg, 11 (2), 106–132.
7. Davis, J., Edgar, T., Porter, J., Bernaden, J., Sarli, M. (2012). Smart manufacturing, manufacturing intelligence and demand-dynamic performance. Computers & Chemical Engineering, 47, 145–156. https://doi.org/10.1016/j.compchemeng.2012.06.037
8. Ciocoiu, C. N. (2011). Integrating Digital Economy And Green Economy: Opportunities For Sustainable Development. Theoretical and Empirical Researches in Urban Management. Research Centre in Public Administration and Public Services, 6 (1), 33–43.
9. Strzelecki, A., Kolny, B., Kucia, M. (2024). Smart Homes as Catalysts for Sustainable Consumption: A Digital Economy Perspective. Sustainability, 16 (11), 4676. https://doi.org/10.3390/su16114676
10. Tamasiga, P., Onyeaka, H., Ouassou, E. H. (2022). Unlocking the Green Economy in African Countries: An Integrated Framework of FinTech as an Enabler of the Transition to Sustainability. Energies, 15 (22), 8658. https://doi.org/10.3390/en15228658
11. Altenburg, T., Pegels, A., Böhl Gutierrez, M., Brandi, C., Fuhrmann-Riebel, H., Jauregui Fung, F. et al. (2024). Greening economies in partner countries: Priorities for international cooperation. IDOS Policy Briefs 2/2024. German Institute of Development and Sustainability (IDOS). Bonn. https://doi.org/10.23661/ipb2.2024
12. Bila, S. (2021). Strategic priorities of social production digitalization: world experience. University Economic Bulletin, 48, 40–55. https://doi.org/10.31470/2306-546x-2021-48-40-55
13. Qin, L., Aziz, G., Hussan, M. W., Qadeer, A., Sarwar, S. (2024). Empirical evidence of fintech and green environment: Using the green finance as a mediating variable. International Review of Economics & Finance, 89, 33–49. https://doi.org/10.1016/j.iref.2023.07.056
14. Sadiq, M., Paramaiah, C., Joseph, R., Dong, Z., Nawaz, M. A., Shukurullaevich, N. K. (2024). Role of fintech, green finance, and natural resource rents in sustainable climate change in China. Mediating role of environmental regulations and government interventions in the pre-post COVID eras. Resources Policy, 88, 104494. https://doi.org/10.1016/j.resourpol.2023.104494
15. Li, Y., Sun, R., Rao, Y. (2023). Digital Technology and Green Total Factor Productivity. Polish Journal of Environmental Studies, 33 (2), 1251–1265. https://doi.org/10.15244/pjoes/172849
16. Vishnevsky, V., Harkushenko, O., Zanizdra, M., Kniaziev, S. (2021). Digital and green economy: common grounds and contradictions. Science and Innovation, 17 (3), 14–27. https://doi.org/10.15407/scine17.03.014

17. Bieser, J. C. T., Hilty, L. M. (2018). Assessing Indirect Environmental Effects of Information and Communication Technology (ICT): A Systematic Literature Review. Sustainability, 10 (8), 2662. https://doi.org/10.3390/su10082662
18. DCO Digital Economy Trends 2024 (2024). Digital Cooperation Organization, 93–112.
19. Demand for electric cars is booming, with sales expected to leap 35 % this year after a record-breaking 2022 (2023). IEA. Available at: https://www.iea.org/news/demand-for-electric-cars-is-booming-with-sales-expected-to-leap-35-this-year-after-a-record-breaking-2022
20. Apple Park. Foster + Partners. Available at: https://www.fosterandpartners.com/projects/apple-park
21. Besta, S. (2019). What are the top carbon capture and storage projects around the world? NS Energy. Available at: https://www.nsenergybusiness.com/features/top-carbon-capture-storage-projects/
22. Shute Creek Gas and Helium Plant. The Center for Land Use Interpretation. Available at: https://clui.org/projects/lighter-air-exploring-landscape-helium/helium-production-sites/shute-creek-gas-and-helium
23. 17 Goals to tranform our world (2024). State Statistics Service of Ukraine. Available at: https://sdg.ukrstat.gov.ua/
24. Affordable and clean energy (2024). State Statistics Service of Ukraine. Available at: https://sdg.ukrstat.gov.ua/7/
25. Pro skhvalennia Stratehii rozvytku sfery innovatsiinoi diialnosti na period do 2030 roku (2019). Rozporiadzhennia Kabinetu Ministriv Ukrainy No. 526-r. 10.07.2019. Available at: https://zakon.rada.gov.ua/laws/show/526-2019-%D1%80#Text
26. Stratehiia nyzkovuhletsevoho rozvytku Ukrainy do 2050 roku. Ministerstvo zakhystu dovkillia ta pryrodnykh resursiv Ukrainy. Available at: https://mepr.gov.ua/diyalnist/napryamky/zmina-klimatu/pom-yakshennya-zminy-klimatu/strategiya-nyzkovugletsevogo-rozvytku-ukrayiny-do-2050-roku/
27. Pro Zvernennia Verkhovnoi Rady Ukrainy do Konferentsii Orhanizatsii Obiednanykh Natsii zi zminy klimatu, yaka vkliuchatyme provedennia 26-yi sesii Konferentsii Storin Ramkovoi konventsii Orhanizatsii Obiednanykh Natsii pro zminu klimatu, 16-yi sesii Konferentsii Storin, yaka ye naradoiu Storin Kiotskoho protokolu, ta 3-yi sesii Konferentsii Storin, yaka ye naradoiu Storin Paryzkoi uhody, Heneralnoi Asamblei OON, Yevropeiskoho Soiuzu, Rady Yevropy, parlamentskykh asamblei, Yevropeiskoho parlamentu, Mizhparlamentskoho soiuzu, inshykh rehionalnykh i mizhnarodnykh orhanizatsii, uriadiv ta parlamentiv inozemnykh derzhav, na pidtrymku hlobalnykh tsilei z pytan zminy klimatu (2021). Postanova Verkhovnoi Rady Ukrainy No. 1870-IX. 05.11.2021. Available at: https://zakon.rada.gov.ua/laws/card/1870-20

28. Sustainable development of cities and communities (2024). State Statistics Service of Ukraine. Available at: https://sdg.ukrstat.gov.ua/11/
29. Mitigate climate change impact (2024). State Statistics Service of Ukraine. Available at: https://sdg.ukrstat.gov.ua/13/
30. Stratehiia formuvannia ta realizatsii derzhavnoi polityky u sferi zminy klimatu na period do 2035 roku (2024). Skhvaleno rozporiadzhenniam Kabinetu Ministriv Ukrainy No. 483. 30.05.2024. Available at: https://zakon.rada.gov.ua/laws/show/483-2024-%D1%80
31. Verkhovna Rada Ukrainy pryiniala Zakon Ukrainy "Pro osnovni zasady derzhavnoi klimatychnoi polityky" (2024). Komitet Verkhovnoi Rady Ukrainy. Available at: https://komekolog.rada.gov.ua/news/main_news/77081.html
32. Conserve marine resources (2024). State Statistics Service of Ukraine. Available at: https://sdg.ukrstat.gov.ua/14/
33. Zbytky ukrainskomu dovkilliu vnaslidok viiny otsineni v $46 mlrd (2023). Borg. Expert. Available at: https://borgexpert.com/news/zbytky-ukrainskomu-dovkilliu-vnaslidok-vijny-otsineni-v-46-mlrd
34. Protect and restore terrestrial ecosystems (2024). State Statistics Service of Ukraine. Available at: https://sdg.ukrstat.gov.ua/15/
35. Sustainable Development Goals Ukraine (2020). Voluntary National Review. Available at: https://hlpf.un.org/sites/default/files/vnrs/2021/26295VNR_2020_Ukraine_Report.pdf
36. 5 porad, yak vidnovyty dovkillia v Ukraini pislia viiny – Vsesvitnii fond dykoi pryrody (2024). VOA. Available at: https://www.holosameryky.com/a/dovkillya-ukrainy/7421920.html
37. Lytvyn, O. (2024). Sustainable Development of Digital Transformations and Innovative Technologies in the Economy / Transformacje cyfrowe i technologie innowacyjne w ekonomii. Łomża: Międzynarodowa Akademia Nauk Stosowanych w Łomży. , Część 1. Charków: PISzW "Charkowski Uniwersytet Technologiczny "SHAG", Ukraina. Wydawnictwo: MANS w Łomży, 1, 324–335. Available at: https://mans.edu.pl/fcp/iOEUfFzs9BjEkLTg1Y1B-Se0N_YAVTHwIIOgIaTAIABCRvRQMEOjBBaHICPXNtSBk6PjIyBV4RBDY-nD1cYTk8cOjYCEg/2/public/wydawnictwa/zbor_materialow_konferencji_czesc_1.pdf
38. Diia.Business. Available at: https://business.diia.gov.ua
39. Lytvyn, O. (2023). Digital tools for creating educational content. The Scientific Paradigm in the Context of Technological Development and Social Change. Part 2. Riga: "Baltija Publishing", 329–366. https://doi.org/10.30525/978-9934-26-297-5-33

40. Lytvyn, O., Onyshchenko, A., Ostapenko, O. (2023). Economic challenges of sustainable development goals in ukraine. Baltic Journal of Economic Studies, 9 (1), 100–112. https://doi.org/10.30525/2256-0742/2023-9-1-100-112
41. Maksymenko, I., Akimov, A., Markova, S. (2024). Trends in the digital transformation of ukraine's economy in the context of war. Baltic Journal of Economic Studies, 10 (1), 175–184. https://doi.org/10.30525/2256-0742/2024-10-1-175-184
42. Fedorov, M. (2022). IT pid chas viiny: vyklyky, dosiahnennia, perspektyvy Interfax. Available at: https://interfax.com.ua/news/blog/881572.html
43. Lytvyn, O., Kudin, V., Onyshchenko, A., Nikolaiev, M., Chaplynska, N. (2024). Integration of digital means in the financial sphere: the potential of cloud computing, blockchain, big data and AI. Financial and Credit Activity Problems of Theory and Practice, 1 (54), 127–145. https://doi.org/10.55643/fcaptp.1.54.2024.4257
44. Lytvyn, O., Kuryliuk, Y., Onyshchenko, A., Kudin, V., Parkhomenko, V., Filiuk, S. (2023). Toolkit for Ensuring Management of Socially Responsible Business Activities. Economic Affairs, 68 (1s), 83–89. https://doi.org/10.46852/0424-2513.1s.2023.10

CHAPTER 8

A decision-making system for managing the remediation of water resources in the Kherson region: agent-oriented modeling in the context of post-war economic recovery

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Abstract

The study explores the theoretical and practical aspects of managing the remediation of territories in Ukraine affected by military activities. The authors argue for the necessity of employing unconventional scientific approaches to address military contamination, reconstruct and restore infrastructure following the largest war in Europe in terms of destruction and consequences since World War II. In the context of mitigating the environmental disaster caused by the destruction of the Kakhovka Hydroelectric Power Plant dam, the authors propose the implementation of a simulation-based agent-oriented model for remediating water resources in the Kherson region. This model integrates geographic information systems, artificial intelligence, machine learning, and the Agile approach. According to the authors, the use of agent-oriented modelling in designing a management system for remediating military contamination on affected territories is a promising direction that can significantly improve the efficiency and effectiveness of recovery efforts. The developed and implemented models are designed to account for the complex interactions and dynamics of events in the socio-economic and ecological systems during remediation efforts. This approach will contribute to the optimal decision-making process for effective management solutions. It is substantiated that the integration of the project with advanced technologies and innovative engineering solutions can minimize the time required for remediation and multiply the effects of the recovery efforts.

As a platform for effective project management, the authors propose using the Agile approach, which has already proven to be a highly efficient method of managing teams in conditions of uncertainty. Agile emphasizes flexibility, adaptability, and active collaboration. This method will facilitate the involvement of all key stakeholders at every stage of project implementation, including government authorities,

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local administrations, public utilities, contractor companies performing remediation work, and international partners. This will help ensure transparency and synchronization of actions among all key agents, forming the basis of agent-oriented modelling. The implementation of the remediation and restoration project for water resources in the Kherson region is critically important to ensure water availability and restore the region's economic activities after the cessation of military operations.

Keywords

Agent-Oriented Modelling, remediation, water resources, Agile approach, Geographic Information Systems, Artificial Intelligence, Machine Learning, post-war recovery, management system, agricultural business, Ecosystem, economic benefit.

8.1 Introduction

The international community recognizes that the war in Ukraine, the second-largest in scale and destruction since World War II, has caused significant damage to the country's ecosystems and natural resources. According to the Ministry of Environmental Protection and Natural Resources of Ukraine, by early 2024, the total damage caused by the war amounted to 60 billion USD. This figure includes forest destruction, water resource contamination, and biodiversity loss. Approximately 9,300 square miles of forests were destroyed by fires ignited during combat, contributing to increased carbon emissions. Reports highlight that attacks on industrial facilities and water treatment plants have contaminated freshwater resources. Additionally, over 67,000 square miles of territory have been affected by landmines and unexploded ordnance. Irreparable harm to wildlife has also been observed, including the extinction of rare species in nature reserves and the loss of fauna. Particularly notable is the ecocide resulting from the destruction of fish in the Kakhovka Reservoir and the biocenosis damage to the Dnipro River's coastal zone [1].

The study highlights the urgent need for innovative strategies, particularly after the Kakhovka Hydroelectric Power Plant (HPP) dam's collapse, to manage ecological disasters and restore critical resources like water. Modern hybrid conflicts require advanced technologies such as Geographic Information Systems (GIS), Artificial Intelligence (AI), and Machine Learning (ML) to address contamination and socio-economic disruptions effectively. The proposed Agent-Oriented Modeling (AOM) project identifies key agents and integrates advanced technologies to optimize decision-making and enhance coordination among stakeholders.

Agile project management ensures flexibility, adaptability, and active collaboration, enabling iterative adjustments based on real-time feedback. The research aims

to develop a decision-making system that integrates AOM, Information Technology (IT) solutions, Internet of Things (IoT) devices, and AI-driven analytics to enhance the efficiency of remediation efforts. This integration is expected to create a synergistic effect, addressing multifaceted challenges in post-conflict recovery and contributing to sustainable regional development.

The proposed system will expedite water resource restoration in the Kherson region, ensuring supply for agricultural, industrial, and domestic needs. It also aims to optimize resource allocation and improve transparency and accountability among stakeholders, offering a scalable model for managing ecological remediation in post-conflict regions globally.

8.2 The genesis of military contamination remediation: preconditions and reasons for the paradigm shift

The essence of the phenomenon under study is deemed expedient to be revealed by identification of the major aspects of the underlying cause, namely, of the consequences resulted from military activities. In the context of remediation of military contamination, the term "military activity", in the author's opinion, can be characterized as a totality of diverse activities and operations undertaken by the armed forces of a particular state or other paramilitary formations, involving various forms of combat operations, training maneuvers, testing and operation of military equipment and weapons, logistical operations, as well as construction and operation of military facilities. Significant environmental exposures often accompany such activities and can result in various levels of soil, water and air contamination, which require remediation activities to restore ecological balance and mitigate risks to human health and ecosystems.

Military activities, encompassing operations, training, and logistics, impose extensive environmental impacts that require a comprehensive understanding and mitigation approach. Explosive use, armored platforms, aviation, and large-scale maneuvers during military operations result in soil contamination with heavy metals, toxic chemicals, and unexploded ammunition. Water reservoirs are polluted by petroleum leaks and untreated wastewater, while air quality deteriorates due to emissions from fuel combustion and explosions, spreading toxic gases and aerosols. The destruction of infrastructure compounds these effects, releasing hazardous materials into ecosystems and severely disrupting environmental balance.

The health implications of military contamination are equally profound. Chemical weapons and toxic residues from ammunition exposure lead to acute and chronic

illnesses, including cancer, neurological disorders, and respiratory conditions. Radioactive emissions from nuclear weapons testing and the use of depleted uranium in ammunition result in lasting health problems such as genetic mutations and kidney failure. Additionally, activities like armament testing and large-scale military training contribute to ecosystem disruption and the release of hazardous substances, further amplifying the ecological and human health crises associated with military actions.

Military logistics, including the transportation of equipment and construction of temporary and permanent facilities, add to the strain on the environment by degrading soil, water, and natural habitats. These diverse and interconnected impacts emphasize the necessity of an integrated strategy for remediation to address soil, water, and air contamination while safeguarding public health and restoring affected ecosystems.

Problems of environmental contamination resulting from military activities, as well as integrated mechanisms for remediation of the territory, will be addressed in the present research paper. However, military activities, apart from the negative consideration described above, result in much broader consequences, including genocide, ecocide, and urbicide.

Consequently, the recent events currently occurring in the world and in Ukraine enhance the relevance of the present research. In the context of the above, an analysis of historical data is deemed appropriate.

Thus, in the book J. Cummins "Why Some Wars Never End: The Stories of the Longest Conflicts in History", Swiss scholar J.-J. Babel cites a calculation stating that mankind has experienced only 292 years of peace over 5,500 years of the documented history. Wars, despite their apparent completeness, continue to be an enduring phenomenon, and multi-generational conflicts constitute complex historical processes involving multiple factors and consequences. In his book, J.-J. Babel studies such conflicts with special concern for their origins and pivotal episodes, as well as analyses the causes for their continuity and residual effects [2].

Periods of absolute peace amount to merely around 300 years in the entire history of the mankind. In accordance with Brockhaus and Ephron Encyclopaedia, the history of nations is presented in the form of a continuous war, where periods of peace are only temporary truces based on fear and distrust rather than on fraternal love and mutual trust [3].

One of the key factors underlying the relevance and significance of this research is that contemporary military conflicts introduce new types of contaminants and their combinations, which exacerbate their impact on ecosystems and biocenoses while also posing serious health risks to populations, including genetic health. In the 20th century, most scientific studies focused on eliminating specific pollutants

associated with particular types of military activities. However, the global community now faces the increasing complexity of military conflicts and the consequent need to shift paradigms in managing their aftermath and recovery processes.

Summarizing the above, it can be concluded that military activities in the early 21st century have undergone radical changes, resulting in the emergence of new types of contamination. This has significantly complicated the processes of remediating contaminated territories. Contemporary contaminants, such as nanomaterials, advanced chemical and biological agents, require the development of new methods and approaches for remediation. Undoubtedly, the growing complexity of military operations' impacts on ecosystems and human health demands a comprehensive approach encompassing technological innovations, international cooperation, and socio-economic measures. Effective remediation of military contamination is only possible through a systemic approach involving active participation from all stakeholders.

Delving deeper into the theoretical understanding of remediation as a scientific concept, it is worth noting that current scientific literature primarily focuses on narrowly defined studies, such as soil restoration or water remediation. There are also studies dedicated to remediating environments following specific large-scale military actions. However, the authors believe that military conflicts and their associated ecological catastrophes (as in the case of the Kakhovka Hydroelectric Power Plant dam destruction) act as catalysts for advancing comprehensive scientific research and development in the remediation field. The urgency of addressing complex environmental problems stimulates the application of unconventional approaches, as well as the development of technologies and innovations aimed at environmental protection and restoration. Moreover, the emergence of new contaminants and the increasing complexity of pollution require constant adaptation to conditions of uncertainty, as well as constraints in time and resources. Consequently, remediation strategies must become more comprehensive and interdisciplinary, uniting the efforts of economists, managers, engineers, ecologists, and safety experts. This integration is where the effectiveness and viability of management decision-making mechanisms at all levels of the territorial socio-economic system's hierarchy are realized.

The considerations outlined above underpin the hypothesis of this study: the nature of modern warfare manifests in the increasing complexity of technological and technical approaches to its conduct, ultimately influencing its consequences, including those for the environment and societal well-being in specific territories. Thus, the remediation of a particular socio-economic system (e.g., Ukraine) is inherently multi-level and multi-vector, with its effectiveness directly dependent on the functionality of management mechanisms at the macro, meso, and micro levels.

8.3 Comparative analysis of methodological approaches to the study of military contamination remediation

In the broadest accepted sense, comparative analysis (lat. *comparativus* – comparative) is the study of different objects or phenomena through comparison. It is employed across various fields of knowledge, helping to identify similarities and differences, uncover patterns, and develop universal approaches to addressing scientific challenges. Below, let's present an in-depth analysis of the methodological model architecture for remediation, viewed as a set of methods constituting its "core", along with complementary scientific methods and techniques suitable for solving specific tasks. It is possible to provide a general characterization, features, and applications in the context of the issues under investigation in remediation.

According to the authors, the "core" of the methodological model should primarily include an integrated and systemic approach. The integrated approach views the elimination of military contamination and subsequent remediation as interconnected tasks within a unified algorithm for restoring war-affected territories. This approach enables the identification of cause-and-effect relationships between actions and their outcomes, ensuring the adoption of well-founded, comprehensive solutions.

The systemic approach is essential due to the multi-component nature of military contamination. Territorial systems, as open systems, are influenced by both internal and external factors. Military activities disrupt these systems, destabilizing their functions. The systemic approach examines how changes in one subsystem affect others, allowing for consistent and coordinated decision-making at all levels of management.

The synergetic scientific approach examines the interactions of various factors and methods (in our case, traditional remediation methods and "green remediation" techniques) that collectively yield a greater effect than their individual application. In the context of remediation, the synergetic approach allows for identifying the most optimal combinations of methods that will best restore the ecosystem and provide impetus for the sustainable development of the territorial socio-economic system.

The adaptive approach emphasizes the dynamic nature of ecosystems and socio-economic systems, constantly influenced by anthropogenic factors. At the core of the adaptive approach lies the principle of continuous monitoring, analysis, and adjustment of management decisions and actions depending on changing situations, weather conditions, resource availability, and new incoming information. Hence, remediation approaches must be adaptive, enabling responses to emerging challenges as they arise.

The optimization approach in military contamination remediation involves applying mathematical methods and algorithms to find the best solutions for cleaning and restoring territories, considering multiple factors such as environmental, economic, and social aspects. Adaptive monitoring and management models are particularly considered by the authors for their application in adjusting strategic and tactical management decisions as new data on the contaminated territory's state become available.

This study explores the potential of the agent-oriented approach for identifying optimal remediation solutions. Agent-Oriented Modelling (AOM), a type of simulation modelling, operates at the micro-level (e.g., local territorial systems) by simulating system functionality through agents with unique attributes. This allows for the study of interactions within the system and the establishment of connections between micro- and macro-levels. A key advantage of AOM is its ability to closely replicate real-world systems. In socio-economic models, aggregated agents typically represent industries or regions [4, 5].

Scientific literature highlights AOM's extensive application in environmental studies and resource management, particularly for simulating ecosystems, managing resources, and analyzing pollution impacts. While many studies address socio-environmental management using AOM, its application in military contamination remediation remains limited [6–10]. The authors argue that employing AOM in this context holds significant potential to enhance the efficiency and effectiveness of remediation efforts.

Among relatively new yet well-established approaches, Agile stands out as highly suitable for achieving the goals of crisis management and rapid response (in our case, managing remediation efforts). The Agile methodology was introduced in 2001 when 17 software development professionals gathered in Utah, USA, to discuss and formulate the "Agile Manifesto". Dissatisfied with rigid traditional approaches like the waterfall model, the group proposed Agile, which is distinguished by its flexibility, ability to adapt to changes quickly, client orientation (in this case, stakeholders in remediation), and continuous improvement. These features make Agile indispensable for projects requiring flexibility, adaptability, and the ability to respond rapidly to changes, which is ideal for crisis management projects like the remediation of water resources in the Kherson region (**Fig. 8.1**).

Its "core" consists of a set of key scientific methodological approaches – seven methods: Agent-Oriented Modelling, the Agile Approach, the Systemic Approach, the Comprehensive Approach, the Synergetic Approach, the Adaptive Approach, and the Optimization Approach. The "periphery" of the methodological framework includes a collection of auxiliary, complementary, and specific research methods designed for scientific analysis and addressing particular problems and issues (12 methods).

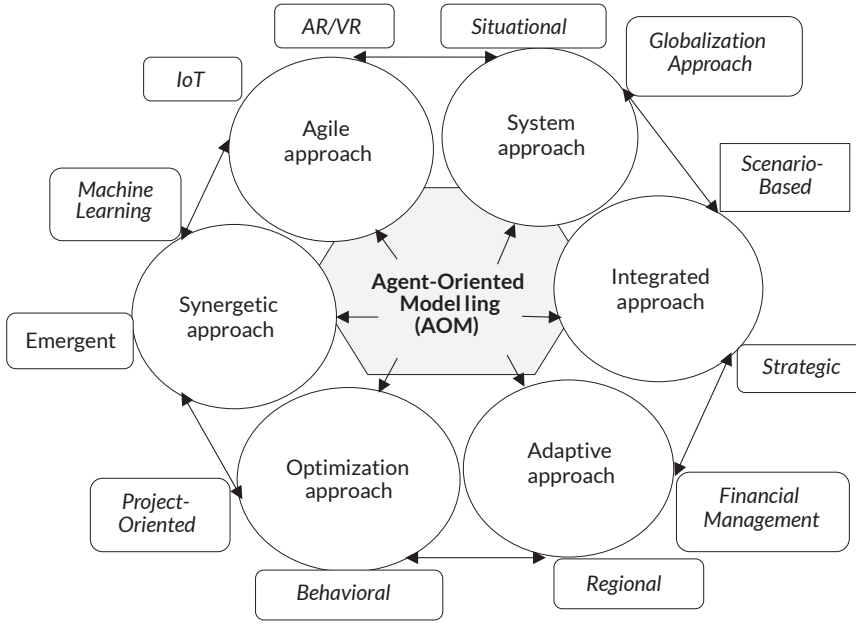

Fig. 8.1 Conceptual methodological model for managing the remediation of contaminated territories based on the agent-oriented approach

8.4 Project of a simulation-based agent-oriented model for remediation of water resources in the Kherson region

The inspiring impetus for developing a project on the remediation of water resources in the Kherson region based on agent-oriented modelling was a scientific study by E. Z. Berglund from North Carolina State University [11]. The author adheres to the idea that the concept of analyzing and understanding systems as complex emergent characteristics of adaptive structural elements offers a new and potentially revolutionary paradigm for a wide range of scientific disciplines. The nature of complex adaptive systems lies in studying their structures, composed of numerous active and interactive elements or actors (individual agents) with diverse capabilities and forms, which possess the ability to adapt through interaction with each other and the environment. The author's research focuses on agent-oriented modelling of such systems, which allows for designing the behavior of various agents and

environments and then experimentally determining the type of complex dynamics that would be optimal for process management.

The second most significant contribution to the formation of our conceptual framework was the publication by a team of scholars titled "Application of agent-based models as a powerful tool in water resource management". The authors highlight that human intervention often amplifies the complexity of water resource systems. In the context of military activities in Ukraine, these challenges become even more critical. Agent-Based Models (ABM) are recognized for effectively modelling complex systems, particularly water resources, by simulating the interactions of autonomous agents, such as agricultural, industrial, and domestic water users, as well as entities managing water resources. These agents, equipped with unique historical memory, interact with each other and their environment, collectively shaping the system's complexity. ABM provides realistic simulations, enabling policymakers at all levels to better understand the outcomes of their decisions, implement bottom-up approaches, devise effective strategies, and identify potential risks and consequences [12, 13].

A review of other authors' publications has further convinced us of the validity of this approach. Specifically, a study by a group of authors on developing the local water supply market using a multi-agent modelling approach was particularly useful in identifying key agents in the territory following the implementation of comprehensive remediation measures [14]. Another publication by a team of authors on data mining methods for water science modelling inspired us to explore the potential applications of advanced technologies such as AI, GIS technologies, drones, and robots in the remediation processes of contaminated territories [15].

In our opinion, after the conclusion of active military actions in Ukraine, particularly in its southern part – the Kherson region –a pressing need will arise to prioritize the restoration of water resources. Given the region's predominantly agricultural specialization, this necessity is primarily linked to the revival of economic activities. Before Russia's military aggression, the region had nearly 2 million hectares of agricultural land, Ukraine's largest area of arable land.

The "Kherson Chamber of Commerce and Industry" highlights the region's strategic location at the crossroads of transport routes in the lower Dnipro, with access to the Black and Azov Seas, favorable climate, and rich human resources, providing vast opportunities for trade, economic development, and investment. The region, situated on both banks of the Dnipro – the largest waterway in Ukraine – features 19 rivers, the Black and Azov Seas, the Kakhovka Reservoir, and Europe's largest irrigation system spanning 400 hectares [17]. The destruction of the Kakhovka Hydroelectric Dam and the near drying-up of the North Crimean Canal during the war already require reflection not only on the consequences for the ecosystem but

also on the restoration of the socio-economic system [18]. In our view, it is imperative for the highest levels of state governance to initiate the search for optimal methods and the implementation of effective projects for the remediation of water resources in the Kherson region.

8.4.1 Project baseline data for remediation

The Kakhovka Hydroelectric Power Plant (HPP), named after P. S. Neporozhny, was located in southern Ukraine, 5 kilometers from the city of Nova Kakhovka in the Kherson region, on the Dnipro River. Its capacity was 334.8 MW.

The construction of the Kakhovka dam and hydroelectric station took four years, from 1950 to 1956. The dam complex rose 30 meters high, spanned 3.84 kilometers in length, and included both automobile and railway crossings. The construction required substantial investments and the relocation of approximately 50,000 people. Together, the Dnipro cascade of dams provided water supply for domestic, industrial, and irrigation purposes across more than half of Ukraine's territory, serving approximately 35 million people, including water-scarce regions such as Donbas, Kryvyi Rih, southern Ukraine, and, until 2014, Crimea [18–22].

The Kakhovka dam retained the waters of the expansive Kakhovka Reservoir, which performed multiple functions: supplying water to the hydroelectric power plant, industrial enterprises, and freshwater fish farms; protecting against floods; and supporting the Krasnoznamenka and Kakhovska irrigation systems as well as the Dnipro-Kryvyi Rih and North Crimean canals. Additionally, the reservoir created a deep-water route that allowed maritime vessels to travel upstream along the Dnipro. The outflow of the Kakhovka Reservoir was regulated seasonally and annually, with a standard headwater level of 16 meters.

On June 6, 2023, Russian forces destroyed the Kakhovka HPP. The station's turbines and generators were also blown up along with the dam. The resulting torrent swept away everything in its path, flooding several downstream towns and destroying residential, industrial, and commercial structures. The hydrological consequences of this event had to be assessed using numerous hydrodynamic models and satellite image analyses, as illustrated in **Fig. 8.2**.

As a result of the disaster, the water level also rose in the Inhulets River, a tributary of the Dnipro that flows from north to south and joins the Dnipro just upstream of Kherson, as clearly illustrated in the provided figure. As of June 9, 2023, approximately 620 km^2 of land within the analyzed satellite area of 19,000 km^2 were flooded according to hydrological analysis [20].

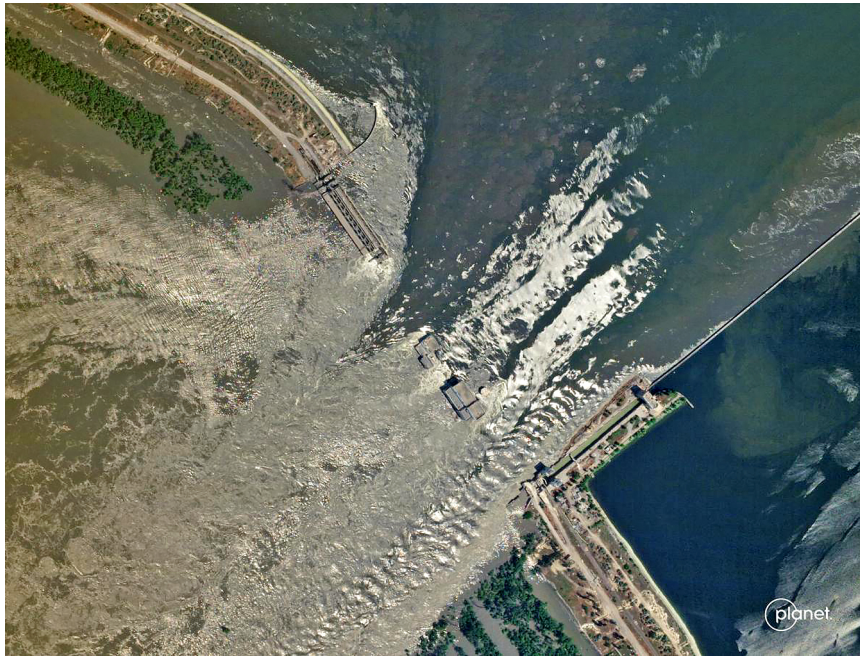

Fig. 8.2 Satellite image of the breached Kakhovka Dam
Source: [19]

These findings were further corroborated by the Ministry of Environmental Protection and Natural Resources of Ukraine, which estimated that the total flooded area during the peak flooding period exceeded 630 km^2 [19]. The decline in water levels was recorded by UNOSAT satellites between July 3 and July 5, 2023, when the flooded area decreased to approximately 40 km^2 [20].

The above map illustrates the satellite-detected flooding extending 90 km downstream of the damaged Kakhovka Dam wall to the Dnipro's mouth in the Rybalsche area of Kherson region, Ukraine. This was captured in ICEYE images acquired on June 7, 2023, at 12:18 UTC, 12:48 UTC, and 13:01 UTC [20] (**Fig. 8.3**).

A more in-depth analytical overview of this situation is presented in **Table 8.1**.

The primary purpose of creating the Kakhovka Reservoir was to provide irrigation water for the adjacent agricultural areas. Additionally, it served as an important source of drinking water, while energy production was secondary but still significant. Since its primary objective was to supply irrigation and drinking water, it can be

assumed that potential contamination in the flooded area was not primarily caused by the reservoir water itself. However, as the terminal reservoir in the cascade, the Kakhovka Reservoir accumulated substantial runoff containing pollutants. As a result, the concentration of heavy metals in both water and bottom sediments was generally higher than in other reservoirs, such as the Kyiv Reservoir, which is less affected by negative impacts from surrounding territories [21].

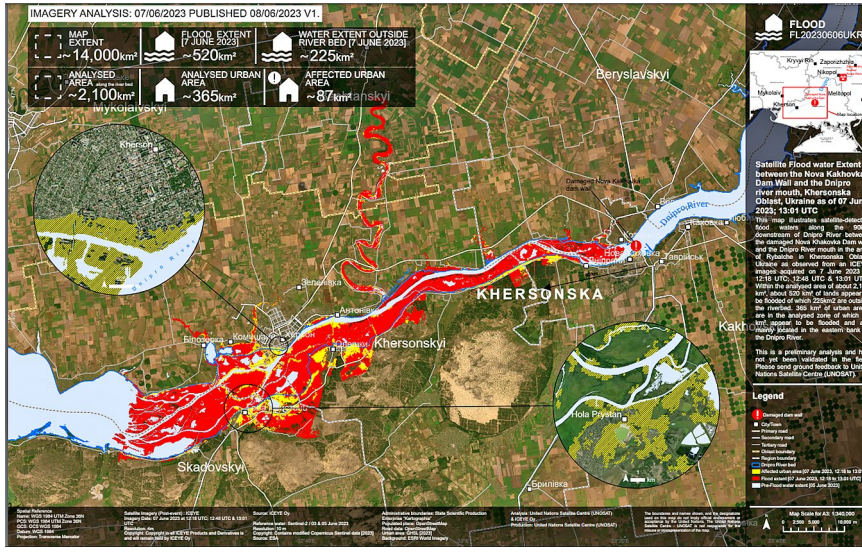

Fig. 8.3 Satellite Flood water Extent between the Kakhovka Dam Wall and the Dnipro river mouth, Kherson region
Source: [20]

Monitoring data from the Dnipro River, provided by the State Agency of Water Resources of Ukraine following the dam breach, indicate that overall ecological water quality met most criteria without exceeding regulatory limits [19].

The dam breach was a disaster for the aquatic flora and fauna, including marine species. According to national authorities, tens of thousands of tons of fish, including commercial species, were affected, with the majority lost due to the drying of the Kakhovka Reservoir. The Ukrainian government confirmed the loss of 11,388 tons of fish. As the breach occurred during the spawning period, it had a negative impact on the fishing industry in subsequent seasons [18].

Table 8.1 Assessment of flooding consequences following the destruction of the Kakhovka hydroelectric power plant

Oblast / Region / Hromada	Total analysed zone, km²	Total water extent observed, km²	Flood extent, km²	Water extent outside river bed, km²	Total urbanarea in analysed zone, km²	Affected urban area, km²
Khersonska	***1 828***	***675***	***499***	***200***	***345***	***85***
Beryslavskyi	***208***	***38***	***26***	***9***	***17***	***2***
Beryslavska	11	–	26	–	–	–
Tiahynska	197	38	–	9	16	2
Kakhovskyi	***183***	***37***	***22***	***11***	***55***	***7***
Kakhovska	19	–	–	–	4	–
Novokakhovska	151	37	22	11	42	7
Tavriiska	13	–	–	–	8	–
Khersonskyi	***1 104***	***413***	***317***	***124***	***219***	***54***
Bilozerska	133	65	42	5	17	3
Chornobaivska	24	1	1	1	9	–
Darivska	258	45	31	28	31	3
Khersonska	346	139	99	20	118	24
Muzykivska	9	–	–	–	2	–
Oleshkivska	292	160	143	69	42	23
Stanislavska	42	4	1	1	–	–
Skadovskyi	***333***	***187***	***134***	***56***	***55***	***23***
Chulakivska	80	10	5	3	6	1
Holoprystanska	253	177	130	53	49	22
Mykolaivska	***270***	***24***	***22***	***24***	***20***	***1***
Bashtanskyi	***270***	***24***	***22***	***24***	***20***	***1***
Horokhivska	164	15	13	15	13	1
Snihurivska	107	9	9	9	8	–
Total	**2 098**	**700**	**521**	**224**	**365**	**87**

Source: [20]

The spread of chemicals associated with the incident primarily originated from two sources: discharges from industrial facilities and infrastructure located in flooded zones and/or the migration of potentially contaminated sediments from the reservoir. The highest concentration of pollution occurred downstream from the breach site, where pollutants and sediments were transported. A list of chemical hazard hotspots was compiled by merging data from CEOBS, Ecodozor, and Reach, followed by cross-verification of object names and locations. According to this data, primary remediation should focus on the following:

1) cleaning facilities outside the flood zone (21 facilities);

2) cleaning damaged infrastructure and communications, such as bridges (56 facilities);

3) dismantling and initial remediation of specific facilities by type, size, and location, prioritizing small-scale objects such as kiosks, stalls, and garages, as well as:

– cemeteries (19 facilities);
– agricultural/livestock facilities (17 facilities);
– construction sites (28 facilities);
– stores/markets (7 facilities);
– ports[1] (2 facilities);
– small and medium enterprises (71 facilities);
– transportation enterprises (5 facilities);
– waste sites (5 facilities);
– other (1 facility) [18].

Although it is currently impossible to fully assess the environmental, economic, and social consequences of the Kakhovka HPP destruction, analytical evaluations of the damage indicate that it is both extensive and multifaceted (**Fig. 8.4**).

At present, it is not possible to determine which types of damage are irreversible and which can be at least partially mitigated through post-incident recovery measures and a comprehensive set of remediation efforts. It is evident that the choice of effective remediation methods (or a combination of selected methods) and the implemented model for managing the remediation process of the affected territory will primarily determine the final outcome [18, 21, 22].

Nevertheless, it can already be stated with full confidence that the objective assessment of the consequences and the full scale of the disaster will only become clear in decades to come.

The goal of the project is to develop and propose a decision-making system based on an agent-oriented model for managing the remediation of water resources in the

[1] *Companies handling chemicals, as well as oil and fuel storage facilities located within port areas, are still included*

Kherson region. The proposed decision-making system will be integrated with advanced IT technologies and will account for various scenarios of identifying and selecting optimal remediation measures for cleaning water resources and addressing military contamination. The optimization of resource management and the effective coordination of actions among all project participants will be implemented using the Agile approach.

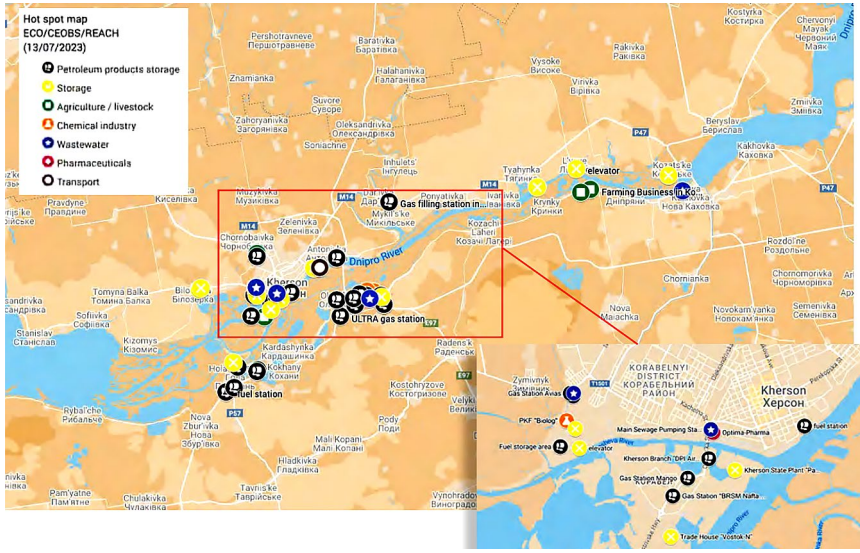

Fig. 8.4 Cartographic overview of 54 selected objects subject to primary remediation
Source: [18]

8.4.2 AOM model: identification of key agents and verification of their roles

One of the initial stages of agent-oriented modelling is the identification of key stakeholders, referred to as "agents". Each agent plays a specific role and contributes to the decision-making process (adjustments to tactical or operational decisions, as noted by the authors) within the framework of remediation activities and the effective allocation of water resources.

Six main groups of stakeholders are identified within the agent-oriented model, who will directly or indirectly influence the decision-making system (**Table 8.2**).

Table 8.2 Characteristics of key agents – stakeholders in the water resource remediation project for the Kherson region

Agent Group	Role in the Project	Significance
Agricultural business entities and farmers	Primary water consumers for agricultural land irrigation	Agricultural business entities and farmers play a key role in ensuring food security in the Kherson region, as the region's primary specialization is agro-industrial production. Their water needs significantly influence the overall allocation of water resources
Public utilities	Providing the population with clean drinking water and maintaining water supply and wastewater infrastructure	Public utilities are responsible for the health and well-being of the population, ensuring access to safe drinking water and proper sanitation
Government authorities	Government authorities regulate and coordinate remediation processes and the distribution of water resources	Government authorities develop regulatory acts that ensure the implementation and oversight of strategic remediation tasks, as well as mediate interests and resolve conflicts among various water users
Local self-government bodies	Local self-government bodies coordinate and implement remediation programs at the community level	Local self-government bodies ensure direct interaction with public utilities, contractors, and the local population, taking into account local needs and challenges while also facilitating the participation of public organizations and other stakeholders in remediation processes
Investors	Participation in project financing through financial and/or tangible investments; provision of equipment and machinery, and the implementation of advanced technologies and engineering solutions for remediation and water resource management	Domestic and international investors bring capital to the recovery and further development of war-affected territories, as well as expertise, which facilitates the acceleration and improvement of remediation processes, the introduction of new engineering solutions and technologies, and the implementation of advanced water resource management methods
Contractors for remediation work	Direct implementation of remediation processes and operations: elimination of military contamination, cleanup and restoration work, waste transportation, and other related activities	Contractor firms ensure the direct execution of remediation project tasks as well as the restoration of water supply and distribution systems

Implementation of agents in the Agent-Oriented Model:

1. *Description of identified agent groups*. Each agent i in the system can be described by the following characteristics:

– the agent's state $S_i(t)$ at a given time t;

– a set of behavioral rules R_i;

– the agent's location in the environment $P_i(t)$.

2. *Modelling the integration of agents into the environment*. The agent implementation environment is represented as a two-dimensional or three-dimensional space in which identified agent groups can move and interact. The 2D or 3D space can be divided into cells, each characterized by parameters $E_j(t)$, such as the level of resource contamination.

3. *Interaction among identified agent groups*. Interactions between the project's key agents can be described by a function $I_{ij}(t)$, which depends on their location and behavior at a given time:

$$I_{ij}(t) = f(S_i(t), S_j(t), P_i(t), P_j(t)). \tag{8.1}$$

4. *Behavioral changes during decision-making*. Agents' behavior changes over time in accordance with their rules of behavior and interactions with other agents involved in the remediation project:

$$S_i(t+1) = g(S_i(t), \sum jI_{ij}(t), E_j(t)). \tag{8.2}$$

5. *Integration of various stakeholders into the Agent-Oriented Model*. Integrating different agents into the agent-oriented model of water resource remediation ensures a comprehensive approach to water management and distribution. Each stakeholder contributes to the process, enabling the consideration of diverse interests and achieving more effective solutions.

6. *Modelling the remediation process*. Behavioral rules for the various agent groups, based on designed and implemented algorithms for each type of agent, optimize management and coordination of the territory's restoration process. For instance, agents directly implementing water resource remediation operations can follow specific algorithms for interacting with other agent groups according to routes and locations of primary or emergency remediation of contaminated areas. Meanwhile, the local population reacts to these activities and makes its own decisions in response.

7. *Analysis and evaluation of results*. The effectiveness of implementing the Agent-Oriented Model for water resource remediation in the Kherson region can be assessed using a set of parameters and indicators, including the efficiency

of management processes, interaction among participants, and resource utilization (e.g., financial, material, and labor resources) relative to the time and degree of task completion.

8. *Optimization.* Conducting a series of simulations during the early stages of project implementation can identify additional opportunities to improve the proposed model. This involves exploring the most promising integrations with advanced technologies, such as drones, robotics, GIS, and satellite systems. These integrations significantly enhance the overall effectiveness of strategies for remediation and monitoring, enabling efficient operational and tactical management of both remediation activities and social responses, as well as identifying optimal cleaning routes and methods [23].

9. *Technological advancements in Agent-Oriented Modelling.* The authors argue that modern technological advancements significantly expand the capabilities of agent-based modelling in the context of territory remediation. Robotics, artificial intelligence, GIS, drones, autonomous vehicles, recognition technologies, and others make the proposed model more precise, adaptive, and effective. Selective and comprehensive integration of these technologies enables the achievement of maximum results under time and resource constraints.

10. *Proposal for decision-making and implementation.* To support the adoption of the model presented in this monograph and its implementation, the authors propose an analysis of the integration of modern technologies into agent-based modelling of territory remediation, considering their functional roles and interactions within the system (**Table 8.3**).

Table 8.3 Implementation of modern IT technologies and IoT solutions in AOM

Implementation in the project	Functional roles and interaction within the decision-making system	Expanding agent-based modelling capabilities
1	2	3
Implementation of robotic technology		
Robots-agents, behavioral models, sensors, and actuators	Defining the types of robots required for the project based on the complexity and scale of remediation tasks they will perform (e.g., robots for drilling, transporting contaminated soil, or monitoring water quality)	Developing robotic behavioral models that include movement algorithms and interaction protocols with other agents during remediation tasks. Integrating data transmitted by robot sensors (e.g., pollution detectors) into the model for more precise monitoring and effective decision-making

Continuation of Table 8.3

1	2	3
	GIS and satellite technologies	
Territorial modelling of remediation work, real-time monitoring, spatial analysis	Using GIS data to create more accurate territorial models as close to reality as possible	Enhancing real-time monitoring capabilities based on updated satellite data, thereby expanding the potential for rapid response and adjustments to strategies and plans for water resource remediation implementation
	The use of drones	
Monitoring drones, spraying drones, delivery drones, analytical drones	Identifying the types of drones required for the project based on the tasks they can perform in remediation work (e.g., for collecting aerial imagery and data on territorial conditions, delivering equipment to hard-to-reach areas)	Used for collecting soil, water, or air samples in high-contamination zones; can also be employed for one-time spraying of chemicals or biopreparations on polluted areas to neutralize contamination or restore the ecosystem, as well as for monitoring emergency situations. Integrating data collected by drones into the project's agent-based model to reduce time and resource costs and minimize risks
	Neural Networks, ML and Artificial Intelligence	
Intelligent agents, decision optimization, forecasting, and remediation scenario analysis (simulation of scenarios)	Incorporation into the project's integrated model with machine learning capabilities to analyze incoming data and adapt agent behavior for effective territorial remediation management	Optimization of remediation management decisions at macro, meso, and local levels, enabling forecasting of force majeure situations, assessment of selected remediation methods and strategies, risk minimization, and overall project efficiency enhancement

8.4.3 Project management model based on the implementation of the Agile approach

Effective project management at various stages of its implementation requires specific skills in using specialized tools and management methods to accomplish tasks such as planning, organizing remediation activities, monitoring the implementation of project objectives, and evaluating intermediate and final results to allow for adjustments and/or alternative replacements if necessary. It is crucial to clearly define goals, tasks, and roles, as well as to establish effective communication and

control mechanisms to ensure the successful achievement of objectives. A project management algorithm is developed that outlines goals, key actions, and tools to maximize efficiency (**Table 8.4**).

Table 8.4 Project management algorithm by implementation stages

Goals	Key actions	Tools
1	2	3
Stage 1. Project initiation		
– defining the project's goals and objectives; – verifying stakeholders and key agent groups in the project; – developing a concept of tactical and strategic project goals, substantiating benefits for key participants	– diagnosing the situation, assessing key needs and challenges; – developing the project business plan; – forming the project team and assigning roles to working group leaders and executors; – defining the main stages and timelines for project implementation	– business plan; – SWOT analysis; – stakeholder diagrams; – project management platforms (e.g., Microsoft Project, Trello, Asana)
Stage 2. Planning		
– developing a detailed project plan, including an organizational plan, financial plan, and material and technical support plan; – identifying necessary resources and sources for their provision/expense coverage; – developing a risk management plan	– creating a detailed project schedule (Gantt Chart); – prioritizing tasks and subtasks; – analyzing and comparing resources and costs; – developing and organizing a communication system for receiving feedback from the team and key agents	– Gantt chart; – Critical Path Method (CPM); – risk management plan; – architecture-oriented agent-based interaction scheme for project participants
Stage 3. Implementation		
– evaluation and selection of the optimal scenario and action plan for project task implementation; – coordination and management of the project working groups' activities; – information and resource support for task execution	– allocation of tasks by responsibility centers, priorities, deadlines, and resource capabilities, and management of their implementation; – monitoring task progress, operational and final control over task execution; – ensuring effective team communication; – operational plan adjustments, adaptation, and change management	– task management platforms (e.g., Jira, Monday.com); – time management tools (e.g., Toggl); – document management systems (e.g., Google Drive, SharePoint); – communication and connectivity tools

Continuation of Table 8.4

1	2	3
Stage 4. Monitoring and control		
– interim evaluation of project task implementation; – identification and management of issues and risks; – oversight of project plan and budget compliance	– regular collection and analysis of aggregated information on task progress; – presentation and discussion of project status reports based on "milestone" dates; – conducting operational meetings during project implementation; – verification of "bottlenecks" in project execution; – quality control of completed remediation work	– monitoring and reporting tools (e.g., Microsoft Power BI, Tableau); – Earned Value Management (EVM) method; – control reports and checklists
Stage 5. Completion and evaluation		
– completion of project tasks; – evaluation of results and expectations of stakeholders and project partners; – audit and summarization of the project, with the transfer of results to stakeholders	– auditing results and providing a final overall evaluation of project task completion; – preparing reports and transferring the relevant documentation; – organizing a presentation of project results for stakeholders, partners, and the public; – conducting a project closure analysis (Lessons Learned)	– final project report; – surveys for feedback collection from the team and stakeholders; – tools for project closure analysis (e.g., Post-Project Review)

Our position is that an unconventional approach to implementing water resource remediation measures in Kherson region should be based on a modern and non-traditional management framework – specifically, the Agile methodology. As previously mentioned, it is possible to consider Agile to be a promising and highly effective approach for managing crisis operations, responding to constantly changing conditions during remediation activities, addressing the dynamic ecosystem situation influenced by weather and other factors, as well as ensuring operational team management and continuous communication to make effective decisions [16].

The rationale for adopting this approach is as follows:

1. *Flexibility over rigidity:* Agile allows for constant plan revisions and adaptations, in contrast to traditional methods. This flexibility is crucial in the context of uncertainty surrounding remediation activities, the coordinated actions of agents, and rapidly changing situations.

2. *Focus on people and their interactions:* Agile has proven highly effective in managing a large number of participants (as in our case – specific remediation activities conducted over a large area with numerous agent groups). It is particularly effective in complex coordination systems, facilitating decision-making processes and ensuring transparency and involvement of all stakeholders.

3. *Reduction of bureaucratic burden:* projects of this nature are typically associated with extensive documentation processes, including preparation, approval at various levels, and ongoing management of documentation throughout the hierarchy, culminating in reporting. Traditional approaches often require significant resources to manage this aspect. Agile, in contrast, reduces bureaucratic barriers, focusing on tangible results and progress [24].

In our case, the project is divided into short cycles (or sprints), each concluding with a review of interim results. This allows for testing and implementing partial solutions (e.g., applying alternative remediation methods or replacing technical equipment), assessing their impact, and making real-time adjustments. This substantially increases the likelihood of success under complex and uncertain conditions. Tools like Jira and Asana help organize collaborative efforts among all project teams and stakeholders. Regular meetings allow for the identification of bottlenecks, discussion of potential problems, and exploration of solutions. Monitoring tools such as Power BI and Tableau provide visualizations of results and progress in cleaning and restoring the territory. These tools facilitate the evaluation of project task performance, effective risk management, and problem resolution.

Thus, the modified agent-based model for managing water resource remediation in Kherson region can be presented as a dynamic system in which agents interact with each other and external phenomena, making decisions based on localized information (**Table 8.5**). The integration of IT technologies, the Internet of Things (IoT), and machine learning (ML) significantly simplifies process management within this system, while the use of Agile enhances adaptability to changes and increases project management flexibility.

Table 8.5 Structure of the modified integrated AOM

Elements of the generalized AOM	Description
1	2
1. General variables of the mediation mana gement system	$W(t)$ – the total volume of water available for safe use at time t. $Z_i(t)$ – the contamination level of water resources at time t, specific to contaminant type i.

Continuation of Table 8.5

1	2
	$R(t)$ – the volume of water entering the system from natural or artificial sources (e.g., rainfall or resources purified through remediation systems). $L(t)$ – the volume of water lost due to infrastructure damage, leaks, or other inefficiencies. $P_i(t)$ – the consumption priority of agent i at a specific time t. $U_i(t)$ – the economic benefit derived from water consumption by agent i, where i represents key agents (e.g., agricultural entities, contractors, or public utilities). $C(t)$ – the volume of water purified using various remediation methods. $ML(t)$ – the machine learning model used to optimize water distribution based on real-time data and predictive analytics. $IoT(t)$ – data collected from sensors, drones, and monitoring devices, providing aggregated information on contamination levels and overall conditions in real time
2. Behavior of agents	*The economic utility function for agent water consumption.* Each agent i (e.g., agribusiness entities, farmers, utilities, contractors, etc.) seeks to maximize their utility $U_i(t)$, which depends on the volume of water allocated $W_i(t)$ and other factors, such as overall contamination levels $Z_i(t)$: $U_i(t) = f(W_i(t), Z_i(t), P_i(t))$, where $W_i(t)$ – the volume of water received by agent i at time t; $Z_i(t)$ – the contamination level of the i-th contaminant, which can reduce the utility of each agent; $P_i(t)$ – the priority level of water consumption assigned to agent i, determined by government authorities or automated systems based on ML algorithms. *The water demand function for each agent i is described as:* $W_i(t) = f(N_i(t), A_i(t), weather(t), IoT(t))$, where $N_i(t)$ – the number of users/area served by agent i (e.g., the size of the farm); $A_i(t)$ – the activity level of agent i (e.g., the area of cultivated land); $weather(t)$ – climatic conditions affecting water needs (e.g., drought or precipitation); $IoT(t)$ – real-time data collected from IoT sensors, which provide a more accurate assessment of water requirements
3. Distribution of water among agents	The distribution of the total water volume $W(t)$ among agents during each remediation time period is determined using an ML model that incorporates various factors: consumption priorities, the pollution level by contaminant type i, and water demand based on real-time IoT data. The volume of water allocated to a specific agent i is determined as: $W_i(t) = ML(t, P_i(t), W_i(t), Z_i(t), IoT(t))$, where $ML(t)$ – machine learning, which optimizes water distribution based on data about needs, contamination, weather conditions, and other factors

Continuation of Table 8.5

1	2
4. Dynamics of water pollution	The level of water resource pollution Z from the i-th type of contaminants at a given time t – $Z_i(t)$ – changes over time based on remediation factors and territorial pollution sources: $Z_i(t+1) = Z_i(t) - C(t) + P_{industry}(t)$, where $C(t)$ – the volume of pollutants removed as a result of water treatment using applied remediation methods; $P_{industry}(t)$ – the level of pollution generated by industrial entities and other contamination sources (e.g., cemeteries, waste dumps, etc.)
5. Remediation of water resources	The volume of treated water $C(t)$ depends on the investment in purification technologies and the implementation of a set of remediation measures, as well as the decisions made through the application of the Agile approach: $C(t) = f(investment(t), technology(t), remediation\_team(t), feedback\_loop(t))$, where *investment*($t$) – the volume of investments in technologies, equipment, and materials for water remediation and purification; *technology*(t) – the effectiveness of implemented remediation technologies; *remediation_team*(t) – the efficiency of contractors and working groups executing the water resource remediation strategy; *feedback_loop*(t) – iterative improvements through the Agile approach, enabling rapid adaptation to changes during project implementation
6. Utilization of IT Technologies, IoT, and ML	*IoT.* The system utilizes sensors and drones for continuous monitoring of the territory's condition, water pollution levels, and water supply issues, transmitting data in real-time: $IoT(t) = \sum Sensor\ k(t)$, where *Sensor* $k(t)$ – data from each IoT sensor k installed in the contaminated area. *ML* (*Machine Learning*). A machine learning model integrated into the system utilizes IoT data to predict water needs, assess pollution levels, and optimize resource distribution: $ML(t) = f(historical\_data, IoT(t), weather(t), priorities(t))$. *Agile Approach.* The implementation of the Agile approach will significantly enhance the efficiency of managing the remediation process and adapt solutions based on feedback: – iterations: the remediation project is divided into short iterations, each of which includes hypothesis testing and adaptation of optimal solutions to the conditions of the remediation activities (e.g., transport and logistics capabilities, financial resources, technical feasibility, weather conditions, etc.);

Continuation of Table 8.5

1	2
	– feedback: at each stage of the project, aggregated feedback is collected from remediation task performers, the operational management team, and incoming IoT data to identify bottlenecks and make adjustments to subsequent actions: $New\_strategy(t+1) = Agile\_feedback(t)$
7. Generalized system equation	The complete equation of the system, incorporating all the aforementioned components, can be expressed as follows: $W(t+1) = W(t) + R(t) - \sum_{[i=1;N]} - L(t),$ $W(t) = ML(t, P_i(t), W(t), W_i^{demand}(t), Z(t), IoT(t)),$ $Z(t+1) = Z(t) - C(t) + P_{industry}(t),$ $C(t) = f(investment(t), technology(t), remediation\_team(t), feedback\_loop(t))$

For the successful implementation of the decision-making system project based on an agent-based model for managing the remediation of water resources in Kherson region, integrating IT technologies, the Internet of Things (IoT), machine learning (ML), and the Agile approach, specific equipment, software (SW), and technologies are required. Below is a summarized analytical table outlining the key parameters of the necessary equipment, software, their purpose, quantity, and estimated cost (**Table 8.6**).

Table 8.6 Assessment of required software and other resources for project implementation

Resource name	Name	Purpose	Quantity	Price range (thousand USD)
1	2	3	4	5
Software, including:				
Agent-Based Modeling (ABM)	AnyLogic/ NetLogo	Modeling the behavior of key agents and simulating potential scenarios for the remediation of water resources	1 license	100–200
Machine Learning (ML)	TensorFlow, PyTorch	Optimization of resource allocation and forecasting outcomes	1 license	0–50
Geographic Information Systems (GIS)	ArcGIS/ QGIS	Spatial analysis of the territory and data visualization	5 licenses	30–60

Continuation of Table 8.6

1	2	3	4	5
IoT platform	AWS IoT, Azure IoT	Management of data transmitted from sensors and drones	1 platform	40–70
Data analytics	SAS, Tableau	Analysis of collected data, visualization of project outcomes, presentation of remediation results	1 license	70–150
Tools for Agile management	Trello, Jira	Team management and coordination of remediation tasks implementation based on the Agile approach	5 licenses	1–10
Technical equipment, including:				
Servers	HPE/Dell	Processing ABM, GIS, and IoT data	10 servers	40–60
IoT sensors and detectors	Senix, Siemens	Monitoring of the situation, territory, and pollution levels; inspection and control of facilities	100 sensors	2.5–5
Drones	DJI Phantom, Parrot	Controlling the state of water resources, water supply facilities, and related infrastructure	10 drones	20–40
Systems for machine learning	NVIDIA GPU/TPU	Processing received data and training ML models	5 GPUs	20–50
Infrastructure software, including:				
Project management systems	Microsoft Project, Asana	Management of project remediation implementation and coordination of team actions	1 license	30–70
DevOps tools	Docker, Kubernetes	Automation of system deployment and updates	1 license	5–15
Communication tools and instruments:				
Communication tools and instruments for integrating the joint efforts of project participants	Microsoft Teams/ Slack	Team interaction, remote work of project participants, idea generation, collaborative work, communication with key agents	10 licenses	5–15
Total				**1,563–2,055**

The estimated total cost range for software (SW), technical, and infrastructure equipment, including communication tools for the effective implementation of the project, is approximately between 1,563 million and 2,055 million USD. This cost range accounts for potential price fluctuations in software and equipment, enabling more flexible budget planning for the project.

8.4.4 Determining the comprehensive efficiency of implementing the water resource remediation management project in Kherson region

The water resource remediation management project in Kherson region, based on an Agent-Based Model (ABM) integrated with IT technologies, the Internet of Things (IoT), Machine Learning (ML), and the Agile management approach, holds critical importance in addressing the aftermath of the destruction of the Kakhovka Hydroelectric Power Plant (HPP). This project is not only a vital step towards the region's recovery after the active phase of military actions but also opens new opportunities for sustainable water resource management in the post-war recovery context.

I. Environmental significance and efficiency of the project.

The destruction of the Kakhovka HPP resulted in severe environmental consequences, including water resource contamination, ecosystem destruction, and threats to the potable water supply for the region's population. Implementing the ABM-based project will:

1. Effectively model and manage the region's complex water resource system, including restoring irrigation channels for agricultural lands.
2. Optimize the cleaning process of contaminated water by integrating advanced purification technologies and scenario-based modelling.
3. Enable real-time monitoring of the ecological state of water bodies using IoT technologies, allowing for timely responses to changes.

II. Social significance and efficiency.

The region's population faces threats of water shortages for household needs and deteriorating drinking water quality. The proposed integrated remediation project will:

1. Ensure sustainable water distribution among the population, agricultural, and industrial consumers based on priorities and real-time water supply data.
2. Reduce social tensions through fair resource distribution, especially in conditions of scarcity, by leveraging machine learning algorithms and IoT data.
3. Improve access to clean drinking water for the population and municipal services by implementing advanced technologies and purification methods.

III. Economic significance and efficiency.

As an agrarian region, Kherson region heavily relies on water resources for agricultural production. The destruction of hydroelectric and irrigation infrastructure has severely affected the region's economy. Implementing the proposed project will:

1. Coordinate the restoration and modernization of water and irrigation systems, ensuring sustainable water supply for all economic actors and the population.

2. Optimize the rational use of water resources, minimizing losses and increasing efficiency through IT technologies and machine learning.

3. Attract domestic and foreign investors to innovation-oriented projects to restore war-affected areas, creating economic incentives for accelerated recovery and development of the region [30].

IV. Technological significance and efficiency.

The integration of IT technologies, IoT, and ML into water resource management elevates remediation efforts to a new level. The use of technologies will:

1. Automate data collection and processing, real-time monitoring, and analysis of water bodies, enhancing decision-making and crisis management responsiveness.

2. Utilize machine learning to predict water supply needs for various agents and scenarios based on implemented decisions, allowing for swift responses to critical changes in the situation.

3. Apply the Agile approach to manage the project team flexibly, enabling iterative implementation of solutions and quick adaptation to changes based on continuous communication and feedback from all project participants [28].

V. Managerial significance and efficiency of the Agile approach.

The use of the Agile approach in managing the water resource remediation project will:

1. Enable flexible project management through iterations and feedback, which is crucial in the constantly changing post-war environment.

2. Coordinate the actions of all project participants across all levels of the management hierarchy – from top-level government bodies, specialized agencies, and ministries to local municipal services and contractors – under a unified remediation management strategy.

3. Ensure transparency and prompt decision-making at every stage of project implementation, contributing to the more efficient use of all types of resources [29].

This comprehensive approach ensures that the project not only addresses the critical challenges of recovery but also lays the groundwork for the region's long-term development, enhancing its resilience to future crises.

Below, let's present a summarized table of the potential effects of implementing the developed project (**Table 8.7**).

Table 8.7 Potential effects of implementing the water resource remediation project in the Kherson region

Parameter	Forecast value/Expected effect
Environmental effect	Reduction in pollution levels by 70–90 % (depending on types of contaminants); restoration of biodiversity up to 80 % within 5 years
Social effect	100 % provision of drinking water for the population of the region and 80 % of economic entities within the first 3 years of project implementation
Economic effect	Total required amount of external loans, investments, and funding: from 150 to 200 million USD, allocated as follows: – 80 million USD for modernization of the water supply system (pipelines, pumping stations, filtration); – 50 million USD for restoration of irrigation systems and infrastructure; – 20 million USD for the development and implementation of IT solutions, IoT, and ML for water resource management; – 10 million USD for the introduction of monitoring systems, state oversight, and regulation in compliance with international standards
Technological effect	Reduction in water supply system management costs by 50 % through project implementation and application of advanced technologies; increase in forecasting accuracy for water demand up to 95 %
Managerial effect	80 % of project tasks are expected to be completed within the established timeframe; reduction in administrative expenses by 40 %

Source: compiled by the authors based on consultations with specialists [25–27]

The final stage of the study involves an analytical assessment of the anticipated benefits for key agents across critical parameters (**Table 8.8**).

For key agents, including government bodies, local authorities, and private sector stakeholders, the project provides a structured framework for collaboration, transparency, and achieving common goals. The expected benefits extend beyond immediate remediation, encompassing socio-economic recovery, infrastructure modernization, and the promotion of innovative ecosystems. Key stakeholders, such as agricultural businesses, local communities, and investors, stand to gain significantly from enhanced water access, improved agricultural productivity, and increased trust in governance. The project's focus on agile management ensures adaptability to changing conditions, fostering cooperation and accountability among all participants. Ultimately, the remediation of water resources in the Kherson region will serve as a catalyst for regional renewal, contributing to national economic growth and setting a benchmark for sustainable post-conflict recovery [30].

Table 8.8 Potential benefits and opportunities for key agents from project implementation on remediation

Environmental effect	Social effect	Economic effect	Technological effect	Managerial effect
1	2	3	4	5
Key agent: agricultural sector and farmers				
Reduction in water pollution and salinity levels through the remediation of water resources and modernization of the water supply system, improvement of irrigated lands, and ecosystem restoration	Stable access to clean water for irrigation will ensure the region's food security	Increased crop yields and reduced overall costs, including those associated with water use for agricultural activities	Implementation of advanced technologies, real-time monitoring systems, and predictive analytics	Enhanced management efficiency and strengthened coordination between key agents and water resource management authorities through Agile methods
Key agent: public utilities				
Improved water quality through the application of advanced purification methods and modernization of the water supply system, reducing the overall negative impact of pollution	Reliable and safe water supply for the local population	Reduced costs for water purification processes, decreased water losses, and increased efficiency of infrastructure for providing high-quality services	Integration of IoT sensors for real-time monitoring of water quality and network conditions	Optimization of water supply system management through digital platforms and predictive analytics
Key agent: government bodies				
Compliance with national and European environmental protection standards and principles of ecological safety	Increased public trust and satisfaction through effective management and protection of national water resources	Focusing on all potential opportunities to restore the most vital resource – water – as a national asset, fostering the post-war revival of the region and economic recovery	Development of a unified centralized water resource monitoring system based on GIS, integrated with AI	Optimization of state governance and decision-making processes with transparent monitoring and reporting

Continuation of Table 8.8

1	2	3	4	5
Key agent: local self-government				
Gradual restoration of local ecosystems and reduction of environmental risks. Improved public health through better water quality and sanitation. Increased population density	Stimulation of the local economy through support for small-scale irrigation and infrastructure projects	Support for entrepreneurial projects of innovation-oriented small and medium-sized businesses	Utilization of advanced water supply technologies, drones, and IoT for monitoring and managing local water infrastructure	Strengthened collaboration with higher authorities and local stakeholders to optimize water resource management
Key agent: domestic and foreign investors				
Ensuring investor protection rights and creating opportunities for implementing and supporting sustainable development projects	Contribution to local community development and promotion of corporate socially responsible business practices	Benefits and incentives for implementing innovative environmental projects and initiatives aimed at restoring and developing priority sectors	Adoption of advanced technologies and fostering the region's innovation ecosystem	Clear structures of interconnection and management architecture based on Agile principles, ensuring transparency and accountability of all project participants
Key agent: contractor firms				
Application of advanced environmentally friendly technologies and remediation methods	Creation of jobs and opportunities for social housing and benefits for workers engaged in restoration activities	Increase in regional and business entity revenues through participation in large-scale remediation and infrastructure recovery projects	Utilization of cutting-edge technologies, equipment, machinery, and materials to effectively achieve remediation objectives	Optimization of the organizational and management mechanism through adaptive project management methods

8.5 Conclusion

The project developed by the authors for remediating military contamination and restoring the water resources of Kherson region holds extremely significant importance for the post-war revival of the region. The ecological disaster resulting from

the destruction of the Kakhovka Dam necessitates the implementation of innovative solutions to address environmental, economic, and social problems. For these purposes, the management of water resource remediation is proposed through an agent-oriented model integrated with IT, IoT, machine learning, and the Agile methodology [28]. The project is aimed at restoring ecological balance, reducing water resource pollution, ensuring clean drinking water, and revitalizing agriculture as a strategically important sector of Ukraine's economic system. The project provides for the modernization of infrastructure in accordance with international standards, attracting investments to eliminate the consequences of war and reconstruct the water supply system, as well as integrating advanced technologies for adaptive and "transparent" management [29]. In addition to the immediate restoration of war-affected territories, the project lays the foundation for future resilience and long-term growth.

References

1. After two years of war, Ukraine sees deepening environmental wound (2024). Yale Environment 360. Available at: https://e360.yale.edu/digest/ukraine-war-environment-2024
2. Cummins, J. (2010). Why Some Wars Never End: The Stories of the Longest Conflicts in History. Fair Winds Press, 280.
3. Brokhauz, F. A., Efron, Y. A. (1890–1907). Entciklopedicheskii slovar. Saint-Petersburg. Available at: https://rus-brokgauz-efron.slovaronline.com/
4. Méndez-Fajardo, S., Gonzalez, R. A., Barros-Castro, R. A. (2017). Using Actor-Network Theory in Agent-Based Modelling. Social Systems Engineering. John Wiley & Sons, 157–177. https://doi.org/10.1002/9781118974414.ch8
5. Ellers, J., Hoogendoorn, M., Wendt, D. (2010). An Agent-Based Modeling Approach to Investigate Emergent Patterns in Ecological Systems. 2010 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology, 6–13. https://doi.org/10.1109/wi-iat.2010.200
6. Radosavljevic, S., Sanga, U., Schlüter, M. (2024). Navigating simplicity and complexity of social-ecological systems through a dialogue between dynamical systems and agent-based models. Ecological Modelling, 495, 110788. https://doi.org/10.1016/j.ecolmodel.2024.110788
7. Sibertin-Blanc, C., Therond, O., Monteil, C., Mazzega, P. (2019). The Entity-Process Framework for Integrated Agent-Based Modeling of Social-Ecological Systems. Law, Public Policies and Complex Systems: Networks in Action, 57–86. https://doi.org/10.1007/978-3-030-11506-7_4

8. Bonabeau, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. Proceedings of the National Academy of Sciences, 99, 7280–7287. https://doi.org/10.1073/pnas.082080899
9. Yang, Y.-C. (2010). Modeling watershed management with an ecological objective – a multi-agent system based approach. Available at: https://typeset.io/papers/modeling-watershed-management-with-an-ecological-objective-a-3ozd9t5ntw
10. Martin, R., Schlüter, M. (2015). Combining system dynamics and agent-based modeling to analyze social-ecological interactions – an example from modeling restoration of a shallow lake. Frontiers in Environmental Science, 3. https://doi.org/10.3389/fenvs.2015.00066
11. Berglund, E. Z. (2015). Using Agent-Based Modeling for Water Resources Planning and Management. Journal of Water Resources Planning and Management, 141 (11). https://doi.org/10.1061/(asce)wr.1943-5452.0000544
12. Bahrami, N., Sadr, S. M. K., Afshar, A., Afshar, M. H. (2022). Application of Agent Based Models as a Powerful Tool in the Field of Water Resources Management. Computational Intelligence for Water and Environmental Sciences, 491–506. https://doi.org/10.1007/978-981-19-2519-1_23
13. Nouri, A., Saghafian, B., Bazargan-Lari, M. R., Delavar, M. (2022). Local water market development based on multi-agent based simulation approach. Groundwater for Sustainable Development, 19, 100826. https://doi.org/10.1016/j.gsd.2022.100826
14. Shirvani-Hosseini, S., Samadi-Koucheksaraee, A., Ahmadianfar, I., Gharabaghi, B. (2022). Data Mining Methods for Modeling in Water Science. Computational Intelligence for Water and Environmental Sciences, 157–178. https://doi.org/10.1007/978-981-19-2519-1_8
15. Gwapedza, D., Barreteau, O., Mantel, S., Paxton, B., Bonte, B., Tholanah, R. et al. (2024). Engaging stakeholders to address a complex water resource management issue in the Western Cape, South Africa. Journal of Hydrology, 639, 131522. https://doi.org/10.1016/j.jhydrol.2024.131522
16. Dong, H., Dacre, N., Baxter, D., Ceylan, S. (2024). What is Agile Project Management? Developing a New Definition Following a Systematic Literature Review. Project Management Journal, 55 (6), 668–688. https://doi.org/10.1177/87569728241254095
17. Khersonska torgovo-promislova palata. Zagalna Informatsiya pro region. Geografichne polozhennya i prirodni resursi. Available at: https://www.tpp.ks.ua/khersonskij-region.html
18. Rapid Environmental Assessment of Kakhovka Dam Breach Ukraine, 2023 (2023). United Nations Environment Programme. https://doi.org/10.59117/20.500.11822/43696

19. EkoZagroza. Official resource of the Ministry of Environmental Protection and Natural Resources of Ukraine. Available at: https://ecozagroza.gov.ua/
20. Satellite Detected Waters Evolution over Khersonska, Dnipropetrovska, Mykolaivska, Odeska and Zaporizka Oblasts in Ukraine as of 03 and 05 July 2023 (2023). United Nations Satellite Office. Available at: https://unosat.org/products/3636
21. Study of the Destruction of the Kakhovka Dam and Its Impacts on Ecosystems, Agrarians, Other Civilians, and International Justice (2024). Truth Hounds. Available at: https://truth-hounds.org/en/cases/submerged-study-of-the-destruction-of-the-kakhovka-dam-and-its-impacts-on-ecosystems-agrarians-other-civilians-and-international-justice/
22. Khoriev, M., Karamushka, V., Huliaieva, O., Kuns, B. (2024). Assessment of water needs in the lower Dnipro sub-basin following the destruction of the Kakhovka Reservoir. https://doi.org/10.21203/rs.3.rs-4480879/v1o
23. Quamar, M. M., Al-Ramadan, B., Khan, K., Shafiullah, M., El Ferik, S. (2023). Advancements and Applications of Drone-Integrated Geographic Information System Technology – A Review. Remote Sensing, 15 (20), 5039. https://doi.org/10.3390/rs15205039
24. Palopak, Y., Huang, S.-J. (2024). Perceived impact of agile principles: Insights from a survey-based study on agile software development project success. Information and Software Technology, 176, 107552. https://doi.org/10.1016/j.infsof.2024.107552
25. Konsultatsii z hromadskistiu. Ministerstvo zakhystu dovkillia ta pryrodnykh resursiv Ukrainy. Available at: https://mepr.gov.ua/topics/ogoloshennya/konsultatsiyi-z-gromadskistyu/
26. Konsultatsii z hromadskistiu. Derzhavne ahentstvo vodnykh resursiv Ukrainy. Available at: https://www.davr.gov.ua/konsultacii-z-gromadskistyu
27. Elektronni konsultatsii z hromadskistiu. Ministerstvo rozvytku hromad ta terytorii Ukrainy. Available at: https://mtu.gov.ua/timeline/Proekti-normativno-pravovih-aktiv.html
28. Cherniavskyi, B. (2024). Digital Technologies as an Accelerator of Remediation: a Strategic Vector for the Post-War Revitalization of Ukraine's Territory. Transformational economy: theoretical and practical aspects. Riga: Baltija Publishing, 653–675.
29. Britchenko, I., Cherniavska, T. (2019). Blockchain technology in the fiscal process of Ukraine. Economic Studies, 28 (5), 134–148.
30. Tanklevska, N., Cherniavska, T., Skrypnyk, S., Boiko, V., Karnaushenko, A. (2023). Financing of Ukrainian agricultural enterprises: Correlation-regression analysis. Scientific Horizons, 26 (8), 127–139. https://doi.org/10.48077/scihor8.2023.127

CHAPTER 9

Corporate governance under economy transformation and geopolitical uncertainty: case of Ukraine

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Abstract

This research explores the impact of instability at the macro- and micro-level on corporate governance. Specifically, the study considers corporate governance reform and ESG-based remuneration trends in Ukraine, focusing on adaptation to crisis contexts and alignment with international standards. Ukraine's corporate governance landscape has evolved significantly, shifting toward formalizing board structures, incorporating independent directors, and enhancing transparency to support accountability and investor confidence. The study assesses the current maturity of corporate governance in Ukraine through data from research companies and professional associations, highlighting gaps in board independence and board formalization in private and state-owned enterprises (SOEs). Ukrainian SOE governance reforms are also examined, guided by OECD principles, and codified under Law of Ukraine No. 3587-IX 2024. These reforms emphasize transparency, risk management, and structured oversight to align SOE operations with EU-integration goals, enhancing governance standards across Ukrainian SOEs and setting a strategic foundation for sustained foreign investment. Research considers the emerging integration of ESG-based remuneration, aligning executive incentives with environmental, social, and governance goals. CSRD influences Ukrainian companies by promoting transparency in ESG-linked pay structures and standardizing sustainability reporting. In a crisis context, ESG-based remuneration becomes particularly relevant, encouraging Ukrainian companies to adapt their ESG targets to include community welfare, environmental restoration, and ethical governance. Drawing from global case studies – such as Japan's post-disaster corporate policies and South Africa's emphasis on social equity – the paper outlines best practices for integrating ESG metrics within Ukrainian corporate governance. This alignment of governance frameworks and ESG-based remuneration in Ukraine aims to strengthen corporate resilience, support investor trust, and contribute to sustainable

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development and national recovery efforts. The study recommends further embedding OECD-aligned practices and crisis-responsive ESG strategies within Ukraine's corporate governance landscape, reinforcing the role of Ukrainian businesses in shaping a resilient and sustainable economy, accounting for specific needs of postwar recovery.

Keywords

Corporate governance, instability, geopolitics, postwar recovery, Ukraine's economy transition, economy transformation, ESG-based remuneration, Ukrainian SOEs, SOE governance reform, OECD principles, board independence, UN SDG, investor trust, raising capital, EU CSRD, sustainability metrics, executive compensation, governance structures, corporate resilience.

9.1 Introduction

Corporate governance has emerged as a cornerstone for economic stability and growth, particularly in economies facing significant socio-political challenges. In Ukraine, corporate governance has gradually evolved, influenced by internal economic transitions and the country's integration into the global market. This evolution is particularly relevant as Ukrainian companies deal with complex crises, such as external geopolitical tensions and internal challenges due to war, a broader global drive to enhance governance structures in alignment with international standards, including those outlined by the OECD, and a specific need for structured postwar recovery. Corporate governance frameworks in Ukraine, characterized by varying levels of board formalization and the presence of independent directors, reveal both progress and areas needing improvement. Data from recent studies [1] demonstrate that most Ukrainian businesses have implemented some form of corporate governance, with 60 % establishing boards of directors and 38 % maintaining boards to ensure oversight. However, gaps persist – for instance, independent directors constitute a minor percentage of Ukrainian board composition, which may limit objectivity and impede optimal governance outcomes. The need for increased formalization and impartial oversight has become more pressing, as these elements are crucial to securing investor trust and facilitating effective decision-making. In the context of SOE governance, Ukraine has initiated critical reforms to align with OECD principles, indicating transparency, accountability, and the independence of boards. Recent legislation and relevant policies, including Law of Ukraine No. 3587-IX 2024 [2] and compiled under this legislation, yet unpublished Ukraine's State Ownership Policy, outlines clear governance criteria, enhancing the strategic management of SOEs, and establishing frameworks for board responsibilities, risk management, and performance evaluations. This reform marks a

significant step towards integrating Ukrainian SOEs into the global economy, positioning them as competitive, transparent entities capable of attracting international investment and supporting public trust. Moreover, integrating ESG criteria within corporate governance and remuneration policies reflects a growing commitment to sustainable practices as Ukraine's economy transitions. ESG-based remuneration, though relatively new in Ukraine, has become an essential mechanism for linking executive incentives to measurable sustainability achievements. Amid Ukraine's specific crisis context, ESG-focused strategies provide a means for companies to demonstrate resilience, align with national recovery efforts, and support community welfare. Insights from global experiences in crises, such as Japan's response to the Fukushima disaster, offer frameworks for incorporating ESG-driven governance in Ukrainian companies, especially in the face of ongoing challenges. This effort could be methodically supported by aligning these corporate and social development goals within the UN SDG framework. This research provides an in-depth analysis of the current state of corporate governance in Ukraine, highlighting recent reforms, challenges, and opportunities in both private and state-owned sectors. Additionally, it explores the role of ESG-based remuneration in strengthening corporate resilience and promoting sustainable business practices within the Ukrainian context. By examining these aspects, this study seeks to contribute to the broader discourse on corporate governance in emerging markets and to offer actionable recommendations for advancing governance practices in Ukraine.

9.2 Corporate governance in Ukraine under economy's transition amidst geopolitical crises

Corporate governance is critical in ensuring business efficiency and resilience to external challenges, especially during transitional periods. Ukrainian businesses continue to adapt their corporate governance bodies to meet new realities. Based on recent data from joint research [1] by the Ukrainian Corporate Governance Academy (UCGA) and research company Gradus, we analyzed the status and structure of corporate governance within Ukrainian companies.

9.2.1 Ukrainian corporate governance amidst crisis: 2024 snapshot

According to joint UCGA & Gradus survey [1] results, most researched Ukrainian companies (60 %) have a board of directors in some form. Board of directors (Supervisory board – before 2024 legislation changes allowing only a 2-tier

system for corporations in Ukraine) is present in 38 % of the surveyed companies, indicating a high level of oversight over management activities. So-called advisory or consultative boards (specific bodies supporting the transition from a dominant CEO/President/Chair entity endemic to post-soviet 1990-s and 2000-s business practices reflecting a gradual transition to a transparent structure required by multi-shareholder model) operate in 21 % of Ukrainian companies emphasizing the importance of expert support and consultation in decision-making processes in Ukrainian business practices. Notably, 15 % of researched companies do not have any listed corporate governance bodies, which may suggest a less formalized approach to corporate governance in these organizations.

Data [1] indicates that 54 % of companies have formalized boards, reflecting a high level of corporate governance maturity in these organizations. However, in 39 % of companies, only some boards are formalized, suggesting a phased approach to implementing formal corporate governance procedures. Only 6 % of companies lack any formalized board, which may imply an absence of a clear management structure in these businesses.

Independent directors are vital to effective corporate governance practices, providing impartial oversight and evaluation of management activities. According to UCGA & Gradus joint research [1] in 48 % of Ukrainian companies, independent directors constitute less than 30 % of the board, highlighting the need for further development of this governance component. Conversely, 35 % of companies have no independent directors, which may reduce the objectivity and effectiveness of managerial decisions. Meanwhile, 16 % of companies have over 30 % independent directors on their boards, indicating high transparency and governance effectiveness.

Analysis of data [1] reveals that Ukrainian businesses are actively working to improve their corporate governance structures, even amid active warfare. Most companies have formalized governance bodies, such as boards of directors, which ensure high control and supervision over management activities. However, specific challenges are associated with the low representation of independent directors in some companies, potentially affecting decision-making objectivity. Overall, the trends indicate a gradual improvement in the corporate governance system, a positive signal for investors and other stakeholders. Based on the analysis of UCGA & Gradus data [1], we crystalize several trends regarding the current state of corporate governance in Ukraine:

Trend 1. Maturity of corporate governance: corporate governance in Ukraine demonstrates a certain level of maturity, evidenced by the presence of boards of directors in most companies (60 %). However, there are significant gaps in the governance structure, with 15 % of companies lacking formal governance

bodies. This indicates a less formal and systematic approach to management in these organizations.

Trend 2. Board formalization: the high level of board formalization in most companies (54 %) is a positive trend, indicating a commitment to enhancing governance efficiency through clear procedures. At the same time, 39 % of companies have only partially formalized their boards, suggesting a gradual adaptation to new governance requirements.

Trend 3. The increasing role of independent directors: independent directors remain a weak link in corporate governance in Ukraine. Only 16 % of companies have more than 30 % independent directors on their boards, while 35 % have none, potentially impacting the objectivity of decision-making and oversight of management activities.

Based on these observations, specific recommendations to support corporate governance in Ukraine at the current stage may be suggested. First, strengthening corporate governance formalization – Ukrainian companies should focus on further formalizing corporate governance bodies, especially in companies where such bodies are absent or only partially formalized. This will enhance governance efficiency and transparency in decision-making processes. Second, efforts should be made to increase the proportion of independent directors on the boards of Ukrainian companies. This can be achieved through regulatory requirements or industry standards, promoting more objective managerial decisions, and improving oversight of management activities. Third, the development of advisory boards as a transition instrument should be given to developing advisory and consultative boards, which can provide companies with expert support and facilitate more balanced decision-making in crises.

9.2.2 Pre-crisis transition developments in corporate governance in Ukraine

According to Corporate Governance Professional Association (CGPA) study [3] from 2018, 97 % of respondents noted that proper corporate governance positively impacted company performance. Notably, foreign company subsidiaries received the highest ratings for implementing best practices in corporate governance (95 %), while state and municipal companies had the lowest (26 %). In terms of corporate governance elements in Ukrainian companies, CGPA data [3] shows that the essential principles are: effective board operations (69 %), conflict of interest prevention (66 %), shareholder rights protection (65 %), a professional approach to decision-making (64 %), timely and accurate disclosure of information and

transparency (57 %), and fair treatment of various shareholder groups (52 %). Ukrainian business perspective on the role of the board is also noteworthy. Most respondents (77 %) believed corporate governance is only possible with a fully functioning board. As of 2018, in 81 % of companies, a board had been established, with over 60 % of respondents noting its positive impact on company performance. In some forms, the existence and function of a corporate governance office are separate considerations. Approximately 74 % of researched companies had a corporate secretary and an internal auditor office, while about 50 % established a compliance office. Ukrainian business understands that corporate governance significantly impacts a company's attractiveness to investors. According to CGPA [3], 52 % of respondents stated that good corporate governance significantly enhanced company performance, and 45 % believed it moderately improved performance. This is supported by high ratings for the importance of shareholder rights protection (65 %), conflict of interest prevention (66 %), and a professional approach to decision-making (64 %) as traits of good corporate governance. Despite the general progress in implementing best corporate governance practices, significant differences exist between different types of companies. Foreign subsidiaries and companies with investment fund involvement show the highest performance (60 % and 57 %, respectively), while private companies (40 %) and state-owned companies (26 %) faced challenges in this area.

The effectiveness of boards largely depends on their composition and organization. According to the survey, 81 % of companies had a board, and 36 % of respondents indicated that its activities significantly enhanced company performance. However, only 15 % of boards were directly involved in strategy development. The average board size was five members, about half of whom were independent, although 48 % of companies had no independent members in 2018.

Several conclusions may be drawn based on CGPA [3] data analysis. Legislative requirements and educational programs for shareholders and managers are necessary to strengthen the role of boards, especially in SOEs. That improves management quality and decision-making effectiveness. Including experts from various fields, such as technology and digital media, on boards is essential to enhance companies' ability to respond to contemporary challenges. That facilitates more flexible and adaptive governance. Improving information disclosure and reporting systems boosts investor and stakeholder trust, crucial for attracting investments and ensuring stable company growth. Strengthening the roles of compliance and internal audit departments is critical to minimizing risks and ensuring regulatory compliance. This helps avoid financial and reputational losses.

The following steps are necessary to ensure the sustainable development and successful integration of Ukrainian companies into global markets. First, legislative

norms should be implemented to strengthen the role of boards, particularly in state- and municipal-owned companies, which enhances corporate governance standards and accountability. Second, training programs for shareholders and managers should be introduced to develop competencies in corporate governance, raising awareness and skills. Third, involving specialists from various sectors, including technology and digital media, in boards to better address modern challenges and innovation. Additionally, improve information disclosure and reporting mechanisms to boost investor and stakeholder trust, thereby increasing the companies' investment appeal. Finally, adequate funding and independence for compliance and internal audit departments are ensured to enable effective regulatory compliance control. That reduces risks and improves companies' financial stability. Hence, implementing these measures will enhance corporate governance effectiveness, which is critical to the sustainable development of Ukrainian companies in the current global environment. For further improvements in corporate governance among Ukrainian companies, attention should be given to the following aspects:

– *increasing independent directors' representation on boards*: engaging independent directors enhances objectivity and impartiality in decision-making, reduces conflict of interest risks, and ensures board transparency. Independent directors can also introduce new ideas and approaches, supporting innovation and long-term growth. It is crucial to ensure these directors possess the necessary qualifications, experience, and conditions conducive to their practical work;

– *further formalization of governance bodies*: formalizing governance bodies, including clearly defining their functions and authority, will create a structured and transparent management system. Implementing robust internal control and audit mechanisms enhances reliability and compliance with legal and corporate governance standards. Developing and implementing policies and procedures that align governance bodies with best practices and international standards is essential;

– *institutionalizing corporate governance*: boards can offer critical expert support and guidance, aiding management in strategic decision-making. Involving professionals from various fields, such as finance, marketing, risk management, and innovation, enables comprehensive analysis and assessment of strategic initiatives. Effective communication channels between advisory boards and management should be established to ensure timely information exchange and the incorporation of recommendations into decision-making processes.

Implementing these recommendations enhances corporate governance effectiveness, strengthening the resilience and competitiveness of Ukrainian companies in the international market. This supports investor confidence, strengthens financial stability, and creates conditions for sustainable company growth.

9.3 Ongoing corporate governance reform in Ukraine: focus on the economy's transition for postwar recovery

Corporate governance of SOEs is a critical component of economic stability and development in Ukraine. In recent years, significant steps have been taken to reform state property management to increase SOEs' efficiency, transparency, and competitiveness. The primary objective of this reform is to align management practices with international standards, particularly the principles of the OECD, which ensure effective governance of public companies, balanced distribution of rights and responsibilities within bodies, and protection of investors' rights. That, in turn, should assist in transitioning Ukraine's economy and stimulate an influx of international capital. The reform's essence is reducing the number of enterprises under state ownership by privatizing the majority of SOEs and improving corporate governance in the remaining SOEs. Approximately 3,000 SOEs operate in Ukraine, of which only strategically important ones are planned to remain under state control. Other SOEs will be privatized or liquidated according to Ministry of Economy of Ukraine [4]. This approach not only reduces the fiscal burden on the state budget but also allows for more efficient resource use and creates favorable conditions for developing a competitive market. For companies that remain under state control, the reform mandates the implementation of rigorous corporate governance standards consistent with OECD and Ukrainian policies [5]. This includes establishing boards with independent members who are empowered to oversee the activities of SOE's management. Such an approach ensures transparency and accountability in strategic decision-making. Effective internal control mechanisms, including risk management, compliance, and internal auditing, are also being implemented to identify and mitigate potential risks to the stability of SOEs.

9.3.1 OECD principles vs. Ukrainian corporate governance practices: a strive for transparency for international capital influx in Ukrainian SOEs

Corporate governance analysis in Ukraine highlights both advancements and challenges in aligning with OECD principles [6]. Ukraine has made noticeable progress in adopting OECD's core standards, particularly regarding transparency, accountability, and the protection of shareholder rights. However, significant obstacles remain to achieving full compliance with these international standards, as demonstrated by both progress and limitations across various governance areas:

Point 1. Transparency and accountability are essential components of the OECD framework, emphasizing the need for companies to disclose financial information, report promptly, and ensure information accessibility for shareholders. Ukraine has started implementing mandatory transparency standards, especially in SOEs, where requirements for disclosing financial and strategic information have been introduced. Yet, bureaucratic processes and potential conflicts of interest hinder these efforts. Despite the commitment to increased transparency, many SOEs still lack the necessary infrastructure and culture to facilitate full and consistent information disclosure.

Point 2. Boards' independence of is another key OECD recommendation aimed at preventing conflicts of interest and strengthening oversight. In Ukraine, the establishment of boards has been made compulsory for certain SOEs under criteria established by the Cabinet of Ministers of Ukraine (the Cabinet), and these boards are gradually gaining extended powers, such as the approval of financial and strategic plans and the appointment of senior management. However, political dependence continues to compromise its effectiveness. Instances of apparent governmental influence over boards reveal an ongoing challenge in ensuring these bodies' ability to provide objective oversight without interference.

Point 3. Rights of shareholders and stakeholders are fundamental to OECD principles, particularly the protection of minority investors and the consideration of all stakeholders' interests. In Ukraine, these principles are evolving predominantly within the private sector, where investor protection is being reinforced through reforms and heightened transparency. In the public sector, however, shareholder rights are often less pronounced, as the state remains the primary owner and directly controls SOEs' operations. This ownership structure restricts private investors and stakeholders from effectively influencing corporate policies, creating a divergence from the OECD's shareholder protection standards.

Point 4. Compensation system for executives in Ukraine is another area where OECD principles emphasize transparency and alignment with a company's performance. Recently, the Cabinet introduced a compensation policy for executives in SOEs, marking a positive step toward OECD-aligned practices. However, the policy remains in an early stage of implementation, and additional mechanisms are necessary to fully realize its potential for promoting transparent and performance-driven compensation structures.

Point 5. The OECD framework critically focuses on investor protection, advocating for strong legal protections and information transparency, especially for minority investors. While Ukraine has made progress in enhancing investor protections in the private sector, where shareholders have access to information and legal support, protections remain less robust within the public sector. This lack of comprehensive

protection creates risks for potential investors and limits capital inflows, underlining the need for further improvements in this area.

The OECD indicates that independent supervisory bodies are essential to effective governance and accountability. In Ukraine, boards have been granted expanded authority and responsibility over the approval of SOEs' strategic and financial plans. Nevertheless, political influence and conflicts of interest continue to hinder their effective functioning. These boards' dependence on government decisions may adversely impact their ability to conduct objective oversight, diminishing the potential for transparency and accountability. Comparative analysis results are summarized in **Table 9.1**.

Table 9.1 Comparative analysis of OECD principles and Ukrainian corporate governance practices' cohesion

Category	OECD principles	Practices in Ukraine
Transparency and accountability	High level of transparency, including open financial reporting and accessible information for shareholders	Transparency is becoming a standard for SOEs; however, the process is complicated by bureaucracy, conflicts of interest
Boards' independence	Mandatory independence of boards to ensure effective oversight and prevent conflicts of interest	Boards are mandatory under certain conditions, with powers aligning to OECD standards, yet some political dependence exists
Shareholders' and stakeholders' rights	Shareholders, including minority investors, have rights to receive information and influence company policy	Shareholder rights protection is advancing in the private sector; in the public sector, shareholder rights are less pronounced due to state control
Compensation system	Compensation should be transparent and performance-based, aligning with long-term goals	A compensation policy for executives in SOEs has recently been introduced and approved by the Cabinet, but transparency still requires improvement
Investor protection	Special focus on the protection of investor and minority shareholder rights, with legal mechanisms for their support	Investor rights protection in Ukraine is gradually improving, though gaps remain, particularly in protecting minority shareholders in the public sector
Boards effectiveness	Boards should perform strategic management functions and maintain independence from executives	Boards have been granted expanded powers, including strategic oversight; however, conflicts of interest may arise due to state influence

Sources: analysis based on [2, 4–8]

In summary, while Ukraine is gradually implementing OECD principles in corporate governance, especially concerning transparency, shareholder rights, and board

independence, achieving full compliance in SOEs is impeded by several persistent challenges. Political influence on boards, limited transparency in the state sector, and insufficient investor protection remain significant issues. Addressing these factors through continued corporate governance reforming efforts – focusing on enhancing board independence, refining the compensation system, and strengthening investor rights – will be essential for Ukraine's alignment with OECD standards and its advancement toward robust corporate governance practices to ensure transparency and influx of international capital.

9.3.2 Current developments in Ukrainian SOE governance reform

The critical component of the corporate governance reform is Law of Ukraine No. 3587-IX 2024 [2], which came into effect in early 2024. This law mandates the development of a State Ownership Policy, which outlines the main objectives of state ownership of enterprises and sets criteria for their privatization or retention under state control. The law also establishes clear powers for boards, including appointing company management and approving development strategies [8]. Furthermore, an internal control system is introduced to detect and prevent violations in the companies' activities.

Ukrainian legislation requires alignment with the OECD Corporate Governance Guidelines, which will enhance the governance of SOEs and improve transparency in their operations. The OECD has established core principles of corporate governance aimed at ensuring transparency, accountability, and efficiency in managing SOEs. These principles include establishing a stable legal and regulatory environment, separating the state's roles as owner and regulator, ensuring a level playing field in competition, promoting transparency and information disclosure, safeguarding the independence of boards, implementing effective risk management, engaging stakeholders, and developing a well-structured policy on executive remuneration and incentives. The main objective of these principles is to improve the competitiveness, accountability, and transparency of SOEs, which, in turn, will attract investment and strengthen trust from both the public and the international community.

The anticipated outcomes of the reform include increased productivity and transparency of SOEs. Reducing corruption risks, achieving high standards of transparency and accountability, and attracting international investment all contribute to enhancing trust in the public sector. These improvements also help minimize corrupt schemes and abuses, thereby improving the overall reputation of SOEs. A critical

aspect of the reform is the adherence to European governance standards and Ukraine's commitments within the framework of economic integration with the EU, which not only strengthens Ukraine's partnerships with EU countries but also attracts foreign investments to develop strategic sectors of the economy.

SOE governance reform aims to harmonize national principles with the OECD and institutionalize SOE governance in Ukraine. Legislation requires the implementation of a comprehensive state ownership policy. It also stipulates the need for a remuneration policy for SOE executives, a remuneration framework for board members, and a state dividend policy. These measures aim to enhance accountability, promote performance, and ensure responsible management of public assets.

Under modern legislation, SOEs' board independence is reinforced. Each SOE is required to establish a two-tier management structure with a board. This requirement applies to SOEs that meet criteria established by the Cabinet. For companies where the establishment of a board is not mandatory, a single-tier management structure may be implemented by the decision of the authorized management body, in accordance with the provisions of the Law of Ukraine No. 2465-IX 2024 "On Joint Stock Companies" [7]. Boards will also assume broader authority – for greater accountability. Boards will be responsible for approving financial, strategic, and investment plans based on state ownership policy and KPIs set by the Cabinet (as the major shareholder) and for appointing and dismissing SOE management. Additionally, a defined list of grounds for early termination of board members' powers has been established, replacing the previous approach whereby the Cabinet could unilaterally terminate any board member based on its assessment of inadequate performance. A clear set of KPIs encompassing financial, operational, and non-financial goals is to be established for SOEs. The KPIs aim to guide the strategic development of SOEs, ensure a low risk of bankruptcy, and fulfill the SOE dividend policy. Fulfilling these goals affects board remuneration and the prolongation of board members' contracts. Positive changes took place in terms of remuneration policy. The Cabinet is empowered to establish the procedure for evaluating the performance of SOE boards and to approve the remuneration policy for SOE executives. This approach ensures transparency and accountability in compensation matters, promoting expert and independent boards. Key developments are summarized in **Table 9.2**.

Hence, the SOEs' corporate governance reform, combined with improving state property management, is a crucial step for Ukraine toward modernizing its economy and supporting the EU integration effort. This effort aims to optimize the use of state resources and attract foreign investments. It seeks to build an economically stable and competitive economy that aligns with contemporary international standards.

Table 9.2 Key changes in Ukrainian SOEs' corporate governance under Law of Ukraine No. 3587-IX 2024 and related policies

Component	Description	Impact/outcome
	Macro-level changes	
OECD alignment	Aligning Ukrainian legislation with OECD principles of corporate governance, which emphasize transparency, accountability, risk management, and efficiency	Enhancing governance standards, strengthening EU and international integration, increasing investor trust
Transparency and accountability	Enhancing SOE transparency and accountability through clear governance structures and reporting requirements aligned with OECD principles	Building public and international trust, reducing opportunities for corruption, and improving SOE reputational image
Institutionalization of SOE governance	Reinforcing the establishment of corporate governance standards in Ukrainian SOEs by mandating a comprehensive governance framework aligned with national and OECD standards	Institutionalizing best practices in SOE management, reducing risk of misuse and enhancing operational efficiency
Economic integration with EU	Adhering to European governance standards as part of Ukraine's commitments to economic integration with the EU	Attracting foreign investment, strengthening international partnerships, and supporting EU alignment
State ownership policy	Mandating development of state ownership policy to outline main objectives for SOE ownership, including criteria for privatization or retention under state control	Enhancing strategic clarity and accountability; streamlining state ownership objectives
	Micro-level changes	
Board authority	Expanding boards' authority to include the appointment of SOE management, approval of development strategies, and establishment of a two-tier management structure (or a single-tier board in qualified SOEs)	Improving governance, accountability, and professional management of SOEs
Board independence	Ensuring board independence and limits unilateral termination by the Cabinet by defining grounds for early termination based on specific performance criteria	Strengthening board independence, minimizing political interference, and improving SOE stability
Modernized internal control system	Introducing an internal control mechanism (i.e. compliance and internal audit – substituting revision commission) to detect and prevent violations in SOE activities	Reducing corruption risks, improving compliance, and enhancing transparency
Remuneration policy transparency	Positioning the Cabinet as responsible for evaluating the performance of SOE boards and setting the remuneration policy, ensuring transparency and accountability	Encouraging performance-driven governance and attracting qualified and diverse expertise for board
Performance KPIs	Setting clear KPIs for financial, operational, and non-financial goals to guide SOEs in achieving strategic objectives and avoiding bankruptcy risks	Promoting strategic alignment, financial health, and performance-based management
State dividend policy	Introducing a state dividend policy with clear KPIs for SOEs, including financial, operational, and non-financial goals	Ensuring financial accountability and supports economic sustainability of SOEs

Sources: analysis based on [2, 4–8]

9.4 ESG-based remuneration as the central issue of modern corporate governance: lessons for Ukraine postwar recovery

ESG-based remuneration has emerged as a vital aspect of corporate governance. This approach links executive compensation directly to a company's performance on ESG metrics. It acknowledges that long-term value creation depends on financial success, sustainable practices, and social impact. ESG-based remuneration ties executives' rewards to specific ESG goals, such as reducing carbon emissions, promoting diversity and inclusion, and upholding strong governance practices [9, 10]. This linkage encourages a forward-looking focus, often incorporating long-term incentives that promote sustainable achievements over immediate profits.

Integrating ESG metrics within corporate governance aligns executive incentives with broader stakeholder interests, spanning employees, customers, communities, and investors. It encourages leaders to support value beyond financial gains, prioritizing the social and environmental well-being associated with stakeholder interests. ESG-based remuneration enhances transparency and accountability, with clearly defined criteria that make companies more open regarding their sustainability performance. Moreover, by embedding ESG factors into remuneration packages, companies can proactively address long-term risks related to environmental and regulatory shifts and social responsibilities that, if neglected, could jeopardize business resilience. Despite its benefits, ESG-based remuneration has challenges. Defining and measuring ESG performance can be complex, as it often involves qualitative assessments that are less straightforward than traditional financial metrics [11]. Additionally, there is the risk of greenwashing, where companies might set superficial ESG goals to satisfy remuneration requirements without enacting substantive changes. Striking a balance between ambitious ESG targets and the need for short-term profitability presents another challenge, as prioritizing long-term goals could potentially detract from immediate business growth and stability. Leading companies exemplify best practices by tying executive compensation to specific ESG targets, such as emissions reduction and social impact improvements. External ESG ratings from agencies frequently serve as benchmarks for setting these targets. Corporate boards also play a crucial role, overseeing ESG-linked remuneration to ensure it aligns with the company's values and sustainability objectives. Looking ahead, ESG-based remuneration is poised to become more standardized as regulations evolve [12]. For instance, proposed EU directives may require companies to disclose the alignment between executive pay and ESG goals, reflecting the growing regulatory focus on sustainability. Investor pressure is increasing as institutional stakeholders advocate for stronger

ties between pay and ESG performance to ensure companies prioritize long-term, sustainable management.

Hence, ESG-based remuneration is a progressive corporate governance trend promoting a balanced view of value creation. When executed thoughtfully, it can stimulate positive organizational change, strengthen long-term performance, and amplify a company's social and environmental contributions. However, to avoid pitfalls like greenwashing, companies have to set realistic, measurable ESG goals aligned with their core strategies, ensuring meaningful contributions to sustainability.

9.4.1 EU CSRD impact on corporate governance: roadmap for sustainability

The Corporate Sustainability Reporting Directive (CSRD) [13], introduced by the EU, significantly influences ESG-based remuneration within corporate governance. It aims to enhance transparency and standardize sustainability reporting across EU companies. This directive mandates that many organizations disclose their ESG performance, align executive remuneration with sustainable practices, and hold companies accountable for their environmental and social impact. By requiring detailed reporting on ESG metrics, the CSRD establishes a more objective foundation for integrating ESG criteria into compensation packages, allowing companies to align executive pay with measurable and verifiable sustainability achievements.

CSRD also promotes consistency in reporting, creating a standardized basis for evaluating ESG performance across industries and countries. This uniformity benefits stakeholders, particularly investors, who can better assess executive compensation's alignment with ESG outcomes. By mandating transparency around executive pay linked to sustainability goals, the directive empowers stakeholders to hold companies accountable if ESG claims do not align with actual performance. This reduces greenwashing risks, compelling companies to ground ESG-linked remuneration in substantive achievements.

CSRD places heightened responsibility on board directors to oversee and align executive compensation with long-term sustainability goals, reinforcing corporate governance structures to prioritize financial and environmental objectives. Governance committees now play a crucial role in setting and monitoring ESG-related remuneration criteria, ensuring these metrics reflect broader sustainability goals. The CSRD bolsters investor confidence in companies committed to sustainable practices and aligns with the EU's sustainable finance initiatives. Investors are increasingly drawn to organizations that are compliant with CSRD standards, which reflect

the EU's Green Deal and UN SDGs. By linking executive pay to ESG targets that support the SDGs, companies signal a commitment to the EU's sustainability agenda, enhancing their reputation and regulatory alignment.

CSRD, however, presents challenges as companies must rely on quantifiable ESG data to substantiate performance and connect it to executive pay, requiring robust reporting infrastructure and data management. While these requirements drive more robust governance, they may necessitate additional resources and expertise, posing challenges for smaller organizations. The CSRD is likely to have a far-reaching impact, affecting various sectors and extending its influence beyond the EU. Its expansive application encourages a broad commitment to ESG-linked executive pay across Europe, and as international companies operating within the EU adapt to these standards, the directive may set a precedent for global corporate governance related to sustainability and executive remuneration.

Therefore, the CSRD solidifies ESG-based remuneration by mandating transparent, data-backed reporting and transforming executive compensation structures to reflect genuine sustainability achievements. By mitigating greenwashing risks and promoting accountability, the directive supports a sustainable, long-term perspective within corporate governance, shaping ESG-driven practices across Europe and potentially inspiring similar standards worldwide.

9.4.2 Incorporating ESG-based remuneration under crisis context: insights for Ukraine

The profound social, economic, and environmental impacts of war demand a specialized approach to ESG-based remuneration policies. Specifying these policies to address wartime challenges enables companies to demonstrate resilience and commitment to their workforce, communities, and the environment.

Remuneration policies could reflect efforts to minimize operations' environmental footprint despite disruptions, focusing on resource management, emissions control, and waste reduction [14]. Additionally, targets could incentivize executives to contribute to ecological restoration, with goals for reforestation and soil remediation in affected areas. As infrastructure faces heightened risk, resilience initiatives could be encouraged through policies that prioritize sustainable resource management and energy efficiency, supporting a proactive approach to environmental security [15]. From a social perspective, companies could emphasize support for employees and local communities. Metrics tied to executive pay could reward initiatives that ensure employee safety, mental health support, and safe working conditions. Corporate

contributions to community resilience (such as humanitarian aid, employment opportunities, and training programs) would also signal a commitment to community welfare. This approach could be extended to support diversity, equity, and inclusion, encouraging hiring practices that prioritize vulnerable groups, including women and minorities impacted by the war. Governance considerations in ESG-based remuneration could highlight ethical leadership and transparency, which are critical in wartime. Executives could be incentivized to prioritize responsible business practices, ethical supply chains, and crisis preparedness. Governance metrics might include achievements in operational continuity planning, cybersecurity, and stakeholder communication, ensuring that companies remain transparent and accountable during conflict. Human rights and compliance remain paramount, as companies operating in a conflict zone must uphold safe labor practices and protect employee rights. Linking executive pay to human rights benchmarks (such as fair labor standards, ethical sourcing, and transparency in supply chains) ensures adherence to ethical business standards, especially in procurement and partnerships. ESG-based remuneration could also emphasize contributions to postwar recovery, rewarding leaders who invest in infrastructure, technology, and partnerships that bolster local economies and support long-term recovery. Companies could incentivize executives to pursue innovative crisis-response strategies, supporting economic stability and resilience through partnerships with small businesses and sustainable practices in rebuilding efforts. Adaptive and flexible ESG targets may be critical to managing the unpredictability of a wartime context. Such targets allow companies to recalibrate expectations based on evolving challenges, balancing performance with the dynamic realities of their environment. Integrating Ukraine's specific circumstances into ESG-based remuneration policies exemplifies a commitment to ethical leadership, social responsibility, and sustainable governance. By aligning executive incentives with meaningful ESG goals, companies reinforce their role as stewards of resilience and recovery, embedding these priorities into their core leadership practices during and beyond the crisis.

Incorporating ESG-based remuneration in times of crisis is a common strategy across countries facing extraordinary challenges. This approach allows companies to respond effectively to environmental, social, and governance needs while supporting resilience. This approach has become particularly relevant for companies in Ukraine, which, amidst the current geopolitical situation, can draw on global examples to align executive incentives with national recovery goals and urgent social priorities.

In Japan, the response to the 2011 Fukushima nuclear disaster highlights how corporate ESG strategies can shift in the aftermath of environmental crises. Japanese companies, especially in energy and manufacturing, redefined executive remuneration to prioritize safety and risk management as core ecological goals.

For instance, Tokyo Electric Power Company (TEPCO) linked executive compensation to adherence to strict safety protocols, environmental restoration, and community engagement in affected areas [16]. The disaster also catalyzed corporate governance reforms in Japan, encouraging companies to adopt greater transparency and accountability measures. Consequently, executive pay began to reflect the company's commitment to clear communication on environmental safety, emphasizing board oversight and executive accountability for ESG performance.

In the Philippines, the devastating impact of Typhoon Haiyan in 2013 led agriculture, logistics, and retail companies to adapt their ESG goals for climate resilience. These adjustments included embedding climate resilience and sustainability in supply chains, which became critical of executive performance metrics. San Miguel Corporation, among others, linked executive pay to environmental conservation and infrastructure projects designed to withstand future natural disasters [17]. Moreover, Philippine companies emphasized social responsibility, with executive bonuses tied to community rehabilitation projects that provided essential services and shelter for displaced individuals. This alignment of corporate and social objectives supported a culture of community engagement and long-term support for vulnerable regions.

Similarly, Brazil's ongoing environmental challenges in the Amazon have prompted companies to adopt ESG-based remuneration structures that address ecological accountability. Companies in agriculture and resource sectors, such as Suzano, a major pulp and paper producer, linked executive compensation to environmental performance targets, including deforestation prevention and biodiversity conservation [18]. Additionally, the social aspects of ESG in Brazil were addressed through initiatives focused on indigenous rights and sustainable land use, which became part of executive performance evaluations. By aligning executive incentives with environmental and social responsibilities, Brazilian companies adapted their strategies to meet global scrutiny over deforestation and to engage responsibly with local communities. Incorporating UN SDGs into ESG-based remuneration policies offers a framework for Ukrainian companies to address wartime challenges while promoting long-term sustainability. Aligning executive incentives with SDG priorities helps companies respond to immediate crises and contribute to national recovery [19, 20]. Environmental goals, such as SDG 13 (Climate Action) and SDG 15 (Life on Land), can drive sustainability-focused leadership. Executives could be rewarded for reducing greenhouse gas emissions, implementing energy-efficient practices, and engaging in ecological restoration, such as reforestation and soil remediation in war-affected areas. These efforts demonstrate resilience and commitment to rebuilding sustainably. Aligning with SDG 8 (Decent Work and Economic Growth) and SDG 10 (Reduced Inequalities) socially ensures a focus on workforce and community well-being.

Metrics could incentivize initiatives for job protection, mental health support, and hiring from vulnerable groups, including displaced populations. Community resilience efforts, such as humanitarian aid and rebuilding essential services, further reinforce corporate social responsibility. Governance measures tied to SDG 16 (Peace, Justice, and Strong Institutions) promote ethical leadership and transparency. Remuneration could be linked to human rights adherence, ethical supply chains, and effective crisis management. Governance-focused incentives ensure accountability and maintain public trust in challenging circumstances. Approach to integrating SDGs in ESG-based remuneration is presented in **Table 9.3**.

Table 9.3 Approach to integrating SDGs in ESG-based remuneration

Dimension	Relevant SDGs	Proposed ESG metrics for remuneration
Environmental	SDGs 13, 15	– reduction in carbon emissions; – implementation of energy-efficient practices; – ecological restoration (reforestation, soil remediation)
Social	SDGs 8, 10	– initiatives for employee well-being (mental health, safety, job protection); – hiring from vulnerable groups; – community rebuilding and aid
Governance	SDG 16	– ethical leadership metrics; – adherence to human rights and labor standards; – transparency in crisis management and supply chain practices
Reconstruction	SDGs 9, 11	– strengthened public trust; – improved corporate accountability; – effective crisis preparedness and operational continuity

Source: analysis based on [19, 20]

These global examples indicate how ESG-based remuneration strategies can be applied effectively in crisis contexts, offering lessons for Ukraine. Japanese practices in environmental risk management could inspire Ukrainian companies to tie executive compensation to ecological restoration and sustainable rebuilding. Governance reforms aimed at transparency and ethical practices in Brazil serve as a model for Ukrainian companies seeking to support public trust and accountability amidst the ongoing crisis. By integrating these ESG-based practices, Ukrainian companies can reinforce corporate resilience and contribute to national recovery efforts. Such alignment of executive incentives with critical social and environmental needs will help Ukrainian businesses play a meaningful role in rebuilding and supporting the country's long-term stability.

9.5 Conclusions

The corporate governance landscape in Ukraine reflects a dynamic evolution driven by the need to align with international standards and adapt to specific socio-political challenges. This research highlights the progress Ukrainian companies have made in formalizing corporate governance structures, mainly through the adoption of boards of directors and advisory boards. UCGA & Gradus data indicates that while most companies have formal governance frameworks, further improvements are necessary, particularly in increasing the representation of independent directors to bolster objectivity and governance transparency. SOEs' governance reform is a critical element of Ukraine's economic context, marking progress toward compliance with OECD principles. Legislative advancements, notably Law of Ukraine No. 3587-IX 2024, have established a robust framework for SOEs, focusing on transparency, accountability, and the clear delineation of state roles. These reforms enhance the strategic oversight capabilities of boards and emphasize performance-based accountability mechanisms, which are crucial for reducing corruption risks and attracting foreign investment. However, challenges remain, particularly in maintaining the independence of boards and safeguarding them from political influence. Incorporating ESG-based remuneration further indicates Ukraine's commitment to aligning corporate governance with sustainability principles. Linking executive compensation to ESG metrics presents an opportunity for Ukrainian companies to prioritize long-term value creation, addressing critical environmental, social, and governance issues amidst the nation's crisis context. This alignment promotes ethical leadership and accountability and positions companies as resilient and socially responsible entities capable of contributing to national recovery efforts. From global examples of crisis-driven ESG strategies, Ukrainian companies may benefit from adaptive and flexible ESG targets that balance immediate operational needs with sustainable growth. This study concludes that corporate governance reforms and ESG-based strategies are essential for enhancing Ukrainian companies' resilience and competitiveness in the global market. Continued efforts are required to fully implement OECD-aligned governance practices, increase board independence, and standardize ESG-driven remuneration policies. By strengthening these governance components, Ukraine will likely enhance its appeal to investors, support economic stability, and pave the way for sustainable growth within a challenging environment. Implementing these recommendations will improve corporate governance effectiveness and contribute to Ukraine's broader economic and social development in alignment with global standards.

References

1. Tupchiienko, M. (2024). "Duzhe malo kompanii dorosly do korporatyvnoho upravlinnia". Yak prokhodyt velyka korporatyzatsiia ukrainskoho biznesu? Doslidzhennia UCGA. Forbes. Available at: https://forbes.ua/money/duzhe-malo-kompaniy-dorosli-do-korporativnogo-upravlinnya-yak-prokhodit-velika-korporatizatsiya-ukrainskogo-biznesu-doslidzhennya-gradus-10072024-22219
2. Pro vnesennia zmin do deiakykh zakonodavchykh aktiv Ukrainy shchodo vdoskonalennia korporatyvnoho upravlinnia (2024). Zakon Ukrainy No. 3587-IX. 22.02.2024. Available at: https://zakon.rada.gov.ua/laws/show/3587-20#Text
3. Korporatyvne vriaduvannia v Ukraini 2018: zvit za rezultatamy opytuvannia (2018). CGPA. Available at: https://cgpa.com.ua/wp-content/uploads/2019/04/corporate_governance_in_ukraine_ukr_1544020354_ua.pdf
4. Reforma upravlinnia derzhvlasnistiu (2024). Ministerstvo ekonomiky Ukrainy. Available at: https://me.gov.ua/Documents/Detail?lang=uk-UA&id=dd071a48-27ce-444d-9166-2ba90c89a43f&title=ReformaUpravlinniaDerzhvlasnistiu&isSpecial=true
5. Reforma korporatyvnoho upravlinnia derzhavnykh pidpryiemstv v Ukraini (2024). JurLiga. Available at: https://jurliga.ligazakon.net/analitycs/228165_reforma-korporativnogo-upravlnnya-derzhavnikh-pdprimstv-v-ukran
6. G20/OECD Principles of Corporate Governance 2023 (2023). OECD, 53. https://doi.org/10.1787/ed750b30-en
7. Pro aktsionerni tovarystva (2024). Zakon Ukrainy No. 2465-IX. 27.07.2022. Available at: https://zakon.rada.gov.ua/laws/show/2465-20#Text
8. CEE Legal Matters Comparative Legal Guide: Corporate Governance 2023 (2023). CEE Legal Matters. Available at: https://ceelegalmatters.com/Magazines/Guides/CEELegalMatters_ComparativeGuide_CorporateGovernance2023.pdf
9. Gernego, I., Petrenko, L., Lavrynenko, V., Dyba, M. (2024). Trends and Focuses for ESG Investment Support: A Cross Country Comparative Analysis. European Journal of Sustainable Development, 13 (1), 167. https://doi.org/10.14207/ejsd.2024.v13n1p167
10. Mackay, W., Xu, L. (2021). Environmental Social and Governance, Executive Remuneration, and Firm Performance. Green and Social Economy Finance. CRC Press eBooks, 10–33. https://doi.org/10.1201/9780429329326-3
11. Stern, H. J. (2020). Better bonus plans for ESG. The Journal of Total Rewards, 4/2020, 1–10. https://doi.org/10.2139/ssrn.3611652

12. Keddie, S. L., Magnan, M. (2023). Are ESG performance-based incentives a panacea or a smokescreen for excess compensation? Sustainability Accounting, Management and Policy Journal, 14 (3), 591–634. https://doi.org/10.1108/sampj-11-2022-0605
13. Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No. 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting (2022). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464
14. Matemane, R., Moloi, T., Adelowotan, M., Biswas, P. K. (2023). The use of non-financial performance metrics in determining directors' remuneration: The case of listed companies in South Africa. African Journal of Business Ethics, 17 (1), 22–44. https://doi.org/10.15249/17-1-301
15. Barontini, R., Hill, J. G. (2023). Sustainability and executive compensation. European Corporate Governance Institute – Law Working Paper, 747/2023, 1–57. https://doi.org/10.2139/ssrn.4671966
16. Goto, G. (2024). ESG, Externalities, and the Limits of the Business Judgment Rule – TEPCO Derivative Suit on Fukushima Nuclear Accident and the Expansion of Caremark. ECGI. Available at: https://www.ecgi.global/publications/blog/esg-externalities-and-the-limits-of-the-business-judgment-rule-tepco-derivative
17. 2022 Sustainability Report. Ready for Tomorrow (2022). SMC. Available at: https://www.sanmiguel.com.ph/storage/files/reports/San_Miguel_Corporation_2022_Sustainability_Report.pdf
18. 2022 Sustainability Report (2022). Suzano. Available at: https://www.suzanoasia.com.cn/en/wp-content/uploads/2023/04/Suzano-Sustainability-Report-2022-EN-1.pdf
19. Kørnøv, L., Lyhne, I., Davila, J. G. (2020). Linking the UN SDGs and environmental assessment: Towards a conceptual framework. Environmental Impact Assessment Review, 85, 106463. https://doi.org/10.1016/j.eiar.2020.106463
20. Aleksin, G.; Diakon, R., Kucher, A., Heldak, M. (Eds.) (2024). Post-war reconstruction in Ukraine within corporate finance framework: UN SDG aspect. Sustainable Development and Circular Economy: Trends, Innovations, Prospects. Riga: Baltija Publishing, 344–371. https://doi.org/10.30525/978-9934-26-390-3-16