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THE EVOLUTION OF THE ENERGY SYSTEMS OF UKRAINE AND THE ORGANIZATION OF MANAGEMENT ACCOUNTING IN ENERGY COMPANIES IN CONDITIONS OF RISK

An essential prerequisite for the development of Ukraine is a rationally formed energy system that covers the electricity demand of society and assures the smooth functioning of the national economy. The study presents the characteristics of different types of power plants in Ukraine, such as thermal, hydraulic, nuclear, geothermal, and tidal. Furthermore, the share of Ukraine's contribution to the energy supply of other countries is indicated.

Today, the United Energy System of Ukraine is one of Europe's most significant energy complexes with seven regional electric power systems (REES), including Dnipro, Western, Crimean, Southern, Southwestern, Northern, and Central. The research presents the structure of electricity consumption by consumer groups in Ukraine. It indicates the extent of the destruction of Ukraine's energy capacities by Russia's invasion. The issue of developing electricity production from alternative energy sources in Ukraine is discussed.

Permanent risks and the threat of destruction of energy system objects encourage managers of economic entities to carefully search for quick and accurate problem-solving tools for avoiding critical situations. The accounting system, in particular, management accounting, provides the informational component that satisfies the timeliness of providing boards with recommendations on making managerial decisions. The study highlights and describes the stages of implementation of management accounting in energy supply companies in Ukraine. The effectiveness of management accounting in this aspect is emphasized.

Keywords: energy systems, energy capacities, risks, management accounting, Ukraine
JEL Codes: M40, B14, M

Introduction

The evolutionary development of the energy system of Ukraine accelerated in the 20th century. It was determined by several critical stages, including: (1) the construction of a hydroelectric power plant on the Dnipro and industrial power plants in the Donbas in 1928, the extension of energy capacities by state district power plants in 1940; (2) the devastation of power plants in 1941-1945; (3) the overhaul and modernization of diesel power plants, power trains, small hydroelectric power stations in the post-war period; (4) the integration of energy systems and most of the country's energy enterprises and organizations by the Ministry of Energy and Electrification of Ukraine in 1962; (5) launching the nuclear power

units in Chornobyl, South-Ukrainian, Zaporizhzhya, Rivne, Khmelnytsky NPPs in the 70s; and (6) Kakhovsk, Kremenchutsk, Dniprodzerzhinsk, Kanivsk HPP, and Dnipro HPP-2 starting operations in Prydniprovska, as well as, over time, in Kryvorizska, Zaporizhia, Zmiivska, Vuglegirska, and Zuyivska DRES in 1963 (Figure 1).

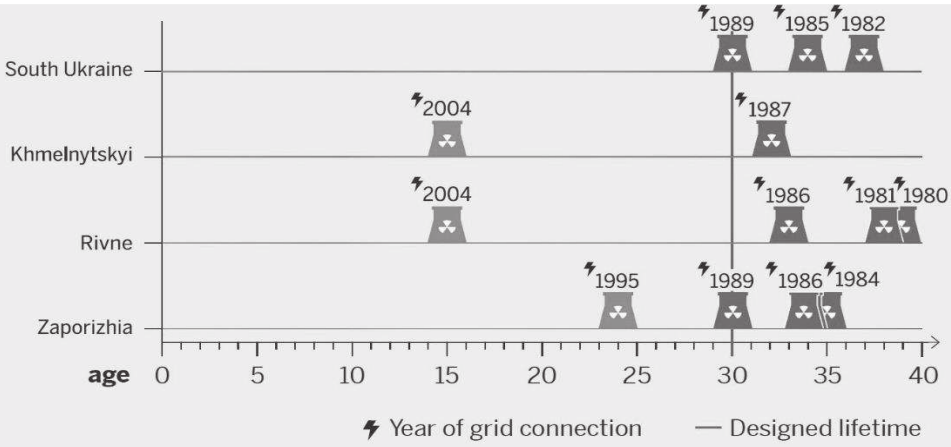


Figure 1. Age of nuclear reactors in Ukraine
Source: Age of nuclear reactors in Ukraine, Ecoaction, 2022. https://en.ecoaction.org.ua (access: 21.11.2022).

Currently, energy is strategically important for the Ukrainian economy. The country has 15 nuclear reactors located at four nuclear power plants. Their safe and stable work depends on the day-to-day uninterrupted functioning of all spheres of the Ukrainian economy.

Theoretical and historical overview

There was extensive research on the energy sector conducted in Ukraine and worldwide. Zakeri[1] examined the impacts of the entire energy system – including fuel supply, renewable energy investment, demand for energy services, and implications for energy equity – through a review of recent research and expert advice in the field and recommended policy to overcome the challenges toward achieving resilient and sustainable energy systems, driven mainly by energy services. Recently, some research work has been devoted to Russia's military aggression against Ukraine and its influence on the national energy sector[2]. Yakymchuk A.T and others[3] analyzed active methods of state energy protection in Ukraine and the world.

[1] B. Zakeri, K. Paulavets, L. Barreto-Gomez, L.G. Echeverri, S. Pachauri, B. Boza-Kiss, S. Pouya: Pandemic, war, and global energy transitions, Energies, 15 (17)/2022, 6114, https://www.doi.org10.3390/en15176114/
[2] X.-Yin. Zhou, G. Lu, Z. Xu, X. Yan, S. Khu, J. Yang, J. Zhao, J.: Influence of Russia-Ukraine war on the global energy and food security. Resources, Conservation and Recycling, 188/2023, 106657, https://www.doi.org/10.1016/j.resconrec.2022.106657/
[3] A. Yakymchuk, O. Kardash, N. Popadynets, V. Yakubiv, Y. Maksymiv, I. Hryhoruk, I., T. Kotsko: Modeling and governance of the Country's energy security: The example of Ukraine, International Journal of Energy Economics and Policy, 12 (5)/2022, p. 280-286.

At the same time, the issue of energy system accounting was studied by Göke L.[4], who discussed the current governance process to plan the energy system and the application of a comprehensive capacity expansion model to modeling framework for comparison of alternative planning approaches for a fully renewable energy system. Shapoval[5] presented studies of solar coating with a direct coolant supply.

At the beginning of the 20th century, the plan of The State Electrification Commission (GOELRO) was developed, according to which almost a third of the new energy capacities were planned to be introduced in Ukraine. In April 1928, the first All-Ukrainian Energy Congress was convened, at which the electrification plan of Ukraine under the GOELRO project was discussed. In particular, the building of a powerful hydroelectric power plant on the Dnipro and industrial power plants in Donbas was confirmed.

At the end of 1940, the capacity of Ukraine's power plants was 2,630 MW, and electricity production reached 12.41 billion kWh. State district power plants, which produced more than 85% of electricity, became the basis of energy in Ukraine.

In the first period of the 1941-1945 war, the work of energy enterprises was directed mainly at meeting the needs of the front and rear. Before the occupation of Ukraine, the central part of the power plant equipment was dismantled and evacuated to the east. The remaining equipment was destroyed.

In the first post-war years, the shortage of energy capacities was acutely felt as diesel power plants, power trains, small hydroelectric power plants, and other means had to be used. The reconstruction of power plants was simultaneously carried out with their technical improvement and the use of advanced scientific and technological achievements at that time. Equipment with high steam parameters was introduced, and automation of production processes and control of unit operation modes were used.

The rapid growth of residential and industrial construction, science, and technology characterized the next development period of Ukraine's economy. In 1962, Ukraine's Ministry of Energy and Electrification was created, which united all energy systems and most energy enterprises and organizations.

In the 70s, the commissioning of nuclear power units with RBMK and VVER reactors (Chornobyl, South-Ukrainian, Zaporizhzhya, Rivne, and Khmelnytsky NPPs) took place. The further development of power grids of all voltage classes from 0.4 to 750 kV made it possible to combine all energy systems into a single powerful energy system. A cascade of hydroelectric power stations on the Dnipro was created at an accelerated pace. From 1950 to 1980, Kakhovsk, Kremenchutsk, Dniprodzerzhinsk, Kanivsk HPP, and Dniprovsk HPP-2 were built.

In 1963, the 300 MW power units were put into operation at Prydniprovska and later at Kryvorizska, Zaporizska, Zmiivska, Vuglegirska, and Zuivska DRES. Every year, the energy capacity of Ukraine has been constantly increasing. In 1999, the President of Ukraine formed the Ministry of Fuel and Energy of Ukraine by combining the Ministry of Energy, the Ministry of the Coal Industry, the State Department of Electric Power, the

[4] L. Göke, M. Kendziorski, C. Kemfert, C.V. Hirschhausen: Accounting for spatiality of renewables and storage in transmission planning, Energy Economics, 113/2022, https://www.doi.org/1 0.1016/j.eneco.2022.106190/

[5] S. Shapoval, N. Spodyniuk, O. Datsko, P. Shapoval: Research of efficiency of solar coating in the heat supply system. Pollack Periodica, 17 (1)/2022, p. 128-132, https://www.doi.org/1 0.1556/606.2021.00420

State Department of the Oil, Gas, and Oil Refining Industry, and the State Department of Nuclear Energy, was formed (Figure 2).

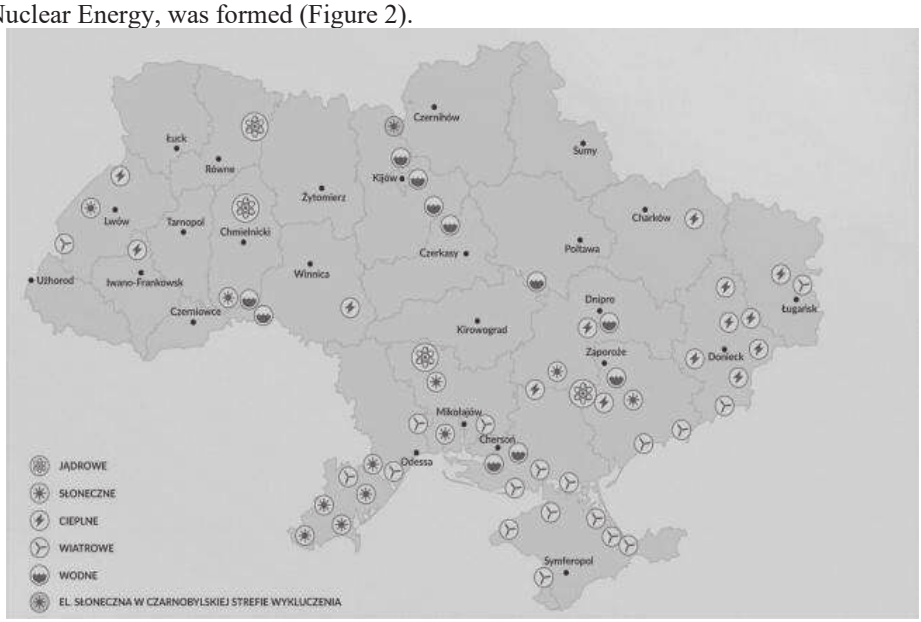


Figure 2. Power stations of Ukraine – overview map
Source: System energetyczny Ukrainy, Biuro PTPiREE, 2022, https://e-elektryczna.pl/rynek-i-regulacje/system-energetyczny-ukrainy/ (access: 08.11.2022).

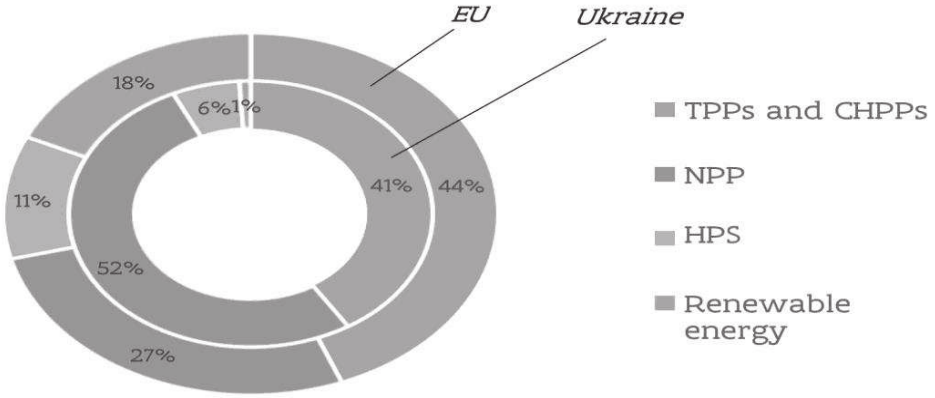
Research methodology

The research is based on methods of scientific knowledge, retrospective analysis, systematization, comparison, grouping, synthesis, and generalization when formulating and scientifically substantiating research results.

The research utilizes the method of scientific knowledge. Historical and systemic approaches were used to highlight the processes of evolutionary development of the energy system of Ukraine; the method of generalization was applied to generalize and highlight the classification features of power plants; for the study of statistical material on electricity consumption in Ukraine, methods of analysis and synthesis; to assess the destruction of energy system objects, methods of observation and generalization; for the visual display of research results, calculation-analytical and graphic methods; to standardize the stages of implementation of management accounting in energy supply companies of Ukraine, the forecasting method.

Empirical findings

The energy industry in Ukraine forms a massive part of the country's economy. Historically, Ukraine played one of the leading roles in the energy supply for its population and other countries. Figure 3 presents the electricity production structure in Ukraine compared to the EU. However, it is difficult to determine the optimal electricity generation structure as energy sectors in each country have their peculiarities and challenges.



*TPP – Thermal power plants
CHPP – Combined heat and power plants
NPP –Nuclear power plants
HPS – Hydroelectric power plants

Figure 3. Structure of electricity production in Ukraine and the EU in 2020, %*
Source: International Energy Agency, State Statistics Service of Ukraine. Eurostat.

Today, the United Energy System of Ukraine (UES) is one of the most significant energy actors in Europe – which includes seven regional electric power systems (REES) of Dnipro, Western, Crimean, Southern, South-Western, Northern, and Central –interconnected by system-forming and power transmission lines (LEP) of 750 kV and 330-500 kV.

In December 2021, the volume of electricity production by power plants of the UES of Ukraine amounted to 15,251 million kWh, decreasing by 30 million kWh (or by 0.2%) compared to December 2020 (Figure 4).

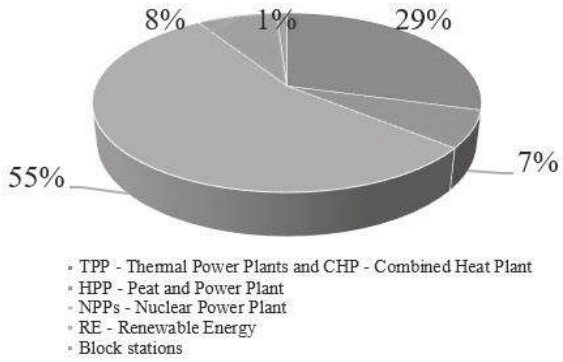


Figure 4. Structure of electricity production in the United Energy System (UES)of Ukraine in 2021
Source: About the main indicators of the work of the PEK of Ukraine for January-December 2021, NGO Scientific and Technical Union of Power Engineers and Electrical Engineers of Ukraine, Kyiv 2022, p. 83.

In 2021, there was an increase in gross electricity consumption, which amounted to 154,857.6 million kWh, which was 8,422.8 million kWh or 5.8% more than last year.

In December 2021, electricity consumption increased by 8,422.8 million kWh (or 5.43%) compared to December 2020, which amounted to 154,857.6 million kWh. Net electricity consumption by the branches of the national economy and the population in December 2021 constituted 125,654.8 million kWh, which is 7,748.0 million kWh (or 6.16%) more than the same indicator in 2020 (Table 1).

Table 1. The structure of electricity consumption in Ukraine (2021)

Groups of consumers	Consumption in 2020	Consumption in 2021		Specific weight, %	
	million kWh	million kWh	+/-	2020	2021
Electricity consumption (gross)	**146,434.8**	**154,857.6**	**8,422.8**		
Electricity consumption (net)	**117,906.8**	**125,654.8**	**7,748.0**	**100.0**	**100.0**
1. Industry (total)	49,307.4	52,392.0	3,084.6	41.8	41.7
Fuel	3,232.2	3,270.9	38.7	2.7	2.6
Metallurgical	27,134.9	28,965.1	1,830.1	23.0	23.1
Chemical and petrochemical	4,156.1	4,331.6	175.5	3.5	3.4
Machine building	3,163.6	3,559.5	395.9	2.7	2.8
Building materials	2,333.2	2,674.9	341.6	2.0	2.1
Food and processing	4,341.4	4,401.8	60.3	3.7	3.5
Another one	4,946.0	5,188.3	242.3	4.2	4.1
2. Agricultural consumers	3,796.9	3,695.4	-101.5	3.2	2.9
3. Transport	5,712.5	6,159.4	446.9	4.8	4.9
4. Construction	956.8	1,069.7	112.9	0.8	0.9
5. Com.-household consumers	14,195.8	14,967.9	772.2	12.0	11.9
6. Other non-industrial consumers	7,383.2	8,591.9	1,208.7	6.3	6.8
7. Population	36,554.1	38,778.5	2,224.4	31.0	30.9

* (without taking into account the temporarily occupied territories of the Republic of Crimea, the city of Sevastopol, Donetsk, and Luhansk regions)

Source: History of energy, Ministry of Energy of Ukraine, 2022, https://www.mev.gov.ua/storinka/istoriya-enerhetyky/ (access: 11.11.2022).

On March 16, 2022, a historical event occurred as the Ukrainian power system was finally disconnected from the power grid of Russia and Belarus. Against the background of the Russian invasion, more than a year ahead of schedule, the energy system of Ukraine was fully synchronized with the power grid of continental Europe ENTSO-E[6].

Since 2014, Ukraine has been in a state of war, with a full-scale Russian invasion on February 24, 2022. Specific solutions have already been introduced and worked out in the territories of Ukraine. During the conflict, Ukraine suffered significant destruction in the electric power sector as the energy sector became one of the main targets of Russia's military aggression. Therefore, at the beginning of the invasion, 57% of TPP capacity (17.4 GW) was under direct threat of destruction, and 27% (8.2 GW) were located in areas adjacent to where military actions for the defense of Ukraine took place. The situation was similar in renewable energy (RES), with more than 75% or 6.4 GW of Ukrainian RES capacity being in the risk zone, 47% of RES or 3.9 GW in the regions where military actions took place, and 29% or 2.4 GW in adjacent areas. Therefore, starting on February

[6] History of energy, Ministry of Energy of Ukraine, 2022, https://www.mev.gov.ua/storinka/istoriya-enerhetyky/ (access: 09.11.2022).

24, 2022, Ukraine introduced several regulatory changes in the energy field designed to stabilize the industry and solve critical problems.

Moreover, Ukraine lost control over the 6 GW Zaporizhzhya nuclear power plant. It faced new challenges such as threats of nuclear terrorism and considerable damage to critical infrastructure, including electricity and gas networks[7]. According to the latest published data, the destruction of the Kakhovskaya hydroelectric power station containing about 19 million cubic meters of water could lead to the flooding of 80 settlements, including the regional center of Kherson. As a result, an artificial ecological disaster would eliminate the possibility of supplying water from the Dnipro to Crimea since the North Crimean Canal would disappear in the event of the destruction of the dam. The following critical dates for the energy sector were October 10-19, 2022, since Russia damaged 30% of Ukraine's energy infrastructure after mass shelling (Figure 5). As a result, a large amount of primarily thermal electricity generation, which was maneuverable and allowed for a rapid increase in production volumes, was lost. Part of it was restored, but on October 20, 2022, starting a heating period began throughout Ukraine. Still, the government of Ukraine was forced to carry out fan power outages in the country's northern, central and eastern regions to stabilize the energy supply.

The decision of the Cabinet of Ministers of Ukraine to suspend the export of electricity due to the Russian attacks on the infrastructure facilities of Ukraine had a negative effect on European countries because it was the Ukrainian electricity supplied to Poland and Moldova that helped reduce dependence on Russian gas.

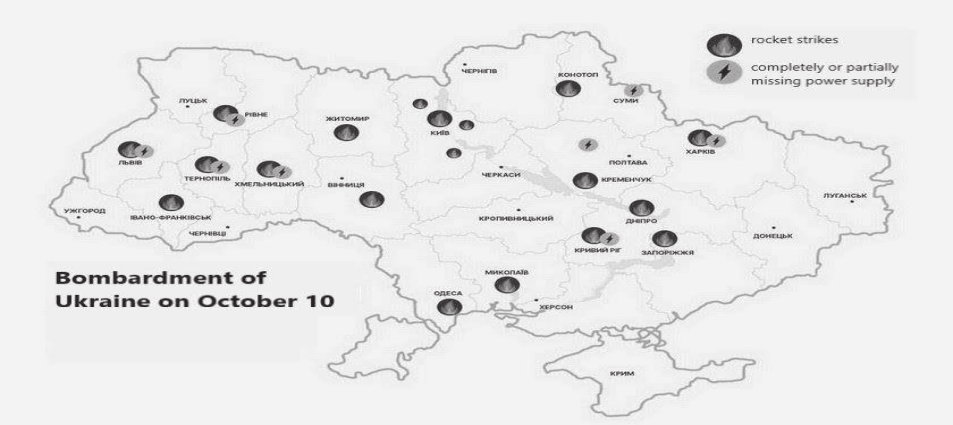


Figure 5. Attacks on the energy structure of Ukraine for 10.10.2022
Source: Ukrainians are asked to limit electricity consumption on the evening of October 10, Zhytomyr.info., 2022, https://www.zhitomir.info/news_210164.html/ (access: 15.11.2022).

One of the ways out, of course, in times of peace would be in-depth financing for obtaining energy from renewable sources (RES). Due to its size and diversity of natural

[7] Energy during the war in Ukraine: what changes in regulation? Jurliga, 2022, https://jurliga.ligazakon.net/aktualno/12602_energetika-pd-chas-vyni-v-ukran-yak-zmni-v-regulyuvann (access: 21.10.2022).

landscape, Ukraine has a significant potential for alternative energy production. Renewable energy sources have attracted considerable interest, but they accounted for only 1.3% of energy production in Ukraine in 2016, with another 6.1% coming from large hydroelectric plants. However, after the occupation of Ukrainian territories by Russia, control of 75% of RES was lost.

In the pre-war period, the Ukrainian alternative energy sector was considered the largest international player and one of the fastest-growing and most attractive European markets among developing economies. It was planned to build powerful solar power plants in the Chornobyl Exclusion Zone.

For many years, Ukraine has been making efforts to stimulate the generation of electricity from alternative sources of energy financially. Such stimulations resulted in legislative provisions for feed-in tariffs, i.e., the guaranteed obligation of the state to purchase generated 'green' power from alternative energy producers. The following types of RES were eligible for the green tariff: wind, solar, biomass (originating from waste, as well as remains of agriculture and forestry sectors), biogas, micro-/mini-/small hydroelectric power plants, and geothermal energy. However, placing renewables differently has no significant effect in the Ukrainian case because the available potential must be exploited almost entirely, leaving little room for optimization. Furthermore, sensitivity to the first-best scenario entirely prohibiting additional transmission lines suggests that grid expansion can be substituted at tolerable costs[8].

Below is the map showing the geography of the commissioned and the potential RES projects in Ukraine by type of RES (Figure 6).

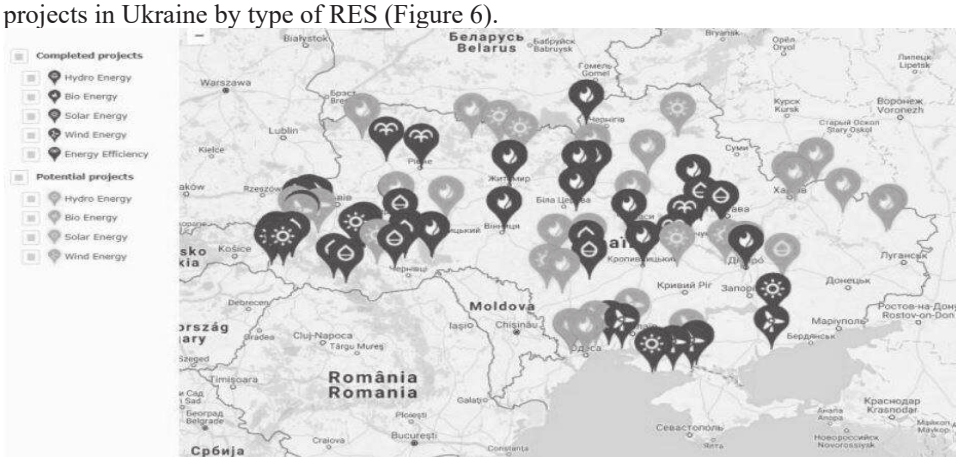


Fig. 6. The commissioned and potential RES projects in Ukraine
Source: Baker&McKinsey, https://www.bakermckenzie.com/ (access: 02.12.2022).

Comparing graphs and charts of Ukrainian energy production with indicators of European countries, one can pay attention to Denmark, Estonia, and Germany, where the most significant amount of renewable energy (new RE) among European countries was

[8] L. Göke, M. Kendziorski, C. Kemfert, C.V. Hirschhausen: Accounting for spatiality of renewables and storage in transmission planning. Energy Economics, 113/2022, https://www.doi.org/10.1016/j.eneco.2022.106190/

located. Ukraine should consider the experience of these countries and adopt appropriate steps to improve its energy capacity (Figure 7).

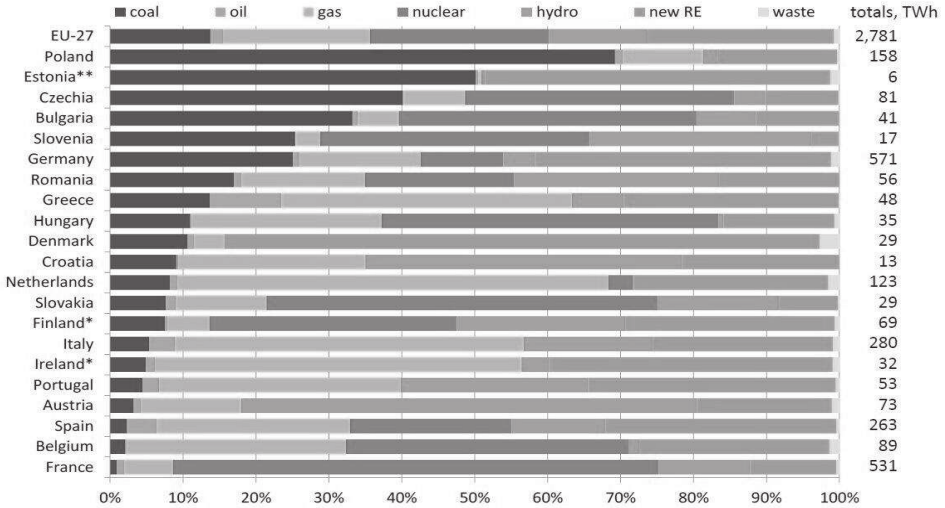


Figure 7. Energy mix for EU electricity generation, 2020
Source: Eurostat database nrg_bal_peh, https://euracoal.eu/info/euracoal-eu-statistics/ (access: 14.04.2022).

Constant risks, conditions of uncertainty and threats of destruction of energy system objects encourage business entities at the macro-, meso- and micro-levels to respond quickly. These events require managers of all levels to solve tasks rapidly and without errors to avoid critical situations. In this chain, the accounting system – in particular, management accounting – provides the informational component that satisfies the timeliness of providing management with recommendations for making management decisions.

Management accounting is entirely subordinate to the requests of the company's management. Its effectiveness is ensured by focusing on specific economic tasks, the solution of which is based on relevant information about expenses and income[9].

In Ukraine, the place of management accounting largely depends on which concept, American or European-continental, the company uses. The European-continental concept of management accounting, identified with the organizational idea of controlling, is mainly implemented in Ukrainian enterprises. It is pretty natural, given the similar definition of accounting in Europe and Ukraine[10].

The analysis of financial and organizational approaches to the introduction of management accounting at Ukrainian enterprises, particularly at energy supply companies, made it possible to identify the stages presented in Figure 8.

[9] S.O. Levitska, I.V. Stovpovets: Administrative (internal) accounting of business entities: organization methodology, development prospects. Bulletin of the National University of Water Management and Nature Management, Economy. Rivne: NUVHP, 2 (38)/2007, p. 199-209.
[10] S.F. Golov: Uprawlińskyj oblik i kontrolinh: koncepciji ta zastosuwannia, Wisnyk KNTEU: Naukowo-praktycznyj żurnał, 5/2007, p. 82-87.

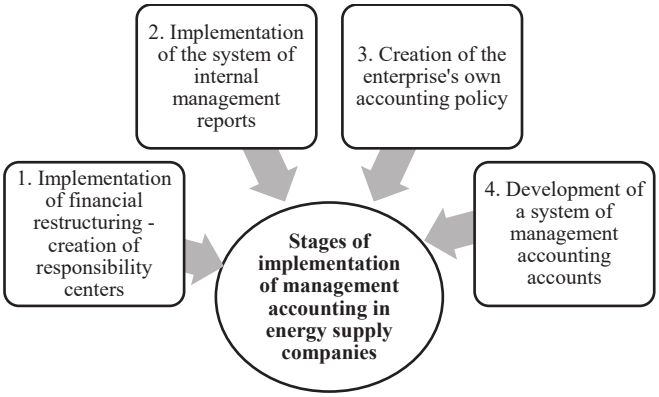


Figure 8. Stages of implementation of management accounting in energy supply companies
Source: created by the authors: I.O. Levitska: Management accounting and audit of costs for the supply and transmission of electrical energy of energy supply companies of Ukraine: Diss... candidate. Economy Sciences, 08.00.09/2015. p. 247-248.

The first stage refers to allocating four types of responsibility centers: a cost center, a revenue center (or a realization/sales center), a profit center, and an investment center (financing, supply). Taking into account the need for comparability of management and accounting indicators to ensure correct decision-making in matters of tariff formation, it is advisable to speak for expenses accounted for according to the principles of Ukrainian National Accounting Standards. The most important and appropriate for the company's management is the data obtained from the cost center – a structural unit of the enterprise in which the managers are responsible for the costs incurred during the activity.

To regulate the cost process of enterprises, including energy supply companies, it is necessary to systematically create financial reports (as a rule, in tabular form) and analyze the activity results in graphic schemes, diagrams, and drawings. It is advisable to introduce a three-level structure of management financial reports: financial reports of the first level – management balance sheet, management report on financial results, management report on the flow of funds; second-level financial reports – reports that are supplementary to first-level reports (for example, a report on receivables, a report on purchases, a report on payables, a report on expenses, etc.); third-level reports – primary financial documentation (invoices, waybills, etc.).

A prerequisite for the accounting policy is the development and consolidation of the method of accounting and grouping of enterprise costs, and the determination of the system for calculating the cost of products (goods, works, services). Furthermore, in the accounting policy, it is necessary to specify the functional distribution of management accounting in the company's departments, to determine the degree of responsibility of each of them, and to establish responsibility for the reliability and quality of management accounting in the relevant internal documents of the enterprise.

The chart of accounts of management accounting can be built following the current working chart of accounts in the enterprise, based on national accounting standards – or an alternative – following international accounting standards.

Conclusions

The United Energy System of Ukraine is one of the largest energy centers in Europe, which includes seven regional electric energy systems (REES): Dnipro, Western, Crimean, Southern, South-Western, Northern, and Central, united by system-forming and main power transmission lines (LEP). Such an infrastructure is the basis of the country's electric power industry, which provides a centralized energy supply to its consumers and interacts with the energy systems of neighboring countries, ensuring the export and import of electricity.

However, the full-scale invasion of Russia has long-term consequences for Ukraine and all participants in the energy market and the world economy, experts of the International Energy Agency (IEA). Considering the conditions of uncertainty and the risks of losing part of assets and capacities in wartime, energy supply companies of Ukraine should have specific ready-made solutions, which are provided by properly organized and effective management accounting. To achieve this priority, the following requirements should be considered:

- carrying out an economic settlement with interested parties involved in the production, transmission, distribution, and consumption of electricity;
- providing complete information to the board of directors to ensure the goals of management accounting;
- developing technological processes of management accounting to ensure the quality of accounting information and the cost-effectiveness of the process of its formation;
- referring to the specificity of the company's activities – in particular, the peculiarities of calculating the cost of electricity, accounting for the costs of transmission and supply of electricity, and determining the results of business decisions.

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Ewolucja systemów energetycznych Ukrainy i organizacja rachunkowości zarządczej w przedsiębiorstwach energetycznych w warunkach ryzyka

Streszczenie

Niezbędnym warunkiem rozwoju Ukrainy jest racjonalnie ukształtowany system energetyczny, który zaspokaja zapotrzebowanie na energię elektryczną społeczeństwa i zapewnia sprawne funkcjonowanie gospodarki narodowej. Artykuł przedstawia charakterystykę różnych typów elektrowni w Ukrainie, takich jak cieplne, wodne, jądrowe, geotermalne, pływowe. Ponadto wskazano udział wkładu Ukrainy w zaopatrzenie energetyczne innych krajów. Obecnie Zjednoczony System Energetyczny Ukrainy jest jednym z najważniejszych ośrodków w Europie, w którego skład wchodzi siedem regionalnych systemów energetycznych (REES), w tym Dniprowski, Zachodni, Krymski, Południowy, Południowo-Zachodni, Północny oraz Środkowy.

Badania prezentują strukturę zużycia energii elektrycznej według różnych grup odbiorców w Ukrainie. Przedstawiono skalę zniszczenia zdolności energetycznych Ukrainy przez działania militarne Rosji. Wyróżniono kwestię rozwoju wytwarzania energii elektrycznej z alternatywnych źródeł energii w Ukrainie.

Stałe ryzyka i zagrożenie zniszczenia obiektów systemu energetycznego motywują zarządzających podmiotami gospodarczymi do rzetelnego poszukiwania narzędzi do szybkiego i precyzyjnego rozwiązywania zadań w celu uniknięcia sytuacji krytycznych. System rachunkowości, w szczególności rachunkowość zarządcza, uzupełnia wymiar informacyjny,

zapewniając terminowość przekazywania kierownictwu zaleceń dotyczących podejmowania decyzji zarządczych. Wyróżniono i opisano etapy wdrażania rachunkowości zarządczej w spółkach energetycznych Ukrainy. Podkreślono skuteczność rachunkowości zarządczej w tym aspekcie.

Słowa kluczowe: systemy energetyczne, mocy energetyczne, ryzyka, rachunkowość zarządcza, Ukraina
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