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# DIGITAL TRANSFORMATION OF ENERGY SECTOR ENTERPRISES IN POLAND. RATIONALE AND PRACTICES

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**Purpose:** With increasing digitalization, the debate on the direction of transformation in various sectors of the economy and their ability to keep up with the changes in this area is becoming increasingly complex. The energy industry is one of the key sectors in the economy, and as such it must follow trends and adapt to changing conditions. The aim of the paper is to diagnose and assess the level of progress in digital transformation among Polish energy sector enterprises.
**Design/methodology/approach**: The research was conducted on a group of 110 entities, with a survey questionnaire. The gathered data was analyzed using descriptive statistics.
**Findings:** Although the level of employing Industry 4.0 tools in Polish energy sector enterprises is at a low level, managers recognize the importance of following the path toward digital transformation. The awareness of particular digital transformation prerequisites differs depending on the phase of the digital transformation process.
**Research limitations/implications**: Among the limitations of the research procedure, issues such as the single respondent design and the exclusion of micro entities from the research should be noted. However, the exclusion of micro entities from the analysis was intentional, and this area deserves the attention of researchers. The specificity of the functioning and organization of the activity of micro enterprises may distort the image of the sector. Referring to the single respondent design, it was assumed that in this phase of the research it is reasonable to collect individual opinions specific to a given enterprise. It would be worth extending the analysis by conducting in-depth interviews or attempting more in-depth research at the level of individual entities.
**Originality/value:** This article contributes to the knowledge of the energy sector in Poland in the context of Industry 4.0.

**Keywords:** digital transformation, digital strategy, digital transformation strategy, prerequisites for digital transformation, energy sector companies.

**Category of the paper:** Research paper.

## 1. Introduction

Today's industrial environment is being shaped by incorporating the concept of Industry 4.0. This primarily involves the digitization of production, automation and the integration of production facilities into a comprehensive supply chain (Roblek, Meško, Krapež, 2016). This concept includes full network integration and real-time information exchange. It is an umbrella term for value chain techniques and principles collectively applying cyber-physical systems, the Internet of Things and cloud computing (Ghobakhloo, Fathi, 2021).

The importance of this concept is growing in the context of a dynamically changing environment, in which it is becoming increasingly important to keep up with technological changes (Ravichandran, 2018). Digital transformation is a wide-reaching process that affects a range of industries (Shahi, Sinha, 2021), on which it has a varying influence (Torkayesh, Torkayesh, 2021). The process of digital transformation is long-term and is shaped by advancements in digitalization and information and communication technologies. These affect not only socio-economic areas, but also different fields of business (Akberdina, Osmonova, 2021). Although research that adopts a societal perspective is crucial due to the participation of communities in sustainable urban development (Huang, Yu, Peng, Feng, 2017), the digitalization process also implies a change in the roles of managers, requiring them to become leaders of digitalization (Trzaska, Sulich, Organa, Niemczyk, Jasiński, 2021). Ultimately, the onus is on executives to capture and interpret changes that are crucial to their organization (Giones, Brem, Berger, 2019).

The issue of digitalization is emerging as a key issue in the context of discussions on the transformation of energy sectors around the world. It is therefore a current research problem as well as an issue for business practitioners. The process of digitalization of the energy sector is considered not only in the macro dimension. On the one hand, it is pointed out that the changes taking place are aimed at ensuring energy security and efficiency, as well as contributing to an increased commitment to renewable sources (Chebotareva, 2021). On the other hand, the issue of progressive digitalization is raised, which also brings with it changes in business models (Trzaska et al., 2021). Given the critical importance of digitalization in business development, it is important to note the variation in digital maturity levels across regions. It has been shown that in Central and Eastern Europe, the level of digitalization is relatively low (Tutak, Brodny, Bindzár, 2021).

Among the rationales for implementing digitalization solutions is the notion that digital technologies create new opportunities for value creation along the value chain (Reuter et al., 2019). However, as digital transformation requires changes to existing business patterns that can positively translate into performance (Singh, Sharma, Dhir, 2021), not all companies are willing to embark on the path of digital transformation (Shahi, Sinha, 2021).

In view of the above, it would appear highly relevant to conduct research on the practices adopted by energy sector entities, as these enable them to implement wide-ranging transformations.

The aim of the paper is to diagnose the level of progress in digital transformation among Polish energy sector enterprises. The article is empirical in character and is the result of research conducted into the transformation of enterprise business models in the energy sector in Poland[1]. This paper presents the results of a study that aimed to identify the practices of energy companies in the area of digital transformation and the reasons therefor. With reference to the main objective, the following research questions were formulated:

1) In what phase of digital transformation are energy companies in Poland?
2) What are the rationales for the implementation of digital transformation in power companies in Poland?
3) What is the meaning of digital transformation from the perspective of the strategy of energy companies in Poland?

The paper is structured as follows. Section 2 presents a literature review, while section 3 describes the methods and research sample. The research results are discussed in section 4, and the final part of the paper provides conclusions, research limitations and directions for further research.

## 2. Literature review

### 2.1. Characteristics of the Polish energy sector

The Polish energy sector has the seventh largest production of energy in the European Union. Compared to other European Union countries, Poland ranks first in terms of hard coal extraction and export, and fourth in terms of lignite extraction. Moreover, it ranks fourth in terms of obtaining primary energy. In the years 2015-2020, there was a decrease in energy exports, while a decline in energy imports has only been observed since 2018. Energy imports still significantly exceed exports. In addition, in the years 2013-2020, a 19% increase in dependence on energy imports was observed in Poland (GUS, 2021). The demand for energy in Poland is systematically growing, however, this situation applies to all highly developed countries. Taking into account the whole of 2021, domestic electricity demand increased by 5.7% compared to the previous year (Wiśniewski, 2022). To provide a comparison to other European countries, the gross available energy per capita in Poland in 2019 amounted to 114.9 GJ, while the EU average amounted to 137.3 GJ. An increase in global consumption was

[1] The project was financed within the Regional Initiative for Excellence program of the Minister of Science and Higher Education of Poland in the years 2019-2023, grant no. 004/RID/2018/19, financing 3,000,000 PLN.

observed in 2020 compared to the previous year in the case of natural gas, renewable energy and other carriers, while there was a decrease in the case of hard coal, lignite and crude oil (Walkowska et al., 2021). In Poland, in December 2021, coal-fired power plants (76%), including lignite (28.3%) and hard coal (47.7%), had a dominant share in energy production. The third source of energy were wind farms, accounting for 11.6 percent (Wiśniewski, 2022).

In the light of the EU energy and climate policy aimed at increasing energy production from renewable energy sources and reducing carbon dioxide emissions by 80% by 2050 compared to 2006 emissions, Poland is faced with the need to make significant capital expenditure in order to reconfigure the production system (Lipski, 2016). The legal regulations of the European Union put the Polish energy industry in a particularly difficult situation. An obstacle in meeting EU requirements and standards in the energy sector is the high degree of dependence on coal. Coal fuel is the backbone of the national energy system. Therefore, in the coming years, it is not possible to abandon coal-fired energy production for two reasons. The first is that the increased demand for electricity and heat has to be met, while the second is related to the country's energy security. The main challenges that the energy sector is currently facing are the responsibility of the energy sector for climate change, and the need to ensure sufficient amounts of energy in the coming years. Such problems make it necessary for the Polish energy sector to take steps towards the development and construction of new production technologies. The current level of development of the production and transmission infrastructure in Poland has not kept pace with the changes in the environment (Szczerbowski, 2018).

Compared to the countries of Western Europe, Polish electricity infrastructure is in a poor technical condition. It is characterized by a low network density, a small number of extra high voltage lines, and above all its advanced age. The average age of power lines in Poland is estimated at 40 years, which means that it is close to being technically worn out (Jankiewicz, 2018). This fact implies not only significant energy losses, but also the risk of breakdowns and long-term interruptions to electricity supplies. The country as a whole, as well as households, are still not prepared to ensure the continuity of operation at an acceptable level in such cases. This is evidenced by incidental and small-scale interruptions in the continuity of energy supplies (Zakrzewska, Gil-Świderska, Szmitkowski, 2020). However, comprehensive transformation of the energy sector related to the reduction of the share of conventional energy based on coal in favor of new production technologies and a significant share of renewable energy requires the modernization of technological infrastructure and the implementation of innovative solutions. Resolutions related to the improvement of technological aspects of the energy sector are included in the document - "Poland's energy policy until 2040" approved on 2nd February 2021 by the Council of Ministers of the Polish government (Ministry of Climate and Environment, 2021).

Moreover, Polish energy policy also includes a departure from centralized generation towards distributed technologies, and from supplying only energy to end users towards combining innovative products. In this way, consumers will slowly become prosumers,

connected to the grid and producing more energy. In Poland, there is a noticeable increase in the use of green technologies (Pietrzak, Igliński, Kujawski, Iwański, 2021), which are becoming more and more profitable. Polish solar farms are experiencing a real boom. Poland was in first place in the European Union in terms of the growth rate of photovoltaic power, with a cumulative growth rate in 2016-2020 of 114%, while the EU average was 10.3% (Instytut Energetyki Odnawialnej, 2021). One of the most important reasons for installing photovoltaic panels is the growing interest of households in energy independence from external suppliers. Undoubtedly, green technologies are starting to compete with traditional power generation technologies, which drives the search for ongoing innovation and generates development. Further improvement of technological solutions, devices and energy storage systems is an activity that supports the spread of renewable energy in Poland and around the world (Zawadka, Pabian, Bylok, Chichobłaziński, 2015).

However, what should be underlined is that the transformation of the Polish energy sector is inextricably linked with the implementation of digital and IC technologies. Digital and mobile technologies in this sector are gaining more and more importance. A common practice among Polish energy companies is investing in implementation of intelligent metering systems and mobile applications, thanks to which their clients gain greater awareness of electricity consumption and can better manage it. According to the adopted assumptions, by 2028, 80% of households are to have remote reading meters at their disposal. The efficient functioning of a smart metering system in the energy sector is key to the implementation of prosumer energy. Furthermore, in accordance with the assumptions of the Polish energy policy, the basis of the energy system in the future will be a so-called distributed citizen energy system (Ministry of Climate and Environment, 2021). The European Commission underlines that digital technologies can unleash the full potential of flexible energy generation and consumption in various sectors, and can enable greater use of energy from renewable sources. The European Commission action plan applies not only to Poland, but to the entire European Union, and aims to help develop a competitive market for digital energy services and digital energy infrastructure that guarantee cybersecurity. Digitalization contributes not only to increasing the level of security, but also to the efficiency, availability and sustainability of energy systems (European Commission, 2021).

### 2.2. Rationale for digitalization of energy sector companies

The energy sector is one of the most important sectors of the economy, as the growing number of users of electronic devices translates into an increased demand for energy. High energy prices have an impact not only on individual companies, but also on countries and their international policies (Tutak et al., 2021). The development and implementation of new technologies and digital transformation strategies in the energy sector can help solve problems such as the growing demand for electricity and the transition to renewable energy sources (Szum, Nazarko, 2020). As a result, the importance of the energy sector continues to grow.

The application of digital technologies in this sector contributes to cost-effectiveness, increased energy efficiency, increased enterprise value and the quality of products and services (Trzaska et al., 2021).

The global energy system is transforming towards an integrated and hybridized grid, with both legacy and new technologies that can create synergies to deliver electricity to factories, businesses and homes around the world. Networking in this field is made possible by the implementation of digital transformation in various spheres of economic and non-economic activity (Paprocki, 2016).

The level of digitalization of energy sector companies is steadily increasing and is creating many opportunities, but also raising challenges. One of the rationales for digitalization of this sector is the desire to increase the transparency and security of digital platforms in the energy sector. This can be achieved by increasing innovation among companies within this sector. At the same time, it should be noted that this process brings with it some problems related to the implementation of integrated smart energy systems, in particular smart information and telecommunication technologies (Voropai, 2020).

Other rationales for digitalization of the energy sector include the need to comply with stringent regulatory requirements, the desire to reduce energy costs, and the aim to provide a real-time model for managing energy infrastructure as locations and energy sources change (Goosen, Nikitenko, Kagan, Pakhomova, 2020). Increasing profitability, efficiency and energy security are other arguments for intensifying the digital transformation process in energy companies. Furthermore, digitalization enables energy suppliers to establish direct relations with end users, who will be able to find intelligent ways of managing their energy resources. However, the main challenge and rationale behind digitalization is to transform the potentially disruptive effects of multi-source energy distribution into an efficient and profitable ecosystem (Zou, Zhao, Zhang, Xiong, 2016).

The development of new technologies, environmental changes and increased energy use are leading to fundamental changes and further growth in both the economy and the energy sector. One mega-trend that has a key impact on the development of the energy sector is scientific and technological progress associated with the emergence of breakthrough technologies in this sector, i.e. progressive digitalization. Digital transformation not only supports other trends such as decarbonization and decentralization of the energy sector, but also increases the possibilities of control, automation and optimization of all elements in the chain of production and consumption of electrical energy (Burda, Volkova, Gavrikova, Kosygina, 2019).

### 2.3. Digital transformation of the energy sector

Progressing globalization and technological changes are influencing the shape of both traditional business models at the industry level and business practice at the organizational level (Gao, Hakanen, Toytari, Rajala, 2019). The consequence of this trend is the development of strategies based on digital technologies, known as digital transformation strategies (Vial, 2019).

This results in emergence of new business models, which change products, services and operations (Chanias, Myers, Hess, 2019).

Digital transformation is defined as a new development in the use of digital artifacts, systems and symbols within and around organizations, and is seen as one of the main drivers of economic growth and sustainable development in today's business world (Litvinenko, 2020). Digital transformation strategies are based on the use of digital technologies, such as: (1) cloud computing, (2) edge computing, (3) big data, (4) artificial intelligence, (5) machine learning, (6) blockchain applications, (7) digital shadow, and (8) VR-reality (Al-Ruithe, Benkhelifa, Hameed, 2018; Kampker, Wessel, Lutz, Bildhauer, Hehl, 2020; López-Guajardo et al., 2021; Lytras, Visvizi, Sarirete, Chui, 2021; Mourtzis, Angelopoulos, Panopoulos, 2022; Munim, Balasubramaniyan, Kouhizadeh, Ullah Ibne Hossain, 2022; Schuh et al., 2020; Sestino, Prete, Piper, Guido, 2020; Tai, Ocone, Christie, Xuan, 2022).

As already mentioned, digitalization leads to changes in business models and enables a competitive advantage to be attained in various sectors, including the energy sector. In recent years, intensification has been observed of empirical research on the digital transformation of the energy sector (Giehl, Göcke, Grosse, Kochems, Müller-Kirchenbauer, 2020; Havle, Dursun, 2019; Loock, 2020; Remane, Hanelt, Wiesböck, Kolbe, 2017; Schaeffer, 2015; Weigel, Fischedick, 2019). Researchers claim that integration of energy companies with information and communications technologies will bring many benefits. As a consequence, companies aware of this fact are striving to implement the digital transformation process as a response to a rapidly changing environment (You, Yi, 2021).

The increased use of digital technologies in energy sector companies, and consequently the formulation and implementation of digital transformation strategies, has a positive impact on firms' operations by increasing the possibility of meeting the growing demand for energy and supporting the transformation towards clean and nuclear or more sustainable and renewable technologies (Sulich, Sołoducho-Pelc, Ferasso, 2022; Trzaska et al., 2021). Despite the benefits of using digital technologies and development in this area, the energy sector is adopting these practices more slowly than other sectors such as the technology, finance, insurance, media and information industries. Research conducted into the energy sector shows that the use of such technologies as automation, advanced data analytic techniques, mobile computing and machine learning have great potential to increase the effectiveness of company operations. At the same time, however, it is suggested that a great deal remains to be done in this area (Beyond the Supercycle: How Technology is Reshaping Resources, 2017). It is predicted that in order to maintain the current level of efficiency, ever more advanced digital technologies will be required as the technical realities of the energy sector become increasingly more demanding. This means that the need to absorb digital innovation in this sector is even greater than it may appear (Maroufkhani, Desouza, Perrons, Iranmanesh, 2022).

Digital transformation is a process that can be divided into specific phases. Based on research on energy sector companies, Dang and Vartiainen (2020) distinguished three phases in this process: the bootstrapping phase, the acceleration phase and the sustain phase. The bootstrapping phase is associated with creating a business environment suitable for the implementation of a digital transformation strategy, and making members of the organization aware of the need for digital transformation. The direction of changes in this phase is top-down, and their scope covers the entire organization. In the acceleration phase, the implementation of the digital transformation strategy is accelerated, and is accompanied by the delivery of tangible outcomes and the continuous increase in the company's value at an appropriate pace. The direction of changes remains top-down. The scope of changes moves from the organizational level towards the individual level. In this phase, the company uses modern information and communications technologies, processes are automated, and there is cooperation with partners and research centers to improve the product manufacturing process. The last phase – the sustain phase – means that all organization members become aware of the vision related to digital transformation, and take action to implement this vision. This means that the company's employees use and create new technological solutions. The direction of changes is both top-down and bottom-up. The scope of changes occurs both at the level of the entire organization and the level of the individual. In this phase, digital transformation becomes the foundation of the company's organizational culture.

Summarizing, it can be stated that the implementation of changes in the energy sector should take place relatively quickly. Successful transformation largely depends on the application of new technologies, such as new consumption and energy saving models. The digital transformation of the energy sector is not only inevitable, but also essential to the survival of the sector's companies. The use of new technologies in the energy sector should not be seen as a threat, but an opportunity to implement a more secure, reliable, cost-effective and low-carbon energy system (Makarov, Mitrova, Kulagin, 2021).

## 3. Research steps and sample

### 3.1. Research steps

In line with the concept of Fatma et al. (2014), the research procedure consisted of five stages. We excluded the factor analysis step due to the sector size and sample size. The research procedure was as follows (see Figure 1).

Critical analysis of the literature allowed the phases in the digital transformation process to be determined, defined in the article as levels of digital transformation, the rationale for the use of digital technologies, and the tools (technologies) of Industry 4.0. described in the previous

section. In the scale development process 12 of 13 invited experts took part in the expert survey. The experts were representatives of business practice working in the energy sector, in particular in managerial and decision-making positions. As a result of this step 6 items were excluded, 8 items were added and 19 items were reformulated. In the following part of scale development process the re-formulated questionnaire was discussed within a group of 12 academic researchers working on the problematics of the energy sector. As a result of the discussion 6 items were removed and 14 items were re-formulated. Subsequently, 4 pilot surveys were conducted in 16 companies with a view to the clarity of the formulated questions. As a results of the procedure the survey was enriched with explanations of technical terms regarding Industry 4.0 tools. Moreover, 11 items were removed, 7 items were re-formulated, and 3 new items were added. The actual research took place in the last part of the scale development process. In total, 110 enterprises were surveyed, including: 55 small-sized, 27 medium-sized, 26 large-sized enterprises.

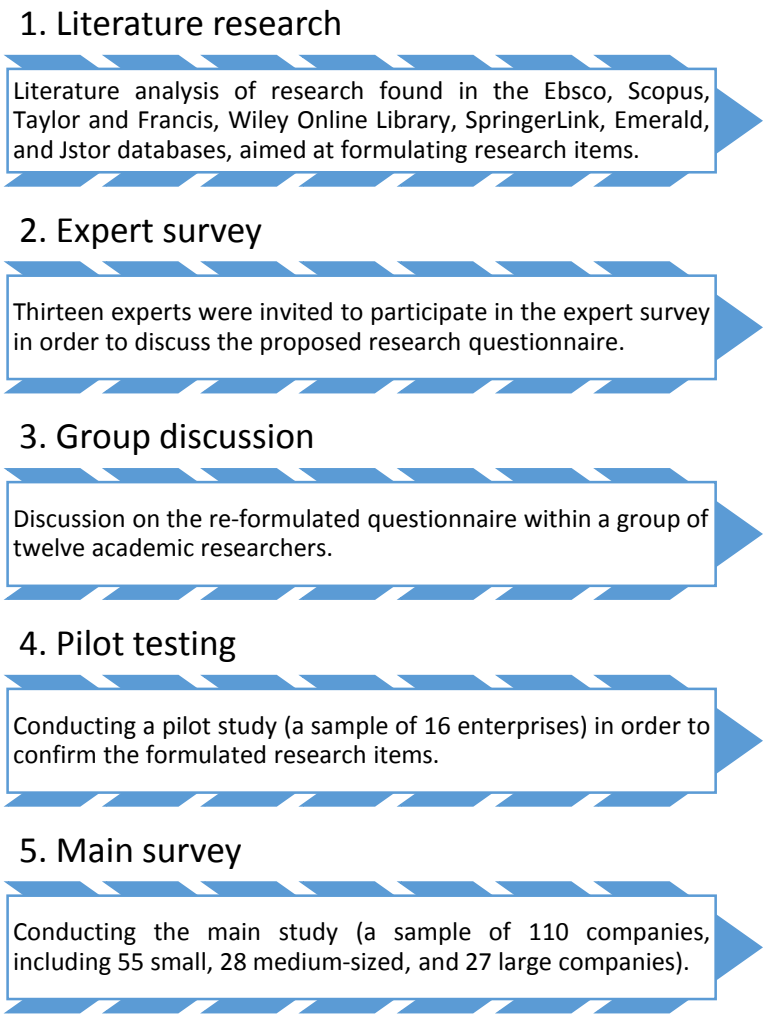


**Figure 1.** Research steps.

Source: Authors' own work, based on Fatma et al. (2014).

The respondents were asked to choose statements on a 7-point Likert scale (1 – very bad, 7 – very good) that corresponded to the level of digitalization in their company, and assess the rationale for the use of digital technologies, as well as indicate the Industry 4.0 tools used in their company. To determine the phase of digital transformation, the concept of Dang and Vartiainen (2020) was applied. After consultation with experts, a 'basic phase' was added, which characterizes companies where the management is considering implementing a digital transformation strategy in the long term, but in which it is not currently a strategic goal of the company.

The survey was conducted by a research company using the CAWI (computer-assisted web interview) method. This method was selected in order to achieve the aim of the work, as it was necessary to conduct quantitative research. Moreover, the CAWI method enables the acquisition of a relatively large sample of respondents.

The research was carried out in June 2021. The respondents were employees of energy companies holding managerial positions, with experience in the industry and knowledge in the field of research. This fact ensured reliable completion of the questionnaire. The one-respondent method was used in the study.

### 3.2. Research sample

The target group covered by the study comprises entities active in the energy sector, subclass PKD[2] 35.1: electricity generation (PKD 35.11), transmission (PKD 35.12), distribution (PKD 35.13) and trade in electricity (PKD 35.14). The activities of these entities are consistent with the implementation of the goal of energy security, which is perceived with a view to implementing the so-called full energy chain (Koczan, 2020), i.e. guaranteeing (both currently and in the long term) the security of resource supply, energy production, transmission and distribution.

Micro-enterprises were excluded from the research due to the specificity of resource management. The hallmark of microenterprises are limited human resources. The population of enterprises in the energy sector in Poland, excluding micro-enterprises, is estimated at around 180 companies. Figure 2 shows the structure of the research sample.

[2] Polish Classification of Activities.

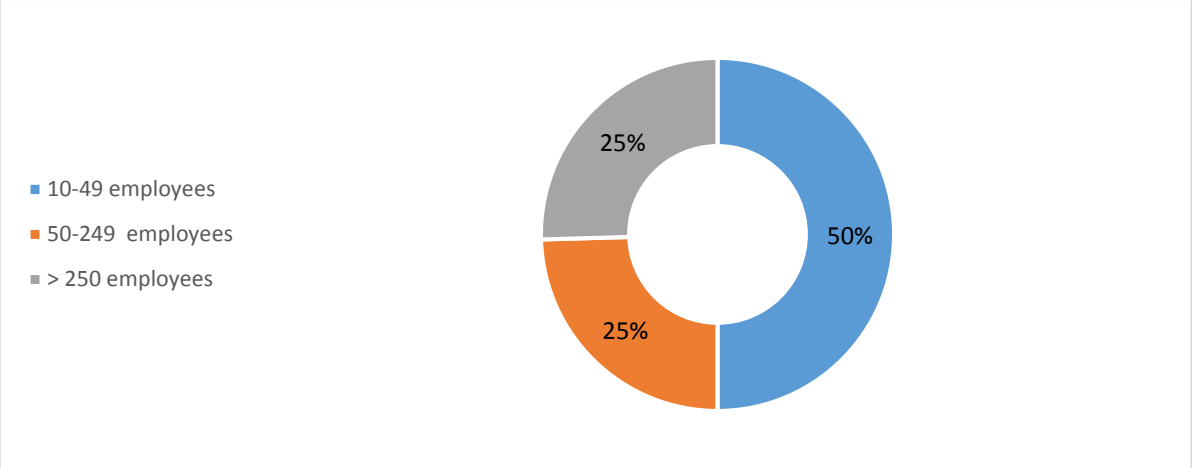


**Figure 2.** Research sample – company size (n = 110).

## 4. Results and discussion

In answer to the first research question about the phase in which energy companies in Poland currently are, it was found that energy sector companies in Poland are generally at a low level of digital transformation (see Figure 3), which is in line with the observations of Brodny, Tutak and Bindzar (2021). The majority of the enterprises studied are at the beginning of digital transformation. According to the concept of Dang and Vartiainen (2020), not even one-fifth of the entities studied have started real activities in this area.

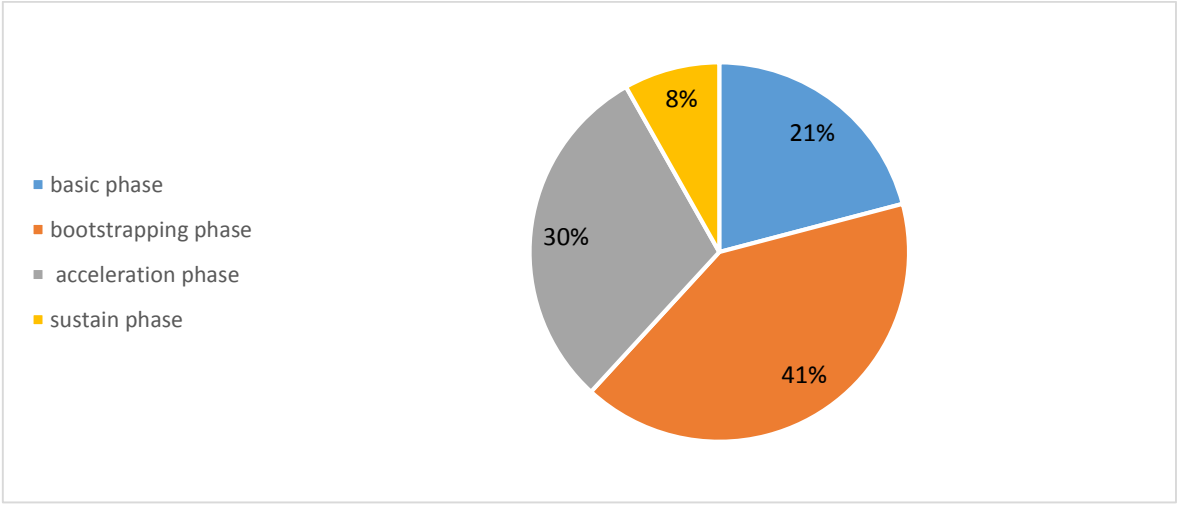


**Figure 3.** Phases of digital transformation strategy (n = 110).

A more in-depth analysis reveals that even in the group of medium-sized and large enterprises, the greatest proportion of companies are at the beginning of implementing a digital transformation strategy (Figure 4). Several indications of the 'sustain phase' among small energy companies suggest that small entities may be able to successfully enter the path to digital transformation. However, digitalization of small companies requires development of specific

digitalization capabilities (Ghobakhloo, Iranmanesh, 2021), therefore this area needs deeper scientific insight and more substantial analysis.

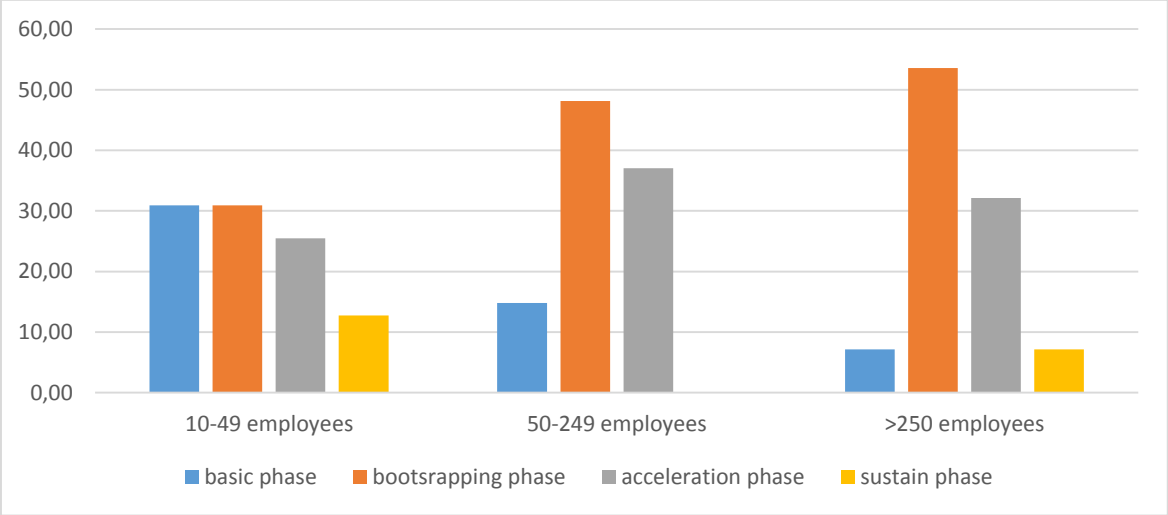


**Figure 4.** Phases of digital transformation by company size.

Despite the dominance of the initial phase of digital transformation, respondents declare that the level of preparation for the automation of processes is rather high. This observation may indicate the importance of being aware of the need for digital change. On the other hand, outdated Polish energy sector infrastructure (Zakrzewska et al., 2020) may hamper real efforts to implement digital transformation solutions.

The results shown in Figure 5 have been aggregated: indications 1-3 were considered as 'disagree', 4 – as 'neutral', while 5-7 qualified as 'agree'.

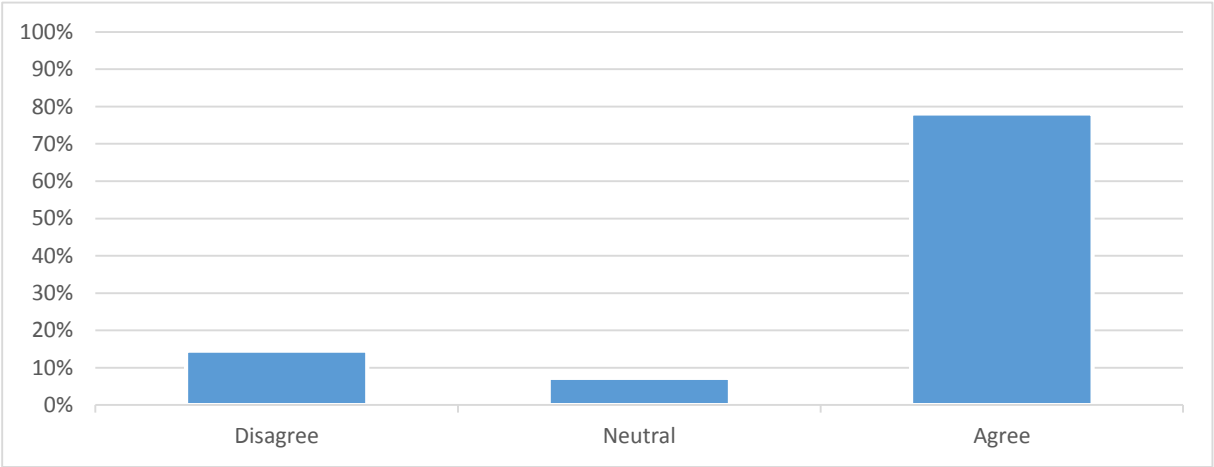


**Figure 5.** Our company is striving to digitalize and automate processes (n = 110).

Studies conducted by Polish researchers indicate the relevance of addressing the digital transformation of energy sector companies in Poland (Boichuk, 2020; Gawlik, 2018; Kiciński, 2021). This research confirms that the issue is also important for practitioners, due to the highlighted importance of implementing automation processes. When answering the second research question on the rationale for implementing digital transformation, respondents

indicated that each rationale was rather important. In-depth analysis of the answers according to the phase the company is in reveals the differences (see Table 1).

**Table 1.**
*The rationale for using digital technologies – means and standard deviations*

| | | enterprise value | customer expectations | maintenance management | energy efficiency | climate change | increase in efficiency | legislative rationale | stakeholders expectations | energy independence |
|---|---|---|---|---|---|---|---|---|---|---|
| **basic phase** | *average* | 4,65 | 4,96 | 4,39 | 4,57 | 4,87 | 5,04 | 4,48 | 4,61 | 4,74 |
| | *standard deviation* | 1,43 | 1,33 | 1,47 | 1,27 | 1,29 | 1,40 | 1,08 | 1,08 | 1,14 |
| **bootstrapping phase** | *average* | 5,42 | 5,71 | 5,29 | 5,38 | 5,16 | 5,51 | 5,27 | 5,29 | 5,31 |
| | *standard deviation* | 1,10 | 1,10 | 1,16 | 1,09 | 1,30 | 1,06 | 1,03 | 1,06 | 1,08 |
| **acceleration phase** | *average* | 5,91 | 5,91 | 5,70 | 5,82 | 6,12 | 6,03 | 5,97 | 5,85 | 5,61 |
| | *standard deviation* | 0,88 | 0,88 | 1,07 | 1,33 | 0,74 | 0,85 | 0,77 | 1,09 | 1,25 |
| **sustain phase** | *average* | 5,67 | 6,00 | 6,00 | 5,67 | 5,89 | 5,89 | 5,33 | 5,44 | 5,78 |
| | *standard deviation* | 1,58 | 0,87 | 1,12 | 1,00 | 0,78 | 0,93 | 1,58 | 1,42 | 0,83 |

When considering the importance of each rationale, the observation can be made that companies at the basic level more often ascribe lower importance to rationales such as stakeholder expectations or legislative rationales. An interesting observation is that customer expectations are a relatively important rationale for realizing digital transformation, regardless of the digital transformation strategy phase (see Figure 6).

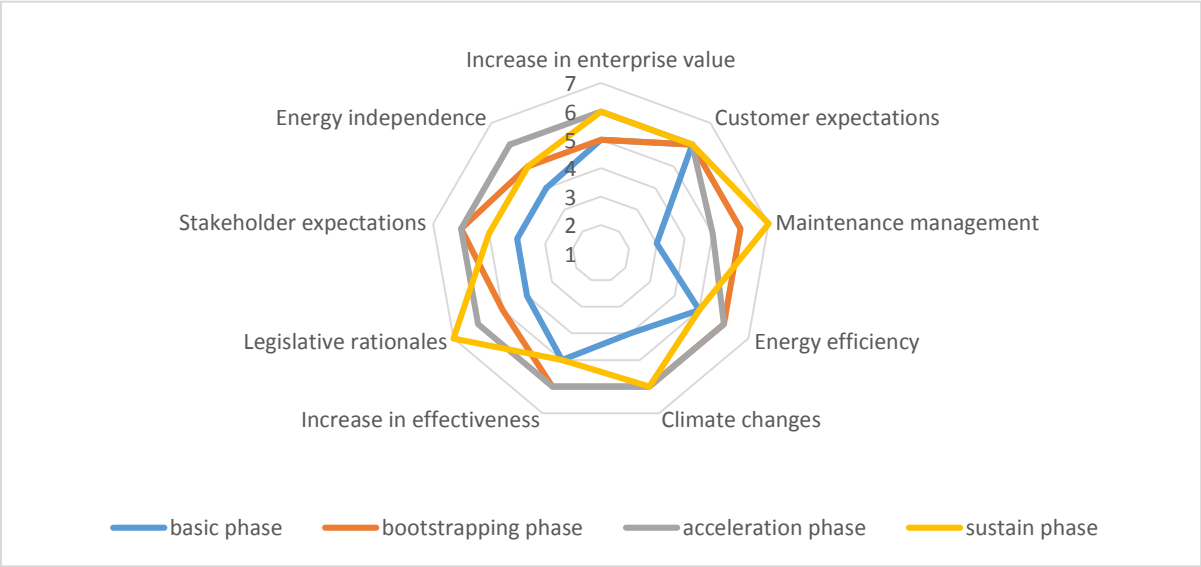


**Figure 6.** The dominant rationales for using digital technologies.

Referring to the third research question, the declared level of use of Industry 4.0 tools is in line with results indicating that the implementation of digital practices is just beginning. Although Figure 7 suggests that cloud computing tools are the most commonly used Industry

4.0 tools in energy sector companies in Poland, the level of use Industry 4.0. tools, regardless of the phase of digital transformation strategy, is low.

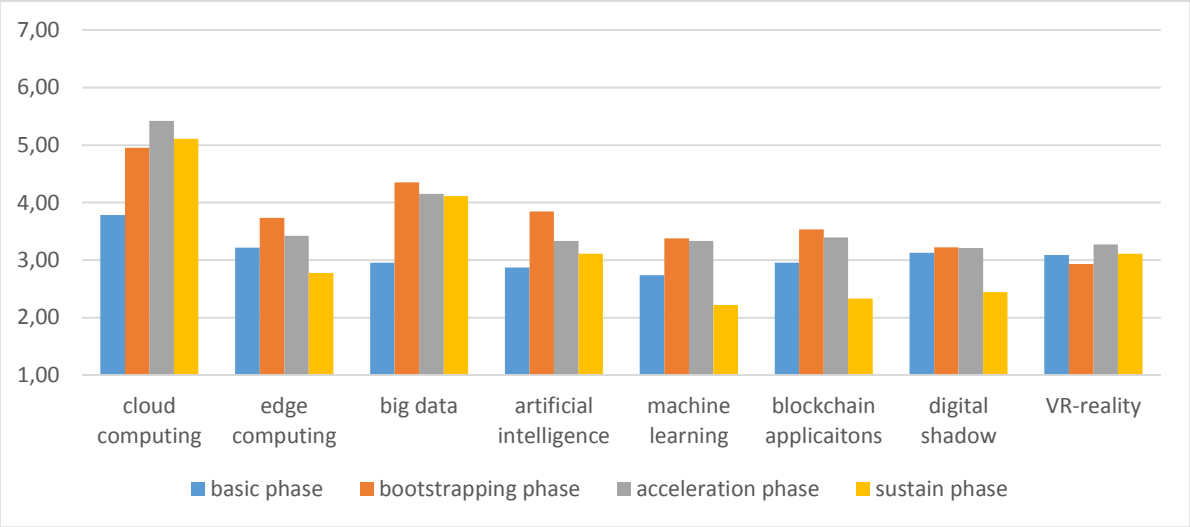


**Figure 7.** The use of Industry 4.0 tools (n=110).

**Table 2.**
*The use of Industry 4.0 tools – average and standard deviation (n = 110)*

| | | *cloud computing* | *edge computing* | *big data* | *artificial intelligence* | *machine learning* | *blockchain applicaitons* | *digital shadow* | *VR-reality* |
|---|---|---|---|---|---|---|---|---|---|
| **basic phase** | *average* | 3,78 | 3,22 | 2,96 | 2,87 | 2,74 | 2,96 | 3,13 | 3,09 |
| | *standard deviation* | *1,31* | *1,35* | *1,43* | *1,10* | *1,21* | *1,33* | *1,39* | *1,28* |
| **bootstrapping phase** | *average* | 4,96 | 3,73 | 4,36 | 3,84 | 3,38 | 3,53 | 3,22 | 2,93 |
| | *standard deviation* | *1,51* | *1,63* | *1,69* | *1,76* | *1,72* | *1,53* | *1,58* | *1,54* |
| **acceleration phase** | *average* | 5,42 | 3,42 | 4,15 | 3,33 | 3,33 | 3,39 | 3,21 | 3,27 |
| | *standard deviation* | *1,70* | *1,94* | *2,03* | *2,03* | *2,07* | *2,01* | *2,00* | *2,02* |
| **sustain phase** | *average* | 5,11 | 2,78 | 4,11 | 3,11 | 2,22 | 2,33 | 2,44 | 3,11 |
| | *standard deviation* | *1,90* | *2,28* | *2,57* | *2,20* | *1,48* | *1,94* | *1,88* | *2,26* |

## 5. Conclusions and further research directions

The research procedure provided answers to the research questions. Firstly, the results of the study show that companies in the energy sector in Poland are at the beginning of the path of implementing a digital transformation strategy, regardless of the size of the company. The outcomes are consistent with the observations of Brodny, Tutak and Bindzar (2021). Secondly, the level of use of Industry 4.0 tools confirms the low level of digitalization. Most of the respondents gave low marks to the use of particular tools. Nevertheless, in answer to the third research question, it is possible to formulate a conclusion that managers in energy

companies in Poland attribute importance to digital transformation processes. The low level of use and implementation of digital transformation strategies may be due to historical conditions, outdated infrastructure and financial constraints (Brzóska, 2016; Nogalski, Szpitter, Brzóska, 2017). Other researchers (Shabalov, Zhukovskiy, Buldysko, Gil, Starshaia, 2021; Zhukovskiy, Starshaia, Batueva, Buldysko, 2018) also point to the worn-out infrastructure as the main reason for the low level of implementation of digital transformation strategies. Światowiec and Stępień (2022) reports that the situation of the Polish energy sector compared to other EU countries looks extremely unfavorable and requires comprehensive investments in infrastructure. However, these issues require in-depth research, which points to directions for further research.

There are several limitations to this study, although these could be considered as an incentive for further research. Among the limitations of the research procedure, issues such as the single respondent design and the exclusion of micro entities from the research should be noted. However, the exclusion of micro entities from the analysis was intentional, and this area deserves the attention of researchers. Conducting research on this group of entities may broaden the picture regarding problems related to the implementation and realization of digital transformation. However, it must be taken into consideration that the specificity of the functioning and organization of the activity of micro enterprises may distort the image of the sector. Referring to the single respondent design, it was assumed that in this phase of the research it is reasonable to collect individual opinions specific to a given enterprise. It would be worth extending the analysis by conducting in-depth interviews or attempting more in-depth research at the level of individual entities.

Digital transformation research (Warner, Wäger, 2019) points out that leaders in various industries are not consistent in defining digital transformation practices. As a result, strategic thinking about digital transformation and engagement with tools takes different directions. A similar observation arises from our study, some of the research outcomes seem to be puzzling. A half of surveyed Industry 4.0. tools show a lower adaption in the ‘sustain phase’ than in the ‘basic phase’. These results are implausible and require in-depth research. Moreover, it would be worthwhile conducting research on implementing digital transformation strategies and the use of Industry 4.0 tools in the energy sector in other European countries. The development of the energy sector is not only the result of political decisions made at a European or global level, but is also affected by the level of economic development and the availability of resources.

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