

Review

# Digitalisation of Enterprises in the Energy Sector: Drivers—Business Models—Prospective Directions of Changes

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**Abstract:** The energy sector has been a pioneer in the use of information and communication technologies for many years, and has undergone enormous changes in recent years as a result of the transition resulting from the fourth industrial revolution. In the paper, we examine and analyse relevant studies and their findings in order to show the current status of research on three selected aspects of digitalisation in energy sector enterprises. The paper sheds light on the diverse drivers influencing the digitalisation processes of energy sector companies. It also provides an overview of business models that are or will soon be implemented in the energy sector thanks to opportunities offered by digitalisation in response to observed trends in the energy market. Finally, it illustrates open research challenges and future dilemmas related to various aspects of energy sector digitalisation. The paper was prepared using the critical literature review method. It covers a large volume of the most recent and relevant literature referring to the three major research areas mentioned above. The literature review allowed us to identify the drivers influencing the digitalisation of energy companies and distinguish between those specific to this sector and those relating to all businesses as a part of the more general phenomena of Industry 4.0 and Industry 5.0. We also show how the digitalisation-based business model innovation presented in the literature empowers new energy producers and consumers through business models. We have also identified the most frequently indicated challenges and dilemmas in the digitalisation of energy companies related to the risk of the destabilisation of the energy market due to decentralisation, new requirements placed on the competences of energy sector workers, the new culture of interaction between energy suppliers and consumers, and the digital security of data used in the energy system.

**Keywords:** digitalisation; drivers; business models; energy sector; changes



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## 1. Introduction

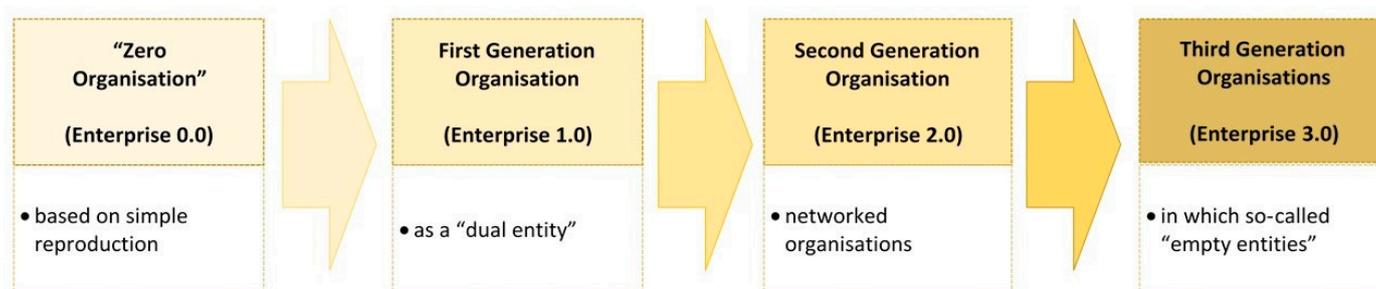
The problem of the digitalisation of firms is one of the multifaceted and multi-threaded issues which, in the context of the contemporary economy, based on knowledge and modern technologies, are an important and worthwhile discussion. Energy sector companies undergoing digitalisation are strategic entities in the economy, as the energy efficiency improvements occurring with their participation are part of the sustainable development policies of Europe and the world. Therefore, the inclusion of the two above-mentioned areas of analysis is an expression of the scientific and research inquisitiveness of the paper's authors, being part of strategic management.

In this research paper, reference is first made to basic issues such as an explanation of the terms 'digitalisation of enterprises' and 'enterprise 2.0 and 3.0', followed by a review of the literature on the drivers and business models of energy sector companies undergoing digitalisation processes. And thus the bases were created towards the linear, time-based approach towards the directions of changes in light of the emerging challenges and dilemmas in their activities. In the last part of the paper, based on logic and lateral

thinking, the above-mentioned components are combined, presenting an attempt to answer the research questions posed in this Introduction.

It should be noted that in the literature on the subject, the term ‘digitalisation’ does not have one commonly used definition. In the narrow sense, digitalisation is the processing of analogue data into digital form, but in the broader sense, it is a multi-stage process: the identification and selection of documents (information, knowledge), their preparation and ordering, collecting basic metadata, digital conversion, quality control of copies and metadata, providing the user with access to digital documents, the maintenance of digital copies and metadata, backup copies and planning for the future. However, as it applies to firms, this concept is understood as the use of digital technologies related to the configuration of their business models to ensure new opportunities to generate value within the organisation.

As A. Manterys [1] emphasises, the multitude of realities in which human activities take place, is the constellation of different arrangements and orderings. For the traditional market, a specific dualism can be seen, which, however, is not reflected in the virtual market, which requires analysis in different categories. It should be mentioned here that enterprises, which are market entities, have undergone a kind of evolution (Figure 1).



**Figure 1.** Evolution of market entities. Own-study based on [2] (pp. 21–22), [3,4], [5] (p. 33), [6,7].

This evolution included successive stages, namely [2] (p. 21):

- starting with so-called “zero organisation”, based on simple reproduction (e.g., family farm of an “original” farmer or hunter);
- through the first-generation organisation, as a dual entity, functioning according to the firm- the environment principle;
- through second-generation firms, i.e., 2.0 (networked organisations), using in their operations collaborative technologies such as web services, P2P networking, collective intelligence, social networks, blogs, RSS feeds, wikis and mash-ups [3,4], [5] (p. 33);
- ending with third-generation organisations (enterprise 3.0) in which so-called “empty entities” exist, both inside and in the environment of such entities. 3.0 Enterprises are based on a flow arrangement, i.e., ‘being in the flow’, where values for and from the customer are composed on the basis of the creation and annihilation (or at least slowing down of transfers) of information and knowledge flow [6,7].

We agree with D.J. Hołodnik and K. Perechuda that networking breaks the traditional dual arrangements, such as “profit-loss, effective-ineffective, good-evil” [2] (p. 22). Of course, this does not mean that there are none, but the boundaries between them are slowly blurring, which is influenced by asymmetry and the excess of information (particularly tacit information) between corporations and skilfully dosed “information junk” for the masses (customers and consumers). The confusion and disorientation of an average customer/consumer in the context of the excess of information, in the absence of appropriate tools to process them, forces them to search for specialists who are able to offer them adequate digital services, both information and process-service ones, being part of the characteristics of 2.0 enterprises [8].

In contrast to 2.0 enterprises, the next generation is de-networked, de-empowered enterprises, based on the humanistic paradigm, which is the context of the density of infor-

mation, knowledge, technological, capital and other densities of contemporary corporations find their place to operate where further network cooperation is not possible—corporations reach the so-called Break-Event-Point of their networking process. However, the management of 3.0 enterprises requires totally new managerial skills, as well as the adoption of a new development perspective [9] (p. 172), for which, however, the majority of modern businesses are not ready yet. Consequently, we can still observe the creation and development of strategies characteristic of 2.0 enterprises [10].

The functioning conditions of 2.0 enterprises focus attention on strategic risk, competition strategy, as well as social sensitivity [11]. The analysis of the critical factors of their development is, in this aspect, an element of the strategy the formulation and adoption of which depends on the position of the enterprise in the network, its network capacity (value creation in the form of a network advantage, relational abilities, as the network participant which favours capturing values [12].

As D.A. Johnston, M. Wade and R. McClean [13] rightly observe, adaptation to the conditions of e-business functioning may be expressed in tangible financial results. However, profits gained may be different depending on the region, type of industry/business sector, as well as the company size class. It can therefore be assumed a priori that there are specific differences in digitalisation:

- enterprises functioning in markets with developed digital structures (developed countries) compared to those which operate in developing countries or in third-world countries;
- industrial firms in comparison with purely commercial or service ones;
- large corporations compared to SME sector companies (in terms of time, scope, finance, etc.).

As P. Depaoli, S. Za and E. Scornavacca [14] indicate, “digital business solutions are commonly adopted with the goal of improving firms’ performance”. It results from the fact that investment in technologies is one of the key decisions in the context of enterprise strategic operations, transforming its organisational activities, as well as deeply penetrating its broadly understood competitiveness and development. It was also a premise to undertake theoretical research based on the literature of the subject.

## 2. The Concept of Research and Its Methodology

The aim of this paper is to review the existing research on the drivers and business models, as well as prospective directions of changes in the energy sector enterprises in the context of their digitalisation. Due to the revealed cognitive gaps, the authors of the paper formulated the following research questions:

1. Among the drivers of enterprise digitalisation, can we identify those which are universal for all businesses and those which are characteristic of only energy sector firms?
2. Which innovative business models in the energy industry are being or will be actively implemented in the near future due to digitalisation as a response to current trends in the energy market?
3. What prospective directions of changes will determine the paths of development for the energy sector enterprises in the nearest future?

We selected keywords from three broad areas, such as drivers, business models and prospective directions of changes in the enterprises of the energy sector to identify research papers that would help to answer the above-mentioned research questions. We searched using the title, keywords and abstract fields according to the searching database. We used Scopus, Google Scholar, Science Direct and Emerald databases as these provided papers that were the most relevant to our research. The time range of the cited scientific sources included, in the vast majority, publications from the last 5 years concerning enterprises in the energy sector.

The methodology of the theoretical research undertaken, in terms of the literature review, was selected in such a way as to enable an objective and structured approach to the study of factors, or more precisely, determinants (drivers), business models and prospective directions of changes in the field of the studied phenomena related to the digitalisation of energy sector enterprises. Therefore, the following research methods were adopted, broken down into research stages:

1. Generating information—based on keywords searched in scientific databases;
2. Collecting and selecting information (scientific publications);
3. Coding based on the thematic criterion (digitalisation of energy sector enterprises) and date criterion (the date of articles, monographs and other scientific studies publication);
4. Organising information by research areas, i.e., in terms of factors, and in particular, determinants (drivers), business models and prospective directions of changes, as well as detailed issues in these areas;
5. Analysing and drawing conclusions.

Taking into account the type of research, it should be emphasized:

- the theoretical and cognitive nature of the research undertaken;
- the scope of theoretical, thematic considerations focused on the digitalisation of enterprises in the energy sector;
- types of research methods used, referring to scientific research methods in the field of empirical sciences;
- the type of reasoning adopted, i.e., deductive reasoning, based on the compatible direction with the result.

As a result, the adopted research methodology allowed for the total compilation of 93 bibliographic items, while the research limitations apply to the adopted four databases indicated above. However, it should be emphasised that the selection of these databases was dictated by the citation rate of their publications and recognition in the scientific community.

The purpose of adopting the research methodology defined in this way was to systematize and also to synthesize the current state of knowledge in this field, and after proper research, it should allow [confirmation or contradiction] and/or extension of the answers to the research questions posed. Thus, the authors' contribution, resulting from the conducted literature research, concerns the systematization and synthetic presentation of the current state of knowledge in the field of the digitalisation of energy sector enterprises, taking into account the detailed issues of factors, including determinants (drivers), business models and prospective directions of changes.

The added value of this paper is the attempt to investigate possibly the most comprehensive appraisal, based on domestic and foreign literature, in the area of social sciences at the scope of relationships between the drivers of digitalisation, new innovative business models of the energy sector enterprises emerging as a result of adapting to changing operating conditions, made possible to introduce digital technologies and the prospective directions of their changes in light of contemporary challenges and dilemmas in their operations.

### **3. The Drivers of the Digitalisation in the Energy Sector Enterprises**

Beginning in the 1960s, common regulations concerning the activities of energy sector enterprises operating in the EU market began to be introduced. They were included in the "founding treaties": the establishment of EURATOM and the European Coal and Steel Community, followed by the establishment of the International Energy Agency in 1974. In turn, the Single European Act (1986) contributed to research on the European energy sector. The first directives on the liberalization of the energy market were adopted in 1996 (First Energy Package). The Energy Charter Treaty (1998) established a framework for energy investment, trade in energy commodities and energy distribution. The second energy package was adopted in 2003 and the third in 2009, which was related to the further

liberalization of the electricity and gas markets, and in 2009 the fourth energy package was introduced, including the European Union Agency for the Cooperation of Energy Regulators (ACER). The fifth energy package (Delivering the European Green Deal) was published in 2021.

These requirements have become a challenge not only for energy sector companies because the implementation of the Common Energy Market has a direct impact on all areas of life. As A. Czech notes, the process of consolidating the European Member States' markets into one competitive energy market is complex and lengthy. It requires a number of strategic political decisions, including energy liberalization and the adoption of sectoral legislation [15]. The activity of enterprises in the energy sector is determined by the heterogeneous energy infrastructure among EU Member States, as well as the frequent differences in legal environments and institutional and administrative systems.

Some EU countries are characterized by modern and developed electricity and gas infrastructure, while others are clearly lagging behind in this respect. Europe's lack of energy self-sufficiency and import dependence is becoming more and more apparent. According to The Dependency Rate on Energy, the import of energy consumed by EU member states has increased from 47% in 2019 to 53% in 2022 [16]. Moreover, there are large variations between Member States, with energy dependency rate ranges from over 95% for Malta, Luxembourg, and Cyprus to below 15% for Estonia and Denmark [16]. This proves the existing heterogeneity and limited intra-market possibilities of meeting the demand for energy.

As noted by A. Carfora, R.V. Pansini and G. Scandurra, the current direction of EU activities in the field of energy is to reduce energy dependence, which is to be achieved by improving the efficiency and maximum use of domestic energy sources as well as the promotion of renewable energy sources (RES) [16]. Actions taken should be implemented in accordance with the disclosed need to ensure more stable and safe supplies, including increasing the use of renewable energy sources, while reducing greenhouse gas emissions. For these reasons, efforts have recently been focused on ensuring energy security taking into account the principles of sustainable development, thus becoming one of the priorities in defining the new energy policy framework in the EU [17] (pp. 155–163), [18] (pp. 127–136). The process of changes related to the consolidation, research, liberalization and common energy policy in the energy market of the European Union countries is presented in Figure 2.



**Figure 2.** Changes related to the research, liberalization, consolidation and common energy policy in the energy market of European Union countries. Own-study based on [15] (pp. 251–262), [17] (pp. 155–163), [18] (pp. 127–136).

Thus, the activity of energy sector enterprises is very strongly related to socio-economic conditions. There is an increasing demand for electricity against the backdrop of a decline in non-renewable energy resources. Therefore, this macroeconomic factor should be considered significant and determining the development of enterprises in this sector.

The adopted direction of development, related to the use of renewable energy sources in the operation of the energy sector—in the context of global socio-economic conditions—seems to be correct [19]. Lutz, Fischer, Newig and Lang list 19 driving factors of renewable energy implementation processes [20]. They have all been grouped into the following four clusters:

1. Planning and process;
2. Exchange and participation;
3. Actors and networks;
4. Economic circumstances.

As shown in the above studies, formal networks emerge as a strong driving factor in the studied regions. Regions where formal networks are important see the positive impact of renewable energy use on the regional economy [20]. Therefore, it can be assumed that networking related to the digitalisation processes of energy sector enterprises is an important factor in their development in the context of plans for the use of renewable energy sources. This corresponds to the idea of sustainable development in relation to natural capital.

Due to the complexity of the research topic undertaken, it is worth paying attention to the closely related terms “condition” and “factor”. The ability to distinguish between static and dynamic variables in the context of the development of enterprises affects the correct determination of the components of this development and the ability to properly prioritize them in the context of setting development goals.

“Conditions” are a feature or set of features on which the existence of something depends, and a situation prevailing in some area (location, circumstances) in which something happens [21]. In turn, the term “factor” should be understood as the cause of a specific phenomenon, and something that has an impact on the observed phenomenon, actions taken or the existing situation [22]. The word “factor” comes from the concept of action (lat. *facere* = to do) and is one of its elements—the cause [23]. An activity is a form of the active human relation to reality or a process aimed at achieving a goal, the structure of which is shaped depending on the existing conditions [24]. As A. Kaleta notes, the two concepts analyzed above are closely related, particularly regarding the development of an enterprise, the relations between the “condition” and the “factor” are indicated [25]. The literature on the subject emphasizes that “development conditions” have a less direct impact than “development factors”, as they are of a potential nature. They may be present in a given place, time and area (legal, economic, social, etc.), they may be favourable and unfavourable, or they may be completely absent. Thus, the existence of appropriate conditions creates the possibility of emergence and development [26]. The disclosure of the development condition contributes to the implementation of certain activities. In turn, the factor triggers some process of action, which is then confronted with the identified conditions. Thus, the factor is an active attitude to reality. The condition, on the other hand, may be of a natural, technical or social nature [23]. Hence, it is assumed that the conditions of development are generally static and are recognized as resources. On the other hand, the factors are dynamic and are treated as streams [27]. In terms of economic capital, the term “conditions”, understood as a set of more or less favourable circumstances (conditions) enabling or limiting development, seems to be a more appropriate term than a “condition”.

According to S. Chomałowski, conditions (for economic capital these are economic conditions) and factors, including drivers of enterprise development can be understood as what is related to the development of the enterprise and influences this development directly or indirectly. In other words, the conditions for the development of an enterprise are permanent or shorter-lasting possibilities, existing in a given place and time. They include all the opportunities and threats that may favor or limit the development of

the enterprise [27]. The conditions of development have a real and material dimension. Their discovery and use contribute to the development of the enterprise, thus becoming its drivers [28].

Returning to today's challenges related to the implementation of sustainable development, three basic conditions useful in the analysis and evaluation of the development of energy sector entities should be indicated. They are part of the "3 Ds of Energy" based on digitalisation, decentralization and decarbonization. These are conditions and factors related to economic, social and natural capital.

Experts from the International Energy Agency [29] (pp. 18–20) indicate that the global demand for electricity will increase by about 2–3% annually [30]. Throughout 2021, global energy demand and emissions increased by 5% compared to 2020, almost reaching pre-COVID-19 levels (~33 Gt energy-related CO<sub>2</sub> equivalent) [30]. As energy consumption increases, so too will greenhouse gas emissions. This could lead to an increase in global temperature of 4–6 °C by 2030 [31]. According to industry analyses, even if all countries with net-zero commitments deliver on their aspirations, global warming is projected to reach 1.7 °C by 2100 [30]. Such a forecast determines further planning of activities in this regard.

The mentioned conditions and factors are closely related. The activity of enterprises in the energy sector is conditioned by the existence of demand for energy by social capital. This is also an important determinant of how much, how and when energy will be used. The process of obtaining electricity and heat, in turn, involves the use of renewable and non-renewable resources that belong to natural capital. Finally, in order for energy to be delivered, economic capital is needed for energy production and transmission infrastructure.

The development of technology determines the technical capabilities of energy production and transmission infrastructure, as well as the degree of its modernity, reliability and efficiency. It is on the basis of the above-mentioned characteristics that the assessment of this infrastructure is made. The digitalisation process of energy sector enterprises has a direct and indirect impact on these characteristics.

The researchers claim that the energy industry can increase energy efficiency through various changes leading to the integration of individual energy companies and information communication technologies (ICT) supporting processes related to energy generation, transmission and delivery [32]. Therefore, digitalisation plays a key role in the implementation of the new model of the 3 Ds of Energy development. Effective digitalisation will allow the development of more and more advanced technologies enabling the diversified production of energy from decentralized renewable sources. This will make possible the switch from non-renewable sources in the form of coal or crude oil to renewable sources.

Park, Cho & Heo distinguish three main entities which will have a strong influence on digitalisation: (1) energy policymakers, (2) researchers and (3) market participants [33]. Based on empirical research by You & Yi, it has been shown that "self-transcendence knowledge" is very important and critical in the knowledge management and promoting energy companies to react quickly to changes and challenges related to digitalisation [32]. The policy of transforming the energy sector adopted in the EU assumes transferring energy production to renewable sources, reducing the emission intensity of the economy and increasing energy efficiency. The implementation of these plans is to ensure energy and environmental security, enable constant civil development, and the creation of low-emission, highly effective energy based on renewable energy sources. In this respect, digitalisation is treated as a tool for the implementation and development of a new energy policy. As A. Kucharska notes, "digitalisation is an essential element of energy infrastructure management, smart grids and smart meters. It allows better equality of energy distribution, which is a factor in combating energy poverty" [34]. One should be aware that the digitalisation of the energy sector is not a "cure for all diseases" in this sector and is associated with specific threats, which will be presented below. However, digitalisation should be seen as an effective tool for more effective management of the production, distribution and storage of electricity and heat. Digitalisation is a significant factor in the develop-

ment of enterprises in the energy sector, which is also part of the concept of sustainable socio-economic development.

The above-mentioned drivers in the digitalisation of energy sector enterprises are specific to this industry and fundamental to its development. They are related to the process of implementing the new energy policy based on the assumptions of the 3 Ds of Energy. There are also other drivers in the digitalisation of the activities of energy sector enterprises, which are also noticeable in other industries and result from the so-called digital transformation of business [35].

Both specific and general factors driving the development of the digital economy (digitalisation of activities) of energy sector enterprises as well as enterprises from other industries are presented in Table 1 ([29] (pp. 21–23), [35–37]).

**Table 1.** Specific and general factors in the digitalisation of energy enterprises.

Type of Drivers	Drivers
Specific drivers of digitalisation of energy enterprises	<ul style="list-style-type: none"> <li>- The 3 Ds of Energy;</li> <li>- Transferring energy production to renewable sources, reducing the emission intensity of the economy and increasing energy efficiency;</li> <li>- Integration of individual energy companies and information communication technologies (ICT) supporting processes related to energy generation, transmission and delivery;</li> <li>- Development of management tools: intelligent energy transmission networks and smart meters as well as tools for controlling the entire energy system.</li> </ul>
General drivers of digitalisation of energy enterprises and entities from other industries	<ul style="list-style-type: none"> <li>- Internet of Things (IoT) and Internet of Everything (IoE);</li> <li>- Hyper-connectivity;</li> <li>- Greater effectiveness in reaching and contacting customers;</li> <li>- Cloud Computing Applications and Services;</li> <li>- Big Data Analytics (BDA) and Big-Data-as-a-Service (BDaaS);</li> <li>- Automation and Robotisation [29] (pp. 21–23);</li> <li>- Multi-Channel and Omni-Channel Models for the distribution of products and services.</li> </ul>

Source: own-study based on [29] (pp. 21–23), [35–37].

The challenges and opportunities related to the above-mentioned factors, which refer straight to the energy sector include [38–40]:

- the implementation of Industrial Internet of Things solutions in electricity supply systems, based on a network of sensors monitoring energy demand, managing its transmission and storage;
- the use of Artificial Intelligence in order to optimize energy transmission and distribution;
- the use of blockchain technology to manage energy resources and logistics, which increases the operational efficiency of energy companies;
- the use of smart grids and models to monitor changes in energy demand and to respond autonomously to emerging changes through proper energy distribution;
- creating “Virtual Power Plants”, which are a combination of decentralised units on the electricity grid coordinated by a common control system that allows them to dynamically plan and adjust production and to trade in the energy market at the lowest possible operating costs;
- the implementation of energy management systems integrating prosumers and consumers, able to optimize the production and consumption of energy coming from various sources, based on the use of smart meters or consumer IoT devices (mobile reporting applications);
- the use of digital modeling to design new and improve existing energy networks. The use of this tool will increase the operational efficiency of energy sector entities, allowing faster (compared to the solutions used so far) data analysis on the basis of

- real energy networks to develop new investments and reducing the cost of designing new installations;
- the use of blockchain, which will increase the level of automation and security of transactions on the power grid, e.g., those involving the sale of micro volumes of energy between prosumers;
  - building systems in the form of “digital twins”, based on a real-time collaboration between a digital replica of a physical object and the object itself, enabling decisions referring to the optimisation of its operations.

Digitalisation in supply chain management, also in the energy sector, allows for the implementation of the most important efficiency criteria in the form of costs, time and service quality. It contributes to maximizing the effectiveness of customer service by delivering the right product (service) as quickly as possible and reducing the cost of service while ensuring high availability and reliability of the service (product) [41].

#### 4. Business Models in Energy Sector Enterprises in the Context of Digitalisation

V. Akberdina and A. Osmonova note that the digital transformation in energy sector enterprises has been taking place in the world for many years [42,43]. As noted by J. Światowiec-Szczepańska and B. Stępień, this sector pioneered the implementation of information and communication technologies and over the past few years it has undergone enormous changes as a result of changes related to the fourth industrial revolution [44]. Digitalisation in the energy sector is linked to the creation and use of computerized information and the processing of the huge amount of data that is generated along the energy supply chain. New digital technologies offer great opportunities to improve the efficiency of managing an advanced energy system: from infrastructure design, operation and maintenance, through energy production and transmission, to its consumption. Due to digitalisation in the energy sector, the necessary infrastructure and interfaces are created that enable the efficient functioning of operators and the intelligent and effective implementation of the processes they support because it enables cheaper, faster and better monitoring using “smarter” networks [45]. P.F. Borowski points out that, as research shows, digitalisation enables energy companies to reduce operating costs and improve efficiency, and additionally helps to extend the life of power plants by about 30% [46].

The most important global digital trends affecting the energy sector and selected concepts of innovative business models corresponding to them, are presented in Figure 3.



**Figure 3.** The main digital trends and the most popular business models observed in the energy sector practice in the 21st century [44,45,47–65].

Global digital trends makes energy sector companies look for effective methods of competing, shaping and implementing new strategies and business models, using them to an increasing extent in various types of innovation and cooperation networks. As rightly noted by J. Brzóska and M. Krannich, for energy companies, a significant factor influencing their strategic reorientation is also the energy and climate policies implemented in specific countries or a group of countries in a specific region [66]. Currently, the key area in the field of strategic management is to ensure that businesses have the capacity to implement quick and abrupt changes that affect the enterprise itself, including its strategy, structures, resources and processes, and its environment. For this reason, the ability to act quickly and flexibly in a turbulent, rapidly changing environment becomes very important. Research conducted by A. Kaleta, J. Radomska and L. Sołoduch-Pelc shows that in large enterprises, such as energy sector companies, innovation is related to strategic management, and this relationship is related to a strategic response to challenges [67]. According to A. Ates, P. Garengo, P. Cocca, and U. Bititci, large enterprises more often than SMEs design and implement formalized processes to manage operational and managerial activities. In the case of SMEs, the systems and processes related to decision-making and the management of the entire business are less structured [68].

The development of industrial strategies is often associated with the occurrence of conflict situations. Some of them, concerning opposing objectives such as, for example, increased production versus environmental impact, or increasing automation versus reducing employment, are very difficult to resolve. Improving productivity is important for wage growth, and at the same time, it is very often associated with the implementation of advanced technologies that reduce employee involvement. Developing countries often accept environmental issues because they want to counteract labour-saving technology [69].

Tensions related to the necessity to meet the needs of customers, the activities of competition and the level of costs result in the emergence of new methods, tools and theories in managing the development of the energy sector. At the same time, energy sector companies design and reformulate their business models, which is difficult in an unstable and complex environment [70]. S. Küfeoğlu, G. Liu, K. Anaya and M.G. Pollitt note that the newly adopted business models in the energy industry vary in terms of four business model dimensions [45]:

- Value Proposition, which refers to the way in which an organisation creates value for its customers;
- Targeted Customers, specifying to whom they are addressed;
- Value Creation (Value Delivery), determining how their service will be created and delivered;
- Value Capture (Revenue Model), relating to the sources of their expected revenues and how they plan to create them.

B. Fattouh, R. Poudineh and R. West note that their effective functioning requires flexible and systematically adapted development strategies [71].

A key driving factor in energy sector digitalisation is the increasingly distributed character of the electricity generation system, which opens up new business opportunities. The decentralization of power generation is part of the transformation based on the so-called 5 Ds (decentralization, digitalisation, decarbonization, democratization, and decreasing consumption), which are the driving forces of the current energy transition [72]. As noted by A. Hirsch, Y. Parag and J. Guerrero, the increasing use of renewable energy sources is playing a huge role in accelerating this trend [73]. S. Küfeoğlu, G. Liu, K. Anaya and M.G. Pollitt add that the development of renewable energy means that today energy is generated within the electricity distribution grid that includes many more nodes than ever before. The problem, however, is the intermittency of this production and the poor match of its supply to demand [45].

According to A. Idries, J. Krogstie and J. Rajasekharan, the decentralized energy means energy that is generated closer to the place where it is used. It is therefore not drawn from a large centralised power station that is part of the regional or national grid [74].

As rightly noted by J. Silvente, G.M. Kopanos, E.N. Pistikopoulos and A. Espuña, the local generation of energy reduces transmission losses that result from the long distance between production and consumption sites and decreases environmental degeneration as it lowers carbon emissions [75]. It also increases the security of supply for all consumers, as they do not use a single power source or depend on relatively few large and remotely located power plants [76]. A.M. Adil and Y. Ko point out, that energy decentralization has three configurations: distributed generation, micro-grids, and smart micro-grids [77]. The backbone of energy decentralization is distributed generation, which can be defined as “generating plant connected directly to the grid at distribution level voltage or on the customer side of the meter” [78,79].

As indicated by H. Khajeh, H. Laaksonen, A.S. Gazafroudi and M. Shafie-khah, decentralized energy is accompanied by the transformation towards a platform-based model, which is a good starting point for service innovation in the energy sector. As a result of this transition, various services will be provided by these platforms, thereby giving many stakeholders and actors the opportunity to benefit from them [80]. Digitalisation helps to better manage the network and congestion, helping to solve the problems of discontinuities related to the production of energy from renewable sources. It makes it possible to use digital platforms to respond to demand, Peer-to-Peer (P2P) energy and carbon credit trading [45]. K. Osmundsen notes that a crucial trend for the digital development of the energy sector is also transforming grid networks into smart grids, which are electricity networks able to process, control, and manage huge data flows [43,81].

As shown in Figure 3, changes important to the existing energy system include business model innovations based among others on the following concepts:

- peer-to-peer (P2P) electricity trading;
- virtual power plants (VPPs);
- flexibility management;
- local energy market;
- the vehicle-to-grid concept.

Irregular small-scale energy production and energy exchange between autonomous micro-grid prosumers [48] can be integrated into the energy system with low indirect costs thanks to P2P energy trading. Peer-to-peer (P2P) electricity trading is a new data-driven business model that is currently being tested in the energy sector [49]. Peer-to-peer (P2P) energy trading is essentially based on direct transactions between prosumers and consumers who trade energy with each other without the electricity supplier or retailer as an intermediary. The place of the intermediary is taken by a third-party digital platform, e.g., blockchain-based, which allows prosumers and consumers to interact directly and negotiate better prices for electricity, relative to the offer of a licensed supplier [50,51]. This type of energy trading can be facilitated by the digitalisation of the economy and by the use of advanced digital technologies such as Artificial Intelligence (AI) or Blockchain [45].

Artificial neural networks allow the analysis of information in an innovative manner. These are mathematical and computer models that imitate the work of neurons in the human brain, so they can analyse information and learn to generate proposed solutions. J. Światowiec-Szczepańska and B. Stepień point out that their application is possible in many areas, and they are used at each stage of the energy value chain [44]:

- energy network design: to forecast energy demand and assess the reliability of generation equipment, in the automation of protection, and controlling of systems’ overload in production and transmission;
- energy production: to prevent and optimise the equipment operating costs;
- transmission and sales: for automation of selecting the most cost-effective or strategic suppliers, dynamic differentiation and optimisation of energy prices according to seasonal trends in customer habits, billing automation, etc.

AI can be used to optimize energy storage and supply management, it has the potential of a predictive system and can be the basis for creating systems that respond to

energy changes [52]. The consequence of AI managing energy transmission is Demand Response Models (intelligent networks supported by models of responding to changes in demand) enabling real-time monitoring of changes in energy demand and proper energy distribution [52].

Other digital technologies, such as blockchain, can improve the information flow process, document flow, property management, logistics and security of supply. Blockchain enables, through the controlled use of data, the management of the increasing complexity of the structure and networks of the energy sector and direct interaction between entities through comprehensive monitoring of energy flows at low costs [44]. The greatest benefits associated with the introduction of blockchain technology include the possibility of concluding direct transactions between energy suppliers and their customers. Blockchain technology solutions can also enable the sale of micro volumes of energy between prosumers [52]. Traditional energy trading faces problems such as single points of failure and privacy leakage. Therefore, efficient and transparent models are needed in this area. The advantages of blockchain technology include trust, security and decentralization. This technology maintains a distributed database, eliminating the need to involve third parties, improves economic efficiency, and reduces management costs [53] and ensures supply security by providing information on the origin of energy [44]. In addition, E. Mengelkamp et al. add that blockchain technology provides user-friendly applications that enable them to participate in making decisions about which technology they use to generate energy and who produces it [54].

One of the most reliable and efficient ways to ensure the efficiency, stability and competitiveness of distributed generation is the use of a business model based on the concept of a Virtual Power Plant (VPP). A VPP is a system integrating a few types of energy sources, which provide a reliable overall power supply. Virtual power plants can be described as decentralized energy management systems, which pool the capacity of different units: renewable and non-renewable ones, different storage devices and distributable loads, participating in the energy market and trading energy (and services) with the upstream network [55]. P. Asmus defines VPPs as “software systems, which remotely and automatically dispatch and optimize generation or demand side or storage resources in a single, secure Web-connected system” [56]. Through software innovation, VPPs use existing energy networks to tailor electricity supply and demand services to meet customer needs. This maximises value, both for the end customer and for the distribution company [56]. The VPP buys spare capacity from energy-producing entities and manages the power plant production according to the real-time sales demand. The produced energy is sold simultaneously on multiple markets—on the Power Exchange (PEx), on the balancing energy market and directly to end users. This business model allows small power plants to earn higher margins without incurring additional energy sales and balancing costs [57]. As noted by S. Baidya, V. Potdar, P.P. Ray and Ch. Nandi, the functional capabilities of virtual power plants are, therefore: (1) optimisation of network modes, (2) management of electricity consumption and (3) market management of the reserve capacity [58,59].

The dynamic development of renewable generation and distributed energy resources presents distribution systems with new operational challenges related to intermittency and uncertainty of supply. Addressing these challenges requires distribution system operators to introduce business models that enable more active and flexible management and system control. This results in a shift to a local approach in energy system management. P. Olivella-Rosell et al. point out that local Energy Markets (LEM), also known as micro-markets or local electricity markets [60], use online platforms and smart grid technologies as a means to integrate and coordinate Distributed Energy Resources (DER) at the distribution grid level [61]. According to S. Beattie, W.K. Chan, A. Wei and Z. Zhu, this is important, especially in relation to the local supply of spatially distributed renewable resources that cannot be directly controlled [62]. As noted by P. Olivella-Rosell, G. Viñals-Canal et al. studies show that with too small distribution networks, LEM can effectively improve social welfare compared to other, simpler solutions [60].

The possibility of implementing new business models is also seen in the development of V2G technology. Electric vehicles (EVs) can be classified in terms of their charging methods, energy storage mechanisms or energy sources. The increase in sales of electric vehicles is related to the need to increase the amount of available energy. In addition, the needs of charging electric vehicles result from the profiles of drivers and their mobility. All this affects the allocation of electric vehicle charging demand [63]. V2G technology creates added value for EV users and Distribution System Operators, as some specific services can be provided to the power grid. By connecting an EV to the grid, the bi-directional energy exchange is possible, from the power grid to the electric vehicle and the other way round, from the electric vehicle to the grid [64]. With the growing number of electric vehicles, these services can support the energy industry to better manage energy generation, its management and, ultimately, its consumption. Electricity management by consumers in the technology of two-way energy exchange is a new approach in terms of building a new power grid and the value of available power consumption [65]. As rightly noted by B. Mroczek and A. Kołodyńska, nowadays more and more attention is paid to the problems of network management. The popularity and effectiveness of V2G services among EV users will depend on the correct definition of electricity demand [65].

In conclusion, it should be stated that the business models introduced by energy sector enterprises are associated with the pressure resulting from the transformation towards the digital economy. In this context, the strategies that relate to gaining a privileged position in the industry are also changing. Changes in the energy sector are influenced by the acquisition of entities from the periphery of the energy sector or those that are still reserved for other products. This mainly refers to big data entities and enterprises using energy-based products [70]. R. Trzaska et al. emphasise the need to implement digital technologies in the energy sector due to their potential to increase efficiency, productivity, speed and security, as well as reduce costs. This becomes possible mainly thanks to the use of artificial intelligence, the development of advanced sensors for process monitoring and remote access in various organisational areas [70]. It is important to develop business models that are based on the real added value that distributed energy can bring to the entire energy system. This added value may be a solution that allow for real local real-time power balancing, which requires an advanced data ecosystem and algorithms for managing a distributed system. However, such business models require a number of innovations in many areas.

These factors emphasise the need to introduce digital solutions in the energy sector due to their potential to increase efficiency, productivity, speed, safety and cost reduction.

## 5. Challenges and Dilemmas of Energy Sector Enterprises Regarding Industry 4.0 and 5.0

The digital transformation of the energy sector is part of the more general current phenomena of Industry 4.0 and Industry 5.0. Moreover, this process is a component of shaping the information society and the implementation of the global plan of sustainable development [82] (pp. 283–294). It is important to distinguish between two ways of understanding the essence of the digitalisation of the energy industry. Firstly, it is the automation of existing engineering and business practices using digital technologies. Secondly, radical technological and civilizational change is associated with the transformation of the very structure of the industry and the emergence of new practices (*Digital transformation*). We will continue to talk about digitalisation in the latter sense [83]. The effects of digital transformation are shown in three projections: in the area of technology, business and culture [84]. Moreover, digitalisation affects the nature of the relationship between the above-mentioned areas (human–technology, human–business, and business–technology). The following opportunities offered by digital transformation can be listed:

- Increasing the efficiency, stability and security of the current energy system (application of mathematical models, digital twins, cloud solutions vs. hosting solutions, real-time control); increased precision in servicing systems and devices (3D-PLM-MES

- expertise); creating new forms of staff training (gamification, virtual and augmented reality technologies) [85,86];
- Lowering operating costs (OPEX) and capital expenditure (CAPEX); introducing new business models and forms of distribution (Energy Aggregator, Internet of Energy, Distributed Energies Resources) to meet the requirements of local energy markets;
- Integration of systems based on different renewable energy sources, e.g., solar power grid control depending on atmospheric changes, optimal adjustment of consumption to the applicable local tariffs (big data, smart grid) [86,87].

At the same time, the digitalisation of the energy sector is associated with new challenges and dilemmas concerning, inter alia, the risk of destabilisation of the energy market resulting from its decentralisation, new requirements for the qualifications of people employed in the energy sector, a new culture of the cooperation between energy suppliers and recipients and ensuring the digital security of data used in shaping a common energy system [82] (pp. 283–294). To a large extent, the above-mentioned dangers related to the digitalisation of the energy sphere are also specific to other areas of life where digital transformation takes place. Generally speaking, meeting new challenges and dilemmas is associated with finding a balanced dynamic relationship between the area of technology, business and culture, ensuring the free flow of information between these areas. Below, we will describe some of the difficulties accompanying the digital transformation of the energy sphere:

1. Risk of instability of electric networks—due to the inexorable increase in energy consumption, the decentralisation of its generation and the increase in the diversity of its sources, the risk of instability of electricity networks has increased, which was partly reflected in the winter blackout in Texas [88] and the summer blackout in Great Britain [89];
2. The need for close integration and information exchange within the energy branch—new methods of electricity distribution require good information exchange between the individual elements of the energy system, matching and close cooperation between the producer, distributor and consumer of electricity [86];
3. Increased requirements for cybersecurity—along with the rapid increase in the number of intellectual devices in automated systems and the exponential increase in the volume of information sent by them, the area susceptible to a possible attack by hackers has significantly expanded. Therefore, solutions guaranteeing digital security must reach a new qualitative level [86];
4. Increased requirements for the professional qualifications of operating personnel—in connection with the implementation of the new technologies mentioned above, the requirements for operating personnel (installation, tuning, scheduled maintenance, repairing) of power plants and other infrastructure in the energy sector are significantly increasing. Today, operating personnel must be familiar with technologies such as MAC address, IP address, VLAN, Cloud Computing control, IEC 61,850 protocol etc. [85];
5. Changing the thinking paradigm—a lack of trust in cloud computing infrastructure on the part of customers is still a frequent phenomenon. In their opinion, if something works well, there is no need to change it. The more so as new technologies cannot always secure the same level of security as provided by earlier, already-proven technologies and solutions [82] (pp. 283–294);
6. Anthropological dilemmas—digital technologies can significantly increase the stability of an energy company, allowing it to be controlled in real-time mode. Therefore, the time needed to adopt important decisions is significantly reduced. At the same time, there is a specific disproportion between the speed, complexity and scope of the changes taking place and human perceptive abilities limited by their natural properties as biological beings [86];
7. New forms of interaction with the service user—digital transformation has significantly changed the culture of communication between the distributor of energy and

its user. This applies, *inter alia*, to ways of shaping flexible tariffs, and the need for clients to know digital technologies. Increasingly, the user is served without an assistant, which is replaced by chatbots. The latter solution, so far, works only in the performance of standard, non-complex tasks. In many cases, solving a problem or doubt requires talking to a person [90] (pp. 189–194). In addition, very often the client's need to get direct feedback from the assistant is still indispensable.

Proposed answers to the above dilemmas and challenges:

1. New technologies are expected to raise the possibility of forecasting unexpected natural or technological phenomena to a qualitatively new level. Apart from that, more and more demands are placed on the technology of producing electric networks. They must be able to adapt to step changes in voltage in the network, to the situation of excess electricity or its increased consumption [91];
2. The lack of homogeneity results in the need to adopt an open standard of information exchange, which will ensure the cooperation of different energy microsystems (Power Line Communication, Common Information Model). This will facilitate the synchronization between photovoltaic stations and windmills subject to different work rhythms and dependencies on the weather and will mitigate against voltage spikes or energy shortages in the grid [91];
3. One of the world leaders in the energy industry, Siemens AG, and its partners work on digital security issues in close cooperation with Kaspersky Lab (Moscow, Russia). The human factor remains the key factor in maintaining safety. In the manuals for its certified products, the corporation recommends, *inter alia*, making frequent updates of all hardware and software. An additional instrument for ensuring digital security in this corporation is a team of experts at a global level and a "rapid response" team at the local level [86]. Other providers of energy services and solutions, such as Schneider Electric (Le Creusot, France), are also expanding their field of activity. Until recently, this corporation was only involved in creating a system, which was then used by the personnel of energy companies. Today Schneider Electric has its own staff to control the Cloud Computing infrastructure and develops solutions and services, which are aimed at, for example, helping customers reduce energy costs (Resource Adviser system based on Cloud computing). At Schneider Electric, security issues are dealt with by the Cyber Security International Center. It is a cross-business team that analyzes and audits new solutions (hardware and software) developed by other departments of the company. The same team is also responsible for the development of the Hardening Guide to support hundreds of individual devices (including printers!) forming a coherent system. This manual includes, among others, a checklist of actions that must not be forgotten (e.g., "disconnect http or default port", "change administrator password"). The company also conducts training courses for customers on the operation of their products [85];
4. Today, the profile of engineering teams dealing with the implementation of systems in facilities has changed significantly. In the past, their qualifications were limited to knowledge of Windows OS and products proposed by a specific developer. Today, these specialists must know at least about the administration in Linux, RESTful API and the HTTP and WebSocket protocols by which data is exchanged between individual system components [85];
5. Digital transformation must be carried out carefully and take into account local conditions (power plants, grids, specificity of a market). Implementation of new technologies should take into account the standards existing in a given area. Due to the rapid expansion of the range of production and the type of technologies that must take into account local specifics, Schneider Electric opens local R&D development centres in various countries, as global centres cannot always meet the requirements of local markets [85,87];
6. There is a high probability that the function of the plant operator will be reduced over time to the role of a bio-robot operating in strict accordance with the recommendations

- of the AI controlling all processes in the plant. This raises more general questions about the place of humans in the new reality shaped by the latest digital technologies;
7. When encountering new digital technologies in the area of customer service, the end user must be convinced that the changes made have contributed to the increase in the convenience and security of contact with the corporation. The user interface has to become more and more intuitive. When proposing new solutions, the corporation should maintain a proper caution, offering clients only proven solutions [91].

The reigning or consciously created social consciousness largely determines our future. We choose how we want to live, and what values and goals are important to us [92]. There may not be only one right strategy for the future. Therefore, when implementing new digital solutions, one should not be radical. Different approaches in the field of energy, more traditional and modern ones, can coexist [91]. One should choose solutions appropriate for a given place and time, solutions effective in solving specific tasks. It is worth following the path of evolution rather than revolution [84]. A rapid transition from one system to another is associated with instability and an increase in risk.

Digital transformation should solve specific problems and bring about concrete improvements in terms of stability, saving, comfort and security. People and their welfare must remain the overriding concern underlying all these changes [91]. It should also be remembered that digital transformation consists not only in the emergence of new business and engineering practices but above all in the transformation of the very culture of production, distribution and use of energy. Digitalisation changes the very paradigm of thinking about energy [93]. In the course of digital transformation, human resources are shifted from existing processes and practices to others, mainly related to the maintenance of information systems. People still remain the main point of digital transformation.

## 6. Conclusions

The energy sector is an important sector of the economy, determining the socio-economic development of each country and, globally, having a strong impact on the environment and climate change. This makes energy an area of the global economy where major technological and organisational transformations are taking place, based on a wide range of digital innovations being implemented. In this paper, we have reviewed existing research on drivers, business models and prospective directions of change of energy sector companies in the context of the digitalisation processes taking place in them.

With reference to the first research question, the conducted literature review allowed us to identify drivers influencing the digitalisation of energy industry enterprises, among which we distinguished those characteristics for this sector and those relating to all business entities, being a part of the more general phenomena of Industry 4.0 and Industry 5.0. We found that a number of sector-specific drivers influence the pace, course and effects of these processes. They include different socio-economic conditions, related on the one hand to the increasing consumption of electricity by economies and societies, and—on the other hand—to shrinking conventional energy resources. They also result from the current energy policy in the European Union, which aims at decarbonising the economy, rising energy efficiency and increasing the share of production from renewable energy sources. The digitalisation of energy companies can greatly facilitate adaptation to these requirements, representing a key factor for their rapid and efficient development, fostering the simultaneous achievement of the three priorities: the sustainability, energy security and competitiveness of the energy sector. As another sector-specific driver, we have identified the increasingly distributed nature of electricity production in the energy sector, in which the voice of prosumers, who want to gain greater control over energy management, use and production, is also increasingly heard. This is shifting more and more attention towards small, distributed, local and dynamic activities and businesses that are changing the fundamentals of the energy market. In parallel, energy sector companies are being impacted by other digitalisation drivers, which are also noticeable in other industries, and are therefore of a universal nature. They stem from the ongoing digital transformation of

the business sector, which is a part of the more general phenomena of Industry 4.0 and Industry 5.0. Our review shows that digitalisation makes it possible to respond to all these challenges in both the supply and demand sides of the market. For energy suppliers, it offers higher system efficiency, the opportunity to make full use of data and implement new strategies and business models, while for consumers and prosumers, it offers comfort and a reduction in energy consumption costs.

The research review showed that a method to improve the efficiency of energy companies is to implement technological innovations, including those enabling their digital transformation, which changes the essence of their operations and affects all aspects of their activities. At the same time, this means introducing new strategies and business models. With reference to the second research question, we have identified several innovative business models in the energy industry, which are or will be actively implemented in the near future thanks to digitalisation as a response to current trends in the energy market. They include new concepts of doing business in the energy sector based on the idea of peer-to-peer (P2P) electricity trading, virtual power plants (VPPs), flexibility management, local energy markets and the vehicle-to-grid concept. Analysing the described emerging innovations in business models in the energy sector as a result of digitalisation, it can be concluded that the boundary between supply and demand may be blurred in a digitised future. The deployment of smart grids, interconnected and interoperable energy trading and management systems, as well as the exploitation of the potential of artificial intelligence, blockchain and other digital technologies, can completely change the position and roles played by suppliers and consumers. New roles and new actors, such as prosumers or aggregators, are emerging in the transforming energy market, and the range of possibilities for their creation seems to be essentially limitless. As the review of research showed, the new business models being implemented in the energy sector encourage, on the one hand, large generators to transform their operations, including through the possibility to use RES, thus enabling them to adapt to the trends observed in the market, while, on the other hand, they support small prosumers in being active in the energy market, which encourages the active building of a demand-supply balance.

Answering the third research question, what prospective directions of changes will determine the paths of development for the energy sector enterprises in the near future, based on a literature review we identified the main challenges and dilemmas in the energy sector in connection with its digitalisation. We have included here: the risk of destabilisation of the energy market resulting from its decentralisation, the new requirements placed on the competences of those working in the energy sector, the new culture of interaction between energy suppliers and consumers and the digital security of data used in the energy system. Digital transformation should correspond closely to these concerns and offer concrete improvements in terms of stability, savings, convenience and security in the energy sector. In this context, this process is a crucial component of shaping the information society and the implementation of the global plan of sustainable development.

Our research contributes to revealing the potential opportunities, threats and challenges of the digital transformation of the energy sector, and all the results obtained and the conclusions expressed should be treated as a stimulus for further in-depth research, especially on the issue of innovation in the field of new business models resulting from digitalisation, which will provide greater opportunities for implementing sustainable energy transformation and on solutions that will be a response to the above-mentioned risks and dilemmas related to the digitalisation processes in this sector. Regarding the directions for future research, it should be pointed out that there is a constant need to monitor the factors forcing the necessary changes or fostering the transformation of the energy sector, especially in the context of the possibility of using digital technologies to improve existing or implement new, innovative business models that meet the complex needs of various stakeholders of the energy system.

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