Digitalisation in the Energy Sector Enterprisess

Subjects: Economics

Contributor: Barbara Siuta-Tokarska, Sylwia Kruk, Paweł Krzemiński, Agnieszka Thier, Katarzyna Żmija

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.

Keywords: digitalisation ; drivers ; business models

1. The Evolution of Enterprises in the Market – the Outline of the Process

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. 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.

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**).

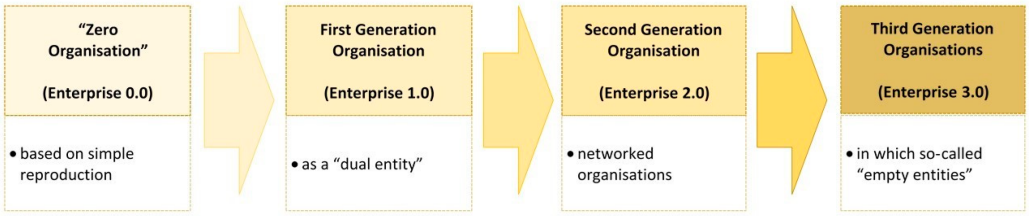

Figure 1. Evolution of market entities. Own-study based on [1] (pp. 21–22), [2], [3], [4] (p. 33), [5], [6].

This evolution included successive stages, namely [1] (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 [2], [3], [4] (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 [5][6].

As P. Depaoli, S. Za and E. Scornavacca[7] 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. 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.

2. The Drivers of the Digitalisation in the Energy Sector Enterprises

There are different drivers influencing the digitalisation of energy industry enterprises, among which one can distinguish 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. 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. Another sector-specific driver is 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.

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** ([8] (pp. 21–23), [9], [10], [11]).

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

Type of Drivers	Drivers
Specific drivers of digitalisation of energy enterprises	- The 3 Ds of Energy; - Transferring energy production to renewable sources, reducing the emission intensity of the economy and increasing energy efficiency; - Integration of individual energy companies and information communication technologies (ICT) supporting processes related to energy generation, transmission and delivery; - Development of management tools: intelligent energy transmission networks and smart meters as well as tools for controlling the entire energy system.

General drivers of digitalisation of energy enterprises and entities from other industries	Internet of Things (IoT) and Internet of Everything (IoE); - Hyper-connectivity; - Greater effectiveness in reaching and contacting customers; - Cloud Computing Applications and Services; - Big Data Analytics (BDA) and Big-Data-as-a-Service (BDaaS); - Automation and Robotisation [8] (pp. 21–23); - Multi-Channel and Omni-Channel Models for the distribution of products and services.

Source: own-study based on [8] (pp. 21–23), [9], [10], [11].

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.

3. Business Models in Energy Sector Enterprises in the Context of Digitalisation

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[12].

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. The most important global digital trends affecting the energy sector and selected concepts of innovative business models corresponding to them, are presented in **Figure 2**.

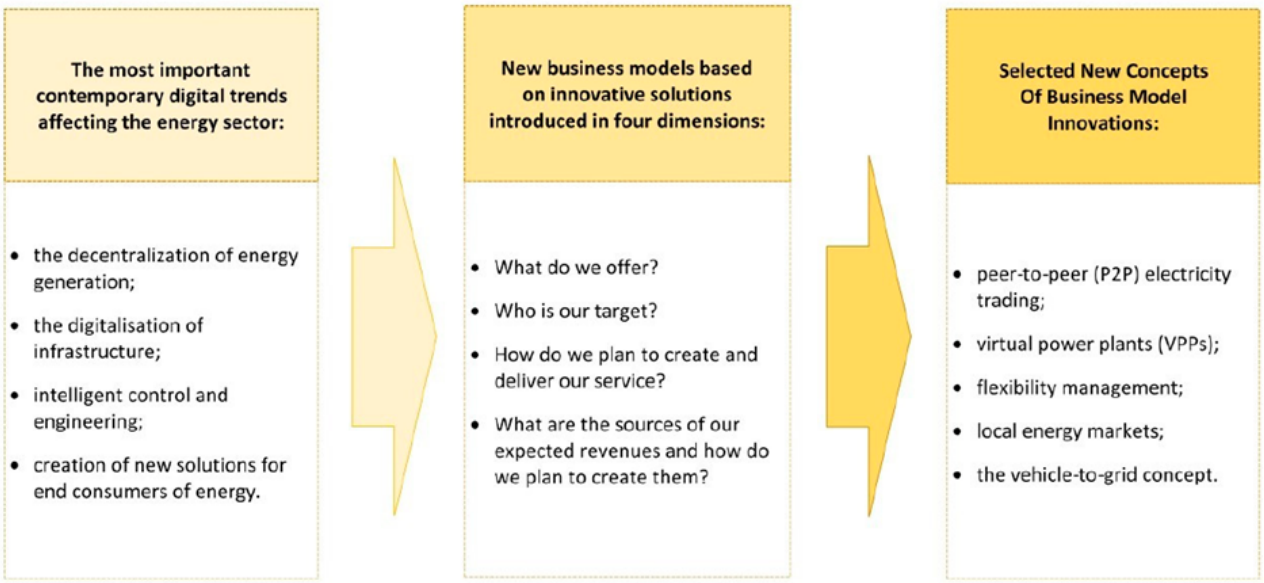

Figure 2. The main digital trends and the most popular business models observed in the energy sector practice in the 21st century [[12], [13], [14][15][16][17][18][19][20][21][22][23][24][25][26][27][28][29][30][31][32].

Analysing the selected 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.

4. 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 [33](pp. 283–294). The effects of digital transformation are shown in three projections: in the area of technology, business and culture [34]. 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) [35], [36];

- 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) [36], [37].

At the same time, the digitalisation of the energy sector is associated with new challenges and dilemmas such as:

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 [38] and the summer blackout in Great Britain [39];
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 [36];
3. Increased requirements for cybersecurity—along with the rapid increase in the numer 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 [36];
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. [35];
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 [33] (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 [36];

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 [40](pp. 189–194). In addition, very often the client's need to get direct feedback from the assistant is still indispensable.

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. Digital transformation should correspond closely to these concerns and offer concreto 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.

References

1. Hołodnik, D.; Perechuda, K. Przedsiębiorstwo nowej generacji. In Annales Universitstis Mariae Curie-Skłodowska, Section H2—Oeconomia; Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej: Lublin, Poland, 2016; pp. 21–27.
2. Bughin, J.; Manyika, J. Leveraging "enterprise 2.0" for competitive advantage. In Proceedings of the IADIS International Conference on WWW/Internet, Vila Real, Portugal, 5–8 October 2007.
3. Trimi, S.; Galanxhi, H. The Impact of Enterprise 2.0 in Organizations. Serv. Bus. 2014, 8, 405–424.
4. Williams, S.P.; Hausmann, V.; Hardy, C.A.; Schubert, P. Enterprise 2.0 Research: Meeting the Challenges of Practice. In BLED 2013 Proceedings; AISeL: Tokyo, Japan, 2013; p. 33.
5. Bassus, O.; Zaščerinska, J.; Ahrens, A. From Enterprise 2.0 to 3.0: Challenges in Engineering and Business Education. In Information and Communication Technologies in Engineering and Business; Bassus, O., Ahrens, A., Lange, C., Eds.; Mensch & Buch: Berlin, Germany, 2011; pp. 79–96.
6. Venselaar, J. (Ed.) Sustainable Enterprise 3.0 The Strategic Approach out of Economic Self-Interest; Avans University of Applied Sciences: Breda, The Netherlands, 2014.
7. Depaoli, P.; Za, S.; Scornavacca, E. A model for digital development of SMEs: An interaction-based approach. J. Small Bus. Enterp. Dev. 2020, 27, 1049–1068.
8. Scenariusze Rozwojowe dla Polski w Perspektywie Roku 2050; Raport; Departament Strategii Rozwoju Ministerstwa Inwestycji i Rozwoju: Warszawa, Poland, 2019.
9. Śledziewska, K.; Włoch, R. Gospodarka Cyfrowa jak Nowe Technologie Zmieniają Świat; Wydawnictwo Uniwersytetu Warszawskiego: Warszawa, Poland, 2020; p. 78.
10. Pieriegud, J. Cyfryzacja gospodarki i społeczeństwa—Wymiar globalny, europejski i krajowy. In Cyfryzacja Gospodarki i Społeczeństwa –Szanse i Wyzwania dla Sektorów; Gajewski, J., Paprocki, W., Pieriegud, J., Eds.; Instytut Badań nad Gospodarką Rynkową—Gdańska Akademia Bankowa: Gdańsk, Poland, 2016; pp. 11–13.
11. Borowiecki, R.; Siuta-Tokarska, B.; Maroń, J.; Suder, M.; Thier, A.; żmija, K. Developing Digital Economy and Society in the Light of the Issue of Digital Convergence of the Markets in the European Union Countries. Energies 2021, 14, 2717.
12. Küfeoğlu, S.; Liu, G.; Anaya, K.; Pollitt, M.G. Digitalisation and New Business Models in Energy Sector. In Cambridge Working Papers in Economics; University of Cambridge, Faculty of Economics: Cambridge, UK, 2019; p. 1. Available online: http: //www.jstor.org/stable/resrep30431 (accessed on 16 September 2022).
13. Światowiec-Szczepańska, J.; Stępień, B. Drivers of Digitalization in the Energy Sector—The Managerial Perspective from the Catching Up Economy. Energies 2022, 15, 1437.
14. Verma, P.; Savickas, R.; Buettner, S.M.; Strüker, J.; Kjeldsen, O.; Wang, X. Digitalization: Enabling the New Phase of Energy Efficiency. Group of Experts on Energy Efficiency, GEEE-7. 2020. NF.3. Available online: https://unece.org/sites/default/files/2020-12/GEEE-7.2020.INF_.3.pdf (accessed on 15 September 2022).
15. Mroczek, B.; Kołodyńska, A. The V2G Process with the Predictive Model. IEEE Access 2020, 8, 86947–86956.
16. Glaa, B. Digitalisation in the Context of Electricity Market Reforms and Liberalisation: Overview of Opportunities and Threats. In Revisiting Electricity Market Reforms. Lessons for ASEAN and East Asia; Phoumin, H., Nepal, R., Kimura, F., Uddin, G.S., Taghizadeh-Hesary, F., Eds.; Springer: Singapore, 2022; pp. 283–294.

17. Wilkinson, S.; Hojckova, K.; Eon, C.; Morrison, G.M.; Sandén, B. Is peer-to-peer electricity trading empowering users? Evidence on motivations and roles in a prosumer business model trial in Australia. Energy Res. Soc. Sci. 2020, 66, 101500.
18. Zhou, Y.; Wu, J.; Long, C.; Ming, W. State-of-the-Art Analysis and Perspectives for Peer-to Peer Energy Trading. Engineering 2020,6, 739–753.
19. The Future of Digitization in the Energy Sector. (In Polish). Transformacja. 2050. Available online: https://transformacja2050.pl/project/cyfryzacja-w-energetyce-analiza/ (accessed on 9 September 2022).
20. Liu, H.; Zhang, Y.; Zheng, S.; Li, Y. Electric Vehicle Power Trading Mechanism Based on Blockchain and Smart Contract in V2G Network. IEEE Access 2019, 7, 160546–160558
21. Mengelkamp, E.; Gärttner, J.; Rock, K.; Kessler, S.; Orsini, L.; Weinhardt, C. Designing microgrid energy markets—A case study: The Brooklyn Microgrid. Appl. Energy 2018, 210, 870–880
22. Shafiekhani, M.; Hashemizadeh, A. Multi-objective scheduling of a virtual power plant considering emissions. In Scheduling and Operation of Virtual Power Plants; Zangeneh, A., Moeini-Aghtaie, M., Eds.; Elsevier: Amsterdam, The Netherlands, 2022; pp. 377–397.
23. Asmus, P. Microgrids, Virtual Power Plants and Our Distributed Energy Future. Electr. J. 2010, 23, 72–82.
24. Ropuszyńska-Surma, E.; Węglarza, M. The Virtual Power Plant—A Review Of Business Models, E3S Web of Conferences. Energy Fuels 2019, 108, 01006.
25. Baidya, S.; Potdar, V.; Ray, P.P.; Nandi, C. Reviewing the opportunities, challenges, and future directions for the digitalization of energy. Energy Res. Soc. Sci. 2021, 81, 102243.
26. Georgakopoulos, D.; Quigg, S. Precision measurement system for the calibration of Phasor Measurement Units. In Proceedings of the Conference on Precision Electromagnetic Measurements (CPEM), Ottawa, AT, Canada, 10–15 July 2016; pp. 1–2.
27. Olivella-Rosell, P.; Viñals-Canal, G.; Sumper, A.; Villafafila-Robles, R.; Bremdal, B.A.; Ilieva, I.; Ottesen, S.Ø. Day-ahead micromarket design for distributed energy resources. In Proceedings of the IEEE International Energy Conference (ENERGYCON), Leuven, Belgium, 4–8 April 2016; pp. 1–6.
28. Schreck, S.; Sudhoff, R.; Thiem, S.; Niessen, S. On the Importance of Grid Tariff Designs in Local Energy Markets. Energies 2022, 15, 6209.
29. Beattie, S.; Chan, W.-K.; Wei, Z.; Zhu, Z. Simulation Analysis of a Double Auction-Based Local Energy Market in Socio-Economic Context. Sustainability 2022, 14, 7642.
30. Klaina, H.; Guembe, I.P.; Lopez-Iturri, P.; Astrain, J.J.; Azpilicueta, L.; Aghzout, O.; Alejos, A.V.; Falcone, F. Aggregator to Electric Vehicle LoRaWAN Based Communication Analysis in Vehicle-to-Grid Systems in Smart Cities. IEEE Access 2020, 8, 124688–124701.
31. Cleveland, C.J.; Morris, C. Dictionary of Energy; Elsevier: Amsterdam, The Netherlands, 2006; p. 473.
32. Mroczek, B.; Kołodyńska, A. The V2G Process with the Predictive Model. IEEE Access 2020, 8, 86947–86956.
33. Glaa, B. Digitalisation in the Context of Electricity Market Reforms and Liberalisation: Overview of Opportunities and Threats. In Revisiting Electricity Market Reforms. Lessons for ASEAN and East Asia; Phoumin, H., Nepal, R., Kimura, F., Uddin, G.S., Taghizadeh-Hesary, F., Eds.; Springer: Singapore, 2022; pp. 283–294.
34. Tiefenbeck, V. Bring behaviour into the digital transformation. Nat. Energy 2017, 2, 1–3.
35. Safety Solutions; Schneider Electric: Le Creusot, France. 2022. Available online: ww.se.com/us/en/work/solutions/safety (accessed on 5 August 2022).
36. Smart Grids für Energieversorger; Siemens AG: Munich, Germany. 2022. Available online: https://new.siemens.com/de/de/produkte/energie/themen/smart-grid.html (accessed on 10 September 2022).
37. Revisiting Electricity Market Reforms. Lessons for ASEAN and East Asia; Phoumin, H.; Nepal, R.; Kimura, F.; Uddin, G.S.; Taghizadeh-Hesary, F. (Eds.) Springer: Singapore, 2022.
38. What went wrong with the Texas power grid? Houston Chronicle, 15 February 2021.
39. GB Power System Disruption; Interim Report; Energy Emergencies Executive Committee; Department for Business, Energy & Industrial Strategy: Washington, DC, USA, 2019; pp. 4–20.
40. Hilbert, M. Digital technology and social change: The digital transformation of society from a historical perspective. Dialogues Clin. Neurosci. 2022, 22, 189–194.