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Digitization, Digital Twins, Blockchain, and Industry 4.0 as Elements of Management Process in Enterprises in the Energy Sector

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Abstract: In the 21st century, it is becoming increasingly clear that human activities and the activities of enterprises affect the environment. Therefore, it is important to learn about the methods in which companies minimize the negative effects of their activities. The article presents the steps taken and innovative actions carried out by enterprises in the energy sector. The article analyzes innovative activities undertaken and implemented by enterprises from the energy sector. The relationships between innovative strategies, including, inter alia, digitization, and Industry 4.0 solutions, in the development of companies and the achieved results concerning sustainable development and environmental impact. Digitization has far exceeded traditional productivity improvement ranges of 3–5% per year, with a clear cost improvement potential of well above 25%. Enterprises on a large scale make attempts to increase energy efficiency by implementing the state-of-the-art innovative technical and technological solutions, which increase reliability and durability (material and mechanical engineering). Digitization of energy companies allows them to reduce operating costs and increases efficiency. With digital advances, the useful life of an energy plant can be increased up to 30%. Advanced technologies, blockchain, and the use of intelligent networks enables the activation of prosumers in the electricity market. Reducing energy consumption in industry and at the same time increasing energy efficiency for which the European Union is fighting in the clean air package for all Europeans have a positive impact on environmental protection, sustainable development, and the implementation of the decarbonization program.

Keywords: innovation; energy efficiency; blockchain; Industry 4.0; digital transformation; digital twin; mechanical engineering

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1. Introduction

The management of enterprises in the energy sector is currently focused on several essential activities, namely the digitization of the sector [1,2] and its development toward zero emissions (decarbonization) and sustainable development [3]. The ability to adapt to the requirements of the legal, ecological, or technological environment allows enterprises to implement new solutions operating on the market in a short time [4,5]. If the enterprise has the ability to react in advance (the so-called anticipatory adaptation [4,5]) and use various flexible processes and integration with high-tech systems, it has the potential to create a digital enterprise. Such an enterprise would be based on virtual reality and integrated solutions from the world of automation and robotization. The direction and actions taken in the process of managing enterprises in the broadly understood energy sector are shown in the Figure 1.

Digitization already contributes to increasing the level of security, efficiency, availability and durability of energy systems. Digitization gives the opportunity to increase energy efficiency thanks to technologies that collect and analyze data. These data are processed into useful information using data analysis technologies such as artificial intelligence algorithms and then sent to devices that can influence physical changes in order to optimize energy consumption [6]. The novelty of research concerns digitization, digital twins, and the latest solutions used in the energy sector. Many solutions are already implemented in some sectors, e.g., the aviation industry (engines in airplanes), but for power plants, these are innovative solutions. This approach is analogous to that of innovation, which can be broken down into relative innovation and absolute innovation. Digital twins are in the initial stage of application in nuclear power; therefore, we will classify them as relative innovations.

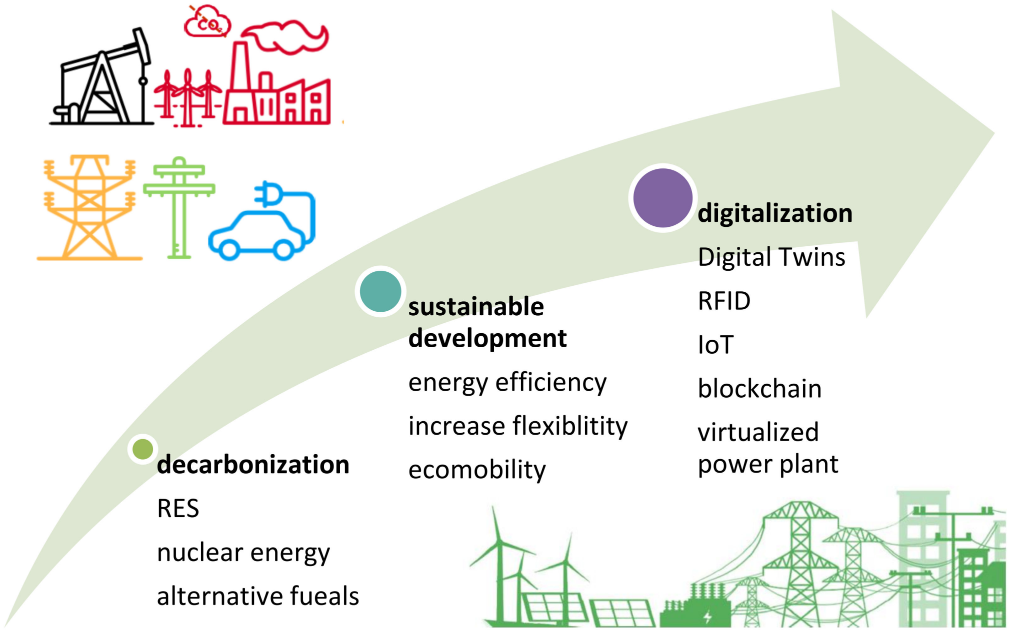

Figure 1. Direction of energy sector development; source: own elaboration.

Decarbonization and energy efficiency, which are a response to the problem of the environment and global warming, require the implementation of appropriate strategies, taking radical decisions to promote effective and timely change in energy systems [3,7].

Zero-emission and sustainable development are associated with the implementation of innovative solutions in the field of renewable energy sources as well as switching the activities of enterprises to operate with regard to energy efficiency. Enterprises more and more often use the energy efficiency standards ISO 1400 and ISO 5001. Particular attention should also be paid to the increasing use of the ESCO (energy saving/service company) formula. Energy service companies (ESCOs) can be effective instruments to overcome some of the barriers to energy efficiency implementation [8]. The growing use of renewable energy sources and energy efficiency technologies is one of the trends in climate transformation and sustainable development identified in the industrial sector [9]. Reducing the intensity of carbon dioxide emissions as well as improving efficiency in industry combined with innovative solutions positively affects the climate and energy situation [10].

This article presents research on activities undertaken by enterprises in order to meet the environmental and technological requirements. In terms of technological issues, the increase in energy efficiency, through the use of ADP and AMT techniques as well as the digitization of the sector (virtual power plants, blockchain, and digital twins), was analyzed. In the environmental aspect, the activities of the European Union related to decarbonization, reduction of harmful effects on the environment, and reduction of energy consumption were examined.

2. Materials and Methods

For several years, management studies have started to adopt, accept, and apply mixed methods, i.e., two methods at the same time: qualitative and quantitative, represented by the inductive model and the hypothetical-deductive model [5]. In the research works carried out and described in this article, qualitative research was used, carried out using the observation method, and classified as primary research, and descriptive methods were classified as secondary research called desk research. The conducted observations made it possible to analyze the behavior of enterprises, while desk research made it possible to perform a descriptive analysis of enterprises and the entire sector. Secondary research used external literature on digitization and innovation in industry and the energy sector. The analysis of the text was based on the literature published in English, as well as reports from various companies, and the annual reports of energy companies. In addition, material published in articles in specialist journals and on websites was analyzed. As part of the source study, a critical content analysis was performed, and the existing data were analyzed. An analysis of data contained in official reports of EU institutions was also carried out.

3. Results

Innovation and new technologies allow companies to function, work, and develop in a constantly changing environment. Moreover, innovations help to reduce the negative impact on the environment. The innovation strategy defines long-term goals, methods, and scope in which the implemented innovations, whether product, process, or organizational, are used to build a strong position on the market. The role and significance of innovations and currently frequently used eco-innovations for the development of enterprises result from their direct or indirect impact on the company's results. Innovations depend on the genre (type) of industry. Innovation can also increase the level of employment in a company and affect efficiency. Desk research shows that some sectors have implemented innovations, digitization, and high-tech solutions much earlier than energy companies. Desk research has also shown that the latest technical and IT solutions such as blockchain and digital twins enable the implementation of a low- or zero-emission economy (decarbonization), e.g., by creating virtual power plants and using a greater share of renewable energy sources and greater activity of prosumers in the energy mix.

4. Discussion

4.1. Energy Efficiency

Over the past two decades, many economies and governments have increasingly focused on investing in energy efficiency. The actions undertaken mainly concern the improvement of production processes, the modernization of devices and buildings, and the introduction of new technologies. Industrial energy efficiency programs have become one of the most popular government policies aimed at reducing energy consumption in energy-intensive industries [11,12]. In 2015–2018, the National Fund for Environmental Protection and Water Management in Poland allocated approximately 510 billion EUR to activities increasing energy efficiency. These funds were allocated to all kinds of activities aimed at increasing energy efficiency [13].

Efficiency in the economy or in industry can be considered, inter alia, as efficiency relating to production processes or energy efficiency. The efficiency of production processes is defined as the result of economic (industrial) activity which is the quotient of the obtained effect to the inputs [14]. Energy efficiency is expressed analogously to the efficiency of production processes or can be generally defined as reducing energy consumption while maintaining or increasing the current level of broadly understood economic activity. In detail, energy efficiency is the ratio of the obtained value of the utility effect of a given facility, technical device, or installation to the amount of energy consumption by this facility, technical device, or installation, or as a result of the service provided, the process necessary to achieve this effect [15].

Energy efficiency contributes to energy security, effective environmental protection, quality of life, and economic prosperity. Energy efficiency is the best way to make better use of existing resources, promote economic growth, and reduce energy costs [16]. The reduction of energy consumption, whether in energy companies or production companies, occurs at the stage of production, transmission, distribution, or end use, mainly as a result of technological changes. In terms of efficiency, it is important to use innovative technological solutions that ensure the same or higher level of production or services [14]. The main motive for implementing these investments is reducing domestic dependence on imported energy sources and reducing carbon dioxide emissions related to the increasing demand and growing energy consumption [17] and moving toward decarbonization. Given the high potential to reduce greenhouse gas emissions, the low cost of improving energy efficiency, and the fact that there is a lot of financial aid available to mitigate climate change, many countries see energy efficiency as one of the directions for decarbonization.

Technological development and, above all, significant drops in the costs of introducing the latest solutions facilitate the adoption of effective decarbonization strategies. Technologies are being implemented to reduce emissions of toxic substances and greenhouse gases emitted by fossil fuel power plants [18]. Governments in many countries are trying to create investment incentives to build new or modernize existing generation units [19] as well as to motivate them to reduce the share of fossil fuels and increase the share of renewable sources in the energy mix [17], although the speed the actions undertake depends on the energy culture of a given country [20] and the size of the company. Adopting a proactive environmental strategy depends on many external factors but also on the size of the company [21].

The transition to a low-carbon economy and increasing energy efficiency are also key objectives of the EU's energy strategy. This transformation requires significant investment in the European energy sector, in terms of energy efficiency and industrial innovation. The European energy sector has enormous potential to boost jobs and growth. It can positively affect the competitiveness of the European economy in many production and service areas. By promoting energy and resource efficiency, a low-carbon economy allows for significant savings in the demand for fossil fuels [22]. In Poland, in the years 2013–2019, approximately 1.1 billion EUR was allocated to support one of the activities for the low-emission energy investments, which made it possible to finance renewable installations with a total capacity of 8.6 GW. About 62% of these funds were allocated to onshore wind farms and 28% to solar PV (photovoltaic) projects [23].

Energy efficiency also applies to or is concerned with industry and the entire economy. Looking at the data published by the IEA, it can be concluded that the manufacturing industry is responsible for almost 25% of final energy consumption, and by 2035 this consumption will be approximately 75% [24]. The industrial sector remains an important factor in energy consumption. The increasing demand for energy in industrial companies is in most cases responsible for the growing demand for energy. In many countries, it is the most energy-intensive sector; therefore, energy efficiency should be particularly promoted there [25]. With the declining share of fossil fuels and the growing share of renewables (four times more in the next 20 years) in the fuel mix, energy prices will rise. In the case of production, this means an increase in the costs of production, logistics, and energy-intensive goods. Therefore, it is worth it to look for ways to reduce unit energy consumption.

Energy efficiency in industry is extremely important as it reduces production costs and reduces the negative impact on the environment. Companies are under constant pressure to develop responsible and environmentally friendly operations. The commitment of companies to protect the natural environment has become an important variable, not only in companies but also in the government and society [26]. The development of green logistics is for the implementation of sustainable development strategy in companies [27]. Industrialization remains the main path to successful development in many countries, and it increases the demand for energy; therefore, it must be environmentally friendly.

4.2. Industrialization and Energy Efficiency

Industrialization enables countries to build and strengthen the skills and capabilities to compete and succeed under the new technological paradigm [28,29]. At the same time, the development of industry contributes to the increase in energy demand. ADP (advanced digital production) technologies used in production have enormous potential to accelerate economic growth and human wellbeing and to protect the environment, contributing to the implementation of the 2030 sustainable development plans, i.e., the EU Council's goal of reducing emissions to 55% by 2030 to values of 1990. However, ADP technology development and diffusion remains concentrated in highly developed economies, while development is weak in most emerging economies. The low technological maturity of companies from emerging countries indicates that their attention and activity should be focused on the implementation of recognized technologies [30].

The Industrial Development Report 2020 on industrial development stated that the world's top 10 richest economies account for 90 percent of all global patents and 70 percent of all exports directly related to these technologies [31]. In addition, it was noted that 40 economies—the so-called followers—are actively involved in these technologies, albeit with much less intensity. The rest of the world is either not very active or not involved in the global creation and use of the latest technologies [31–33]. The percentage of the costs of an average manufacturing company while in energy-intensive industries is much higher. Therefore, energy efficiency savings in industry contribute to reducing dependence on energy imports as well as to improving the sector's competitiveness in terms of direct and indirect cost savings [17]. Tax reductions and government incentives further increase savings in many countries. Most of the savings are generated by adapting equipment such as engines, drives, boilers, furnaces, pumps, compressors, and ventilation and heating systems, and by improving production processes [17].

4.3. Advanced Digital Production and Additive Manufacturing Technologies

Energy efficiency activities that can be undertaken by manufacturing companies and by different energy consumers in general can be divided into three categories. The first category includes optimization of the production processes, including using appropriate materials and devices and adjusting the machine settings and their performance to the actual needs [34]. The second category includes the prevention of energy losses caused by equipment failure or leakage of media distribution installations—for example, steam [14]. The third group of activities consists in replacing the most energy-consuming devices with energy-saving versions. Nevertheless, energy efficiency is the main path to reducing the carbon intensity. Therefore, at a company level, investments in improving energy efficiency are fully justified. This is particularly true for energy-intensive manufacturing companies that can benefit from double dividends to achieve significant direct and indirect cost reductions and generate revenue by trading their carbon offsets in the carbon market.

The abovementioned activities can be realized thanks to the emergence and dissemination of the advanced digital production (ADP) technologies of the fourth industrial revolution. Industry 4.0 refers to a new phase of the industrial revolution that focuses heavily on interconnectivity, automation, machine learning, real-time data, the Internet of things, blockchain technology, and advanced digital manufacturing technologies [35]. ADPs are radically changing industrial production, increasingly blurring the lines between physical and digital manufacturing systems. To use ADP to address critical variables such as achieving the sustainable development goals, the industrial strategy should focus on upgrading to intelligent production levels [36]. According to a 2019 study by the United Nations Industrial Development Organization (UNIDO) [31], there appear to be five levels of maturity in the use of ADP. They are (i) analog, (ii) rigid, (iii) economical, (iv) integrated, and (v) intelligent. Leveraging ADP, intelligent manufacturing focuses on fully integrated, connected manufacturing processes where information flows through operations and generates real-time feedback to support decision making. In such a production environment, intelligent sensors and machine-to-machine communication, big data analytics, cloud computing, artificial intelligence, and 3D printing are very popular. You can also use augmented-reality solutions.

Augmented reality increases production efficiency by providing a higher level of production or service. The application and use of the assumptions of augmented reality and lean culture in the field of sustainable enterprise development management is an important aspect in enterprise management [37]. Both products and processes should be redesigned to reach the stage of intelligent production [36].

Advances in robotics, artificial intelligence, additive manufacturing technologies (AMT) (currently the fastest-growing manufacturing method in high-development countries), and data analysis offer significant opportunities to accelerate innovation and add value to producing in manufacturing industry [31]. Additive technologies are widely used in many industries. They are used by various sectors and industries, including automotive, aerospace, food, textile, and plastics processing. AMT has grown rapidly in recent years from the design of prototypes with polymers in the automotive industry to large-scale production of metal parts, as evidenced by Boeing's use of additive manufacturing technology to reduce weight in the Boeing 787 Dreamliner [38]. In the power industry, additive manufacturing can be used for the construction of reactors. For the time being, additive technology is used to a limited extent in small parts for existing nuclear power plants [39]. As mentioned, these technologies are not widely used in the manufacture of components for the operation of nuclear power plants but may soon be widely deployed and can drastically reduce production costs, combine multiple systems, and increase safety and efficiency [38].

4.4. Investments in the Field of Energy Efficiency

Industrial investments in energy efficiency can be divided into two types. On the one hand, investments in one's own energy sources gains importance and on the other hand, investments in optimization of energy consumption. In the first case, polygeneration technologies, allowing for the simultaneous production of heat/cold and electricity, and renewable energy technologies, allowing for direct generation of energy from sources with low marginal costs, are of key importance. With the increase in energy prices on the market, the profitability of obtaining energy from renewable sources is growing very quickly. In many companies, the topic of new energy sources is a category of projects that are important from a business point of view. Already, some companies are moving toward not only renewable energy supply but also the production of their own renewable energy. Many companies, driven by the need for greener operations and opportunities through increasingly available renewable energy technologies, are now seeking their own energy independence [40].

Pro-ecological activities observed in the global economy force the search for new solutions limiting the use of harmful technologies in industry. At the same time, along with the growing awareness of people about the negative impact of fossil fuel technology on the environment, any action to improve the surrounding environment is well perceived by the public. The use of all-natural raw materials, consistent with the principles of sustainable development and "zero waste", is an important criterion in the production of modern products.

In the second case, the increase in efficiency is influenced by investments optimizing energy consumption. It concerns both devices reducing energy consumption per production unit (new materials, machines, lighting systems, etc.) and new digital technologies allowing for dynamic management of energy consumption. The selection of equipment and machines tailored to the production process or adequate to the specificity and needs of the enterprise with the right hardware parameters affects the achievement of better energy efficiency. New technologies are among the key areas of innovation on the border of energy and digitization [9]. Virtual power plants (VPP) will start to function more and more often as a network of decentralized medium-scale generation units. Thanks to the remote control and communication technology, VPP aggregates distributed energy resources functioning as an integrated whole [41]. These units include distributed energy resources such as wind farms, solar parks, and combined heat and power (CHP) cogeneration units, as well as flexible energy receivers and storage systems. The connected units communicate through the central control room of the virtual power plant but nevertheless remain independent in operation and ownership. The purpose of the virtual power plant is to relieve the grid by intelligently distributing the power generated by individual units during peak load periods. In addition, VPPs participate in wholesale energy markets to ensure the flexibility that is needed in a decarbonized energy system rich in renewable energy sources [3,42,43].

4.5. Digital Transformation in the Energy Sector

Digitization supports the increasingly automated and digital energy sector [19,44] based on the elements of Industry 4.0, which include, e.g., Internet of things (IoT), machine-to-machine (M2M) technology, and machine learning (ML). The main components of an M2M system include sensors, RFID (radio frequency identification), Wi-Fi or cellular link, and process control systems, which are essential for process automation and optimization. Autonomous data-processing software programmed to assist a network device in interpreting data and making decisions can trigger programmed, automated actions in manufacturing companies as well as in the energy sector [45,46].

Digital technologies for Industry 4.0, such as the Internet of Things, cloud computing, big data, and analytics, have attracted a lot of attention from researchers and practitioners alike. Based on the theory of information processing, digital technologies are influencing economic and environmental outcomes in the new era of Industry 4.0. Thus, digital technologies influence economic and environmental performance and increase efficiency and provide management with an insight on how to promote sustainable economic and environmental development in the era of Industry 4.0 [47]. In the era of Industry 4.0, the issue of the role of man in the enterprise is also important. People are involved in the entire production system as system designers and as employees. With the development of Industry 4.0, the tasks and requirements for people in the factory change. Workers are faced with a wide variety of tasks, from specification and monitoring to verification of the production strategy. The staff and workforce must have qualifications and skills to adapt to the effects of introducing the latest solutions related to IoT, because as a result of implementing elements of Industry 4.0, their role is transformed from operators into employees solving problems [48]. In addition to the undisputed advantages, some also report certain Industry 4.0 threats regarding human capital. There may be a reduction in creativity due to the increase in machine automation and the loss of human capital from production technology, as human capital is replaced by artificial intelligence (AI), robotics, nanotechnology, and other elements of Industry 4.0. To prevent this, there is a need to constantly adapt human capital to new and evolving technological trends [48,49]. New trends in increasing the share of renewable energy sources are activities that, despite digitization, still need highly qualified knowledge workers.

With the growing access to renewable energy sources and the fast, ubiquitous connection of everything (peer to peer), the traditional one-way energy flow from centralized generation to end-users will give way to a two-way energy flow with a multidirectional energy network between central grids and distributed prosumers [50]. Digital systems integrating various energy sources will be increasingly used to manage energy distribution by monitoring and controlling its production and demand. The final step in the application of AI algorithms in the energy sector enables effective and efficient management of not only transmission but also energy production in the ecosystem of thousands of producers and prosumers [51]. To strengthen the prosumer energy internet (EI) and strengthen the integration of energy conscious services, digitization and decentralization are key factors enabling the achievement of transactive EI. This article provides a systematic overview of how the Internet of things (IoT) drives EI transactional digitization and how blockchain enhances EI transactional decentralization. An extensive discussion of key infrastructures was foreseen to present how the digitization and decentralization of EI transactions are being implemented, including "advanced metering infrastructure" last mile (AMI), renewable energy integrator "smart inverter", energy flow regulator "energy router", and coordinator "microgrids". Challenges and future trends are discussed from a broad perspective, including physical energy space, data cyberspace, and human social space [50].

The RFID system is used in energy companies and serves, inter alia, for marking network assets and allows one to track the use of materials in an energy company, e.g., poles and transformers or other components of network infrastructure and energy devices. In the case of poles and transformers, passive UHF RFID tags are attached to all poles and transformers, letting one know where the materials are [52]. The company can control whether the materials are still in stock, have already been installed, or have been returned to the warehouse because they were not used for installation. Mobile or fixed RFID reader allows for remote querying of RFID tags in order to learn their properties or to automatically detect movements (inventory, entry/exit from the storage place, etc.) [53]. The basic RFID system scheme is shown in the Figure 2.

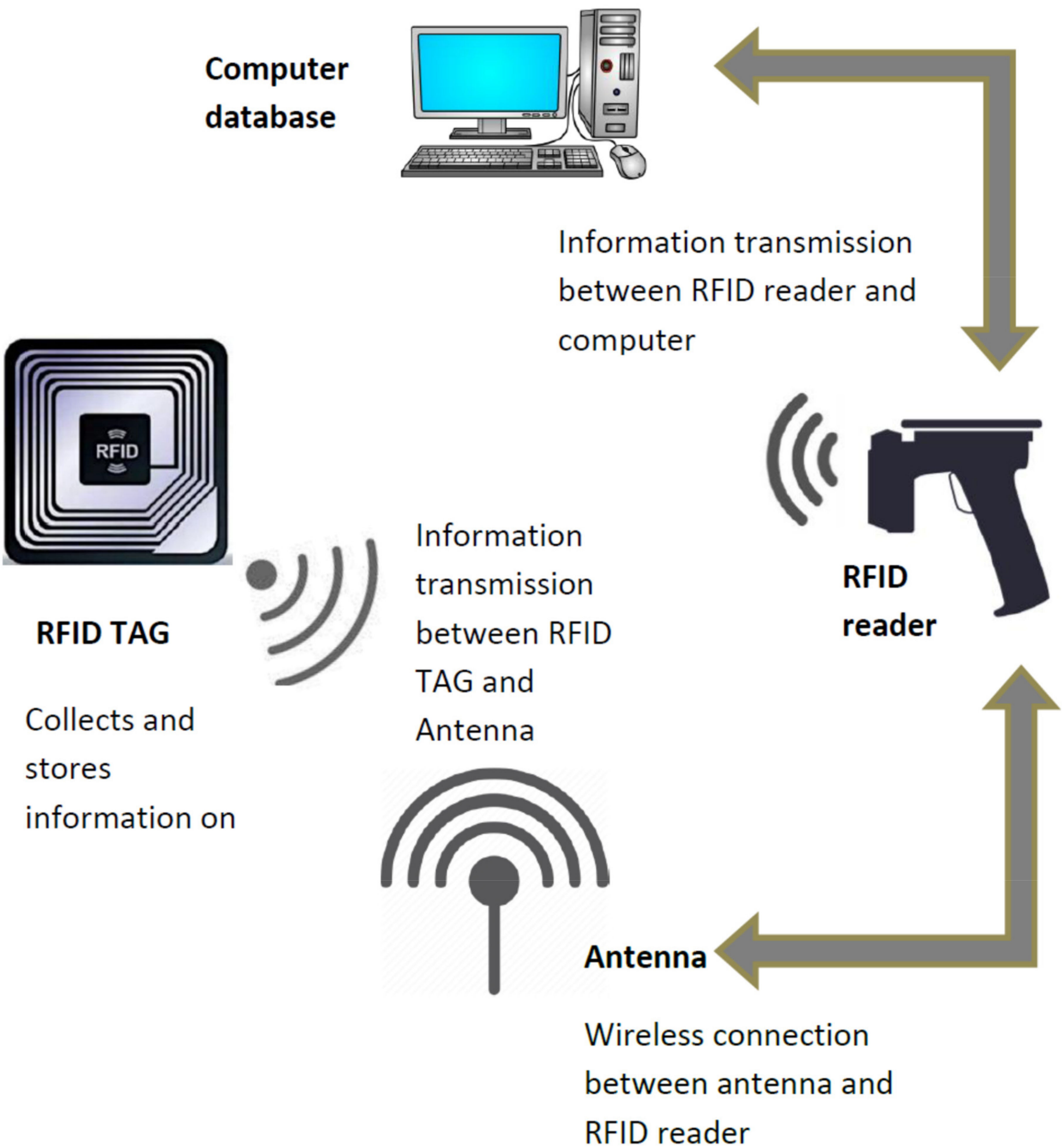

Figure 2. Basic radio frequency identification (RFID) system. Source: own elaboration.

Currently, RFID technology focuses mainly on tags and readers, which are used in systems where very large amounts of data are used. RFID helps in quick and detailed identification of items and reduction of lost and misplaced devices. The technology can be used to identify, track, sort, or detect a wide variety of energy objects and products. Communication takes place between the reader or interrogator and the transponder or tag. The RFID scheme used in the oil logistics company is shown in the Figure 3.

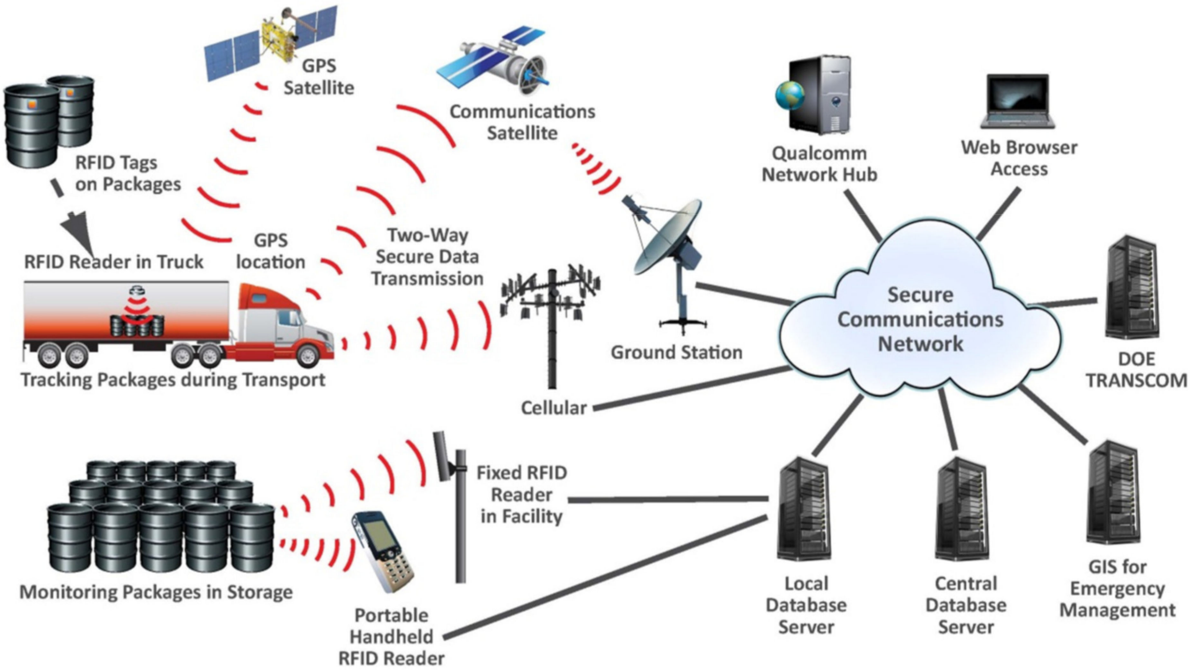

Figure 3. RFID scheme in the oil logistics company [54].

The RFID system can also be used as an element of intelligent metering and can enable network diagnostics. A properly configured RFID system can also monitor data from balancing meters and data from the field controller, modem, and power supply.

4.6. The Importance of Blockchain in the Energy Sector

Big data, innovative machine-learning processes, the use of artificial intelligence, and the Internet of things and distributed ledger technology (DLT) are now known in the scientific community as blockchain [55]. The use of DLT can improve the flow of processes that use databases. Distributed ledgers are relatively new and pose significant challenges. As more and more attention is paid to research into more fragmented market models in the energy industry, including peer-to-peer trade, microgrids, and local demand response, DLT can play a key role in stimulating interactions without the need to involve a central authority [19,56]. With this breakthrough technology, you can create a peer-to-peer network where nodes have to reach consensus and chain accepted blocks, while no central processing unit or trusted controller is required. Among all the existing applications of this technology, decentralized storage systems are one of its main applications [57].

Advanced smart-grid technologies enable prosumers to trade surplus energy from their distributed renewable energy sources with other peer-to-peer (P2P) energy trading [58]. Such activities activate individual prosumers. Blockchain technologies offer innovative solutions that enable consumers, end-users, and small producers of renewable energy to play a more active role in the energy market and maintain liquidity by easily selling assets [19,59]. Recently, many scientific studies have been written on the use of blockchain technology in peer-to-peer networks [60–62], energy trade [63,64], and micro-grid demand response programs [19,65]. Blockchain can build an open and collaborative data flow system, turn data into mobile assets, and launch various open and integrated business models. [66]. Blockchain can drive renewable energy development and support sustainable energy [67]. Blockchain is a new combination of energy flow, data flow, and business flow on the DLT platform. Blockchain can change the relationship between entities in the energy industry [66] on blockchain technology, by guaranteeing security and opening the way to the sale of microamounts of energy between prosumers. Blockchain enables the automation of transactions within the power grid (automatic conclusion of contracts upon fulfillment of a certain condition) and monitoring of energy consumption and production by prosumers [51]. The scheme of microgrid is shown at the Figure 4.

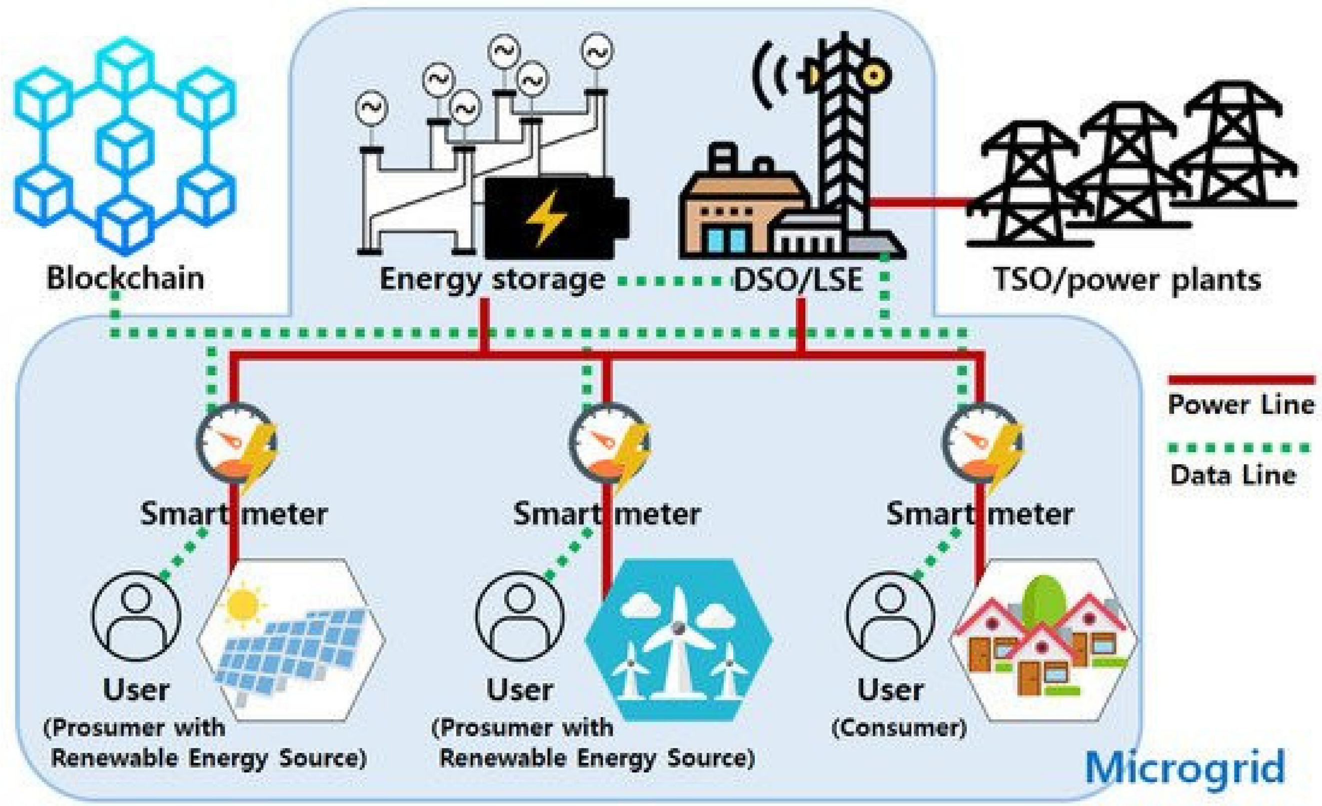

Figure 4. Microgrid scheme on the energy market [58].

The dynamic development of distributed generation, including renewable energy sources (RES) connected to the distribution grid, will have a significant impact on the role and functioning of distribution system operators (DSOs). The transmission system operator (TSO), which transmits electricity from the power plant through the transmission line, is primarily to support optimal management and promote the reliable operation of the system.

Blockchain solutions have already been successfully used as the basis for digital transactions in areas such as the electricity market (decentralized settlement of transactions) [68], trading, cryptocurrencies, and stock trading, and used in many other different scenarios where its unique features have allowed the definition of innovative and sometimes groundbreaking solutions [6,69]. Digital technologies can enable more dynamic, efficient, reliable, and sustainable electrical systems. Future power systems may be able to provide energy in response to anticipated demand at the right time, in the right place, at the lowest cost, and with the lowest emissions [70]. It is important that energy companies systematically initiate and implement digital innovations on a large scale and on a global scale. More than five billion people in developing countries will look for a way out of poverty [71].

Thanks to digitization, the offer of solutions for all electricity and heat consumers can significantly expand—from large industrial plants to individual recipients. There is a high probability that in the near future, new business models will appear on the energy market, implemented by new competitors in an increasingly open and pluralistic ecosystem [72]. Microgrids in the power industry based on renewable energy sources (renewable microgrids) are new solutions that increase safety and reliability. They improve the quality of energy and proper operation in power systems. By using various sources of renewable energy such as solar panels and wind farms, renewable microgrids can increase greenhouse gas reduction and improve efficiency in the energy sector. One of the solutions used is a machine-learning approach to energy management in renewable microgrids. Machine learning in microgrids is often used to model and estimate the charging needs of hybrid electric vehicles (HEVs). The use of this solution allows one to mitigate the impact of HEV charging on the system load [65].

4.7. Digital Twins in Energy

The digital revolution includes advances in building smart grids, managing renewable energy, and distributed generation. Currently, the Internet of things (IoT) is in the spotlight, but the industry is already starting to discuss the digital twins [73] at a large scale. Digital twin is not only a model but above all a dynamic and digital replica, and it offers completely new, wider possibilities. In addition, energy companies will more and more often move toward the use of digital twin, which is a combination of a physical object and its digital mapping in virtual space. In the case of nuclear power plants, one of the main challenges in creating a digital twin is its complexity. However, for a true digital twin to exist, the virtual model must be very precise and contain even the smallest elements. To get closer to the digital twin, nuclear power plant operators need to be able to connect data from suppliers, customers, simulators, and on-site information [74]. Digital twins (DT) is the concept of creating a digital replica (digital twin) of a physical object (physical twin) and synchronizing data between a physical twin and a digital twin to monitor, simulate, and optimize a physical object [75]. A digital twin is realized thanks to the possibility of real-time data processing and constant updating of the state of facilities and processes. The digital twin is used to track construction and identify problems by visualizing changes over time. These processes will also grow in popularity as the smart factories trend unfolds. With the advancement of enabling technologies such as 5G development, Internet of things (IoT) standardization, artificial intelligence (AI), and the use of blockchain 3.0 technology, it is only a matter of time before the industry moves to a digital-twins approach. Global efforts and government policy are already leaning toward harnessing better industrial energy efficiency and saving energy. This provides a promising future for the development of a digital-twin energy saving system in the industry [76]. Member states should encourage the modernization of distribution grids, for example by deploying smart grids, which should be built in a way that encourages decentralized energy production and energy efficiency [77].

Digital twin refers to a virtual machine or production line simulation model that is capable of mimicking the use and behavior of an actual machine or production line in real time. Using the digital-twin model, it is possible to check strength issues, material fatigue, forces, and stresses in individual elements, i.e., all mechanical engineering. The model also authentically simulates the natural user environment of the product and the work process. Thanks to the simulation, one can see exactly how the equipment works, as well as control how it is maintained by engineers. Digital-twin solutions used in enterprises combine machine learning, artificial intelligence, and software analysis with data collected in production plants to create digital simulation models. Digital twins can simulate any aspect of a physical object or process. Digital models allow for continuous updating when individual parameters of the production process or operating conditions of a given device change [78]. Access to larger amounts of data allows one to create simulations that are more detailed and more dynamic than in traditional solutions [79,80]. The twin can be used to simulate the operation of a piece of equipment or production line in a virtual environment before any production decisions are made. This helps you save on costs and reduces the risks associated with expensive investments. Digitization has significantly surpassed traditional productivity improvement ranges of 3–5% per year, with a clear cost improvement potential of well-above 25% [81]. Digital twins are important for the designed installations and systems, as simulation (used in all aspects from production to work safety to organization) helps in research and conducted analysis. The idea of a digital-twin engine with its mechanical elements is presented in the Figure 5.

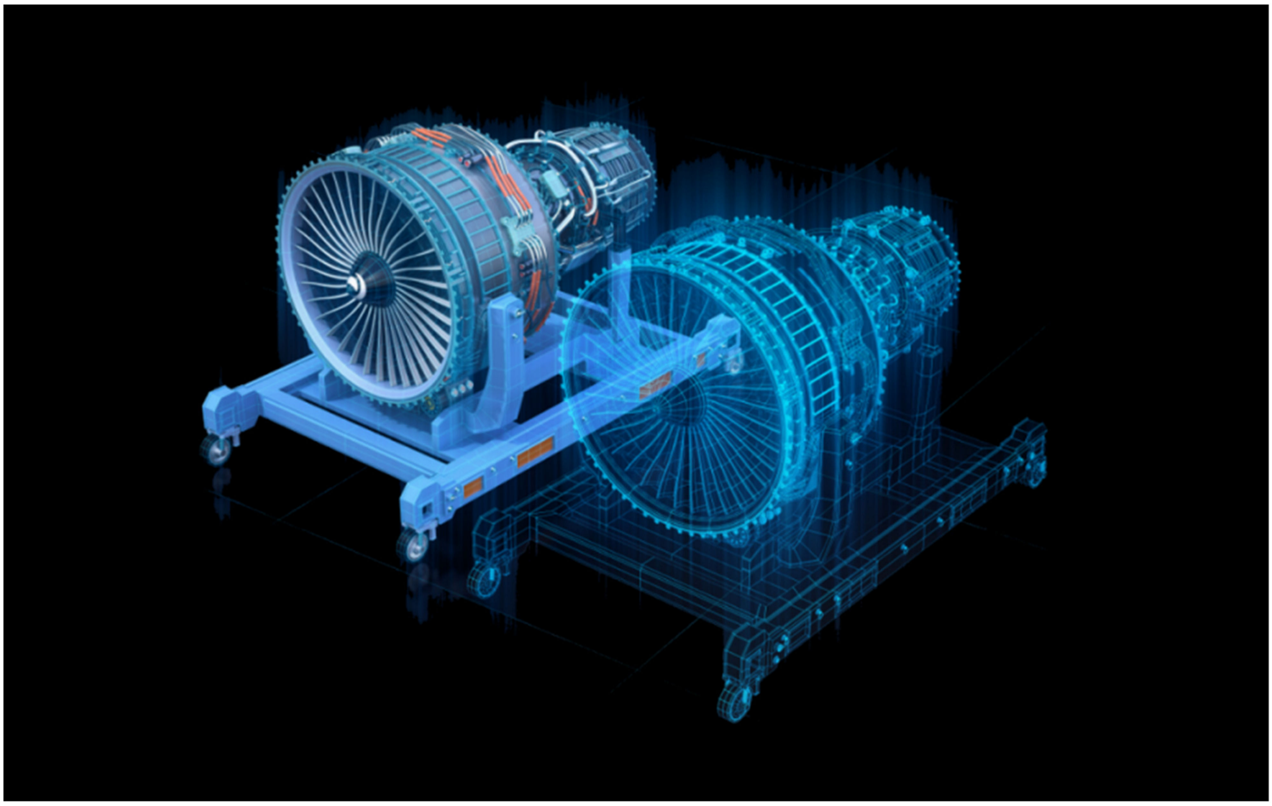

Figure 5. Real object and digital-twin model [82].

Figure 5 shows a real object of jet engine and its digital-twin model. That prototype with a physical 3D model of the real object that will actually be manufactured incorporates all requirements, annotations, bill of materials, and bill of processes. VR-enabled digital-twin technology enables designers, experts, and dispersed operations teams to collaborate on potential modifications or problems based on 3D representations and use real-time data from existing systems. For example, stakeholders working on overheating the shafts of wind turbines can do so without being physically present at the location, saving money on travel costs without wasting time making decisions. The Norwegian startup Visualiz is developing a platform for the visualization of physical assets in various industries, including the energy sector. They use VR to create a collaborative space for users where they can delve into different aspects of energy resources, monitor their online health, and spot areas for problem resolution or improvement. Their VR space is configurable depending on the scope of the project [83]. Digital-twin technologies in the power industry enable the development and maintenance of smart grids equipped with high-tech sensors and machine-learning models for increased efficiency and monitoring. Smart-grid meters enable energy service providers to make informed, strategic decisions and mitigate vulnerabilities and risk factors by disseminating up-to-date data. By combining cyber-physical systems, cloud computing, and intelligent industrial solutions, digital-twin technology becomes the basis for smart-grids deployment, renewable energy management, better integration, and efficient transmission [84]. The network of sensors in the energy infrastructure allows for better monitoring of energy demand and effective management of its transmission and storage. Sensors operating in the network also enable the maintenance of the network by monitoring its elements (e.g., the level of corrosion) [72]. Virtual models based on data obtained from the existing, real power grids reduces the time and cost of designing new installations. Already at the design stage, the possibility of obtaining data on a specific unit using sensors is taken into account. Large, time-varying, and diverse datasets after processing with artificial intelligence algorithms can yield conclusions about future improvements and user-anticipated features.

State-of-the-art technologies are making an impact on the energy industry. The increasing use of renewable sources leads to the diversification of energy resources and the need for real-time virtual testing is used more and more. Digital-twin technology enables companies to test ways to effectively combine these energy sources without risky action.

4.8. The Clean Energy Package as an Increase in Energy Efficiency

The EU is trying to reduce energy consumption. In 2019, final energy consumption (by end users) in the entire EU remained at the level of 990 Mtoe (million tons of oil equivalent), which means a slight decrease compared to 2005, where consumption amounted to 1041 Mtoe. However, in individual member states, final energy consumption in 2019, compared to 2005, was changed as shown in the Figure 6. The chart shows the change in energy consumption of EU member states in 2019 compared to 2005, and their 2020 targets [85].

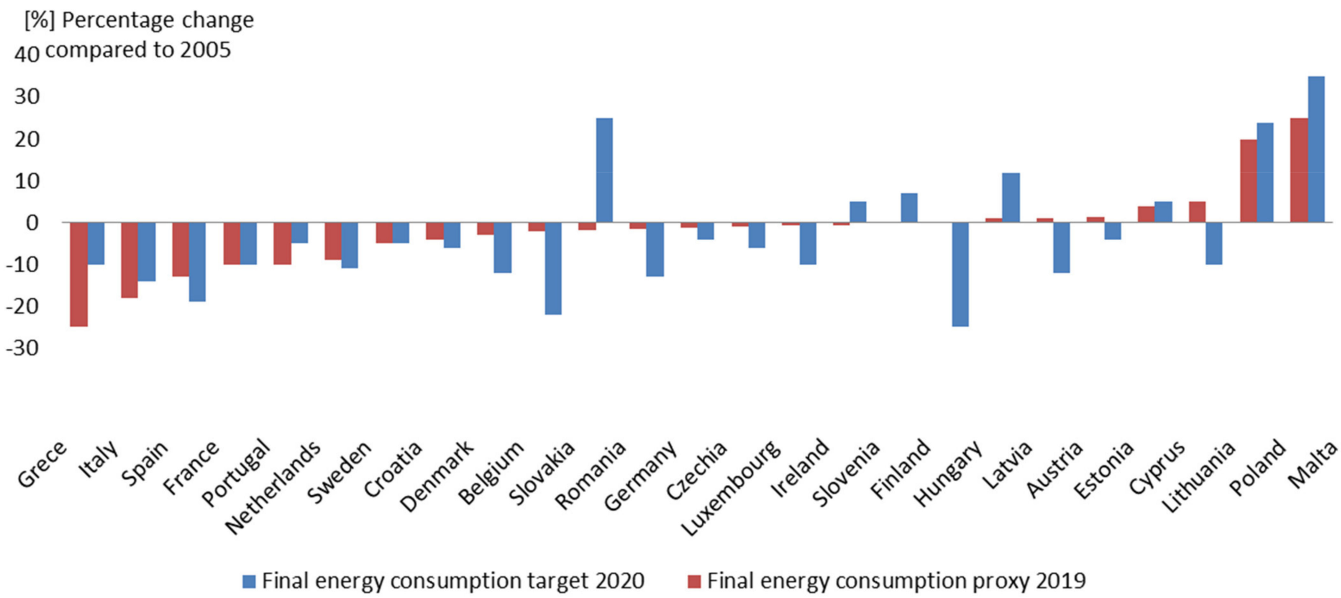

Figure 6. The changes in energy consumption of EU member states [85].

This chart shows change in consumption of energy in 2019 in EU countries compared to 2005, and their targets for 2020. From the figure we can noticed that Poland achieved the goal for 2020, but by contrast, Malta significantly exceeded its target, consuming more final energy.

In the Clean Energy for All Europeans Package (CEP) [86], a new target has been set to reduce energy consumption by at least 32.5% by 2030. A flexible energy plan, reducing peak consumption, offers even greater savings. It is estimated that the manufacturing industry is responsible for 20% of total CO_2 emissions. It definitely exceeds energy (40%) and transportation (23%). Although numerous efforts are required to reduce CO_2 emissions in the industry, programs aimed at reducing CO_2 in the energy industry are also important. Measures to ensure energy efficiency are increasingly recognized not only as a means of ensuring sustainable energy supplies, reducing greenhouse gas emissions, increasing security of supply but also an important factor in reducing energy import expenses.

The CEP package strengthens the position of prosumers as it enables them to consume, store, and sell their own electricity on the market. In addition, prosumers can participate in all electricity markets by providing system flexibility, for example through energy storage such as electric vehicle storage, through demand response, or through energy efficiency systems [77]. The CEP package reduces the country's dependence on imported energy sources. Every country that is a net energy importer adopts funds from the EU budget to help reduce its dependence on imports, even if oil prices are around 20 USD per barrel (April 13, 2020). This was the lowest figure recorded in over ten years. Crude oil prices in the years 2005–2020 are shown in the Figure 7.

Figure 7. Crude oil prices at Brent, London, in the years 2005–2021 [87].

From the point of view of the global economy, a sharp rise in oil prices has a negative impact on the economy, especially in countries that are net importers. The permanent increase in oil prices reduces the GDP growth. The increase in fuel prices is associated with higher costs of transport and production companies and is an impulse to increase inflation. The rapid increase in the prices of energy carriers (especially petroleum fuels) forces the implementation of rational energy-use programs and limiting the energy consumption of the economy. The dependence of the European Union (EU) on energy imports, in particular oil and natural gas, gives rise to energy policy concerns regarding the security of energy supply. The EU is increasingly dependent on imports of primary energy carriers and secondary derived products from non-EU countries due to a shortage of production in relation to consumption. In 2018, more than half (58.2%) of the gross available energy in the EU was imported [88].

The biggest role in increasing the share of RES in the Polish electricity balance was played by private energy companies and prosumers, which together built 81% of all renewable capacities installed in 2013–2019. The share of the public sector and energy companies with state treasury share in the construction of renewable energy sources in 2013-2019 did not exceed 15% [23]. One can see the direction of decentralized energy production from renewable sources, such as solar or wind energy, because companies and consumers decide to generate their own electricity. Consumers are becoming prosumers at the same time. Prosumers can also generate electricity and meet their own needs (off-grid) or generate surpluses that are transferred to the grid [19].

In addition to the benefits mentioned above, companies that are committed to improving energy efficiency in industry meet regulatory requirements, may seek new business opportunities, and fulfill social obligations. Energy regulations for commercial and industrial companies are increasing. There is evidence that the demand for commercial (elevators, electric drives, electric transmission equipment, and pumps) and consumer products (air conditioners, refrigerators, washing machines, light bulbs, and cars) meeting energy saving and energy efficiency requirements is steadily increasing. Companies with an energy efficiency culture are sure to take a leading role—not only in how they use energy, but also in the products and services they develop. Energy efficiency leaders often report increased innovation potential in their organizations. Some are discovering new business models that help other companies and consumers increase energy efficiency [17]. Increasingly, the issue of creating innovation in organizations is being considered, taking into account the importance of intangible assets, such as human capital, thanks to the appropriate innovative climate [89]. Decisions regarding the sources of value creation, e.g., innovation and shaping strategic potential, often result from the organization's ability to learn and develop a reliable strategy based on interactions, constructive dialogue, and facts [90].

When developing an industrial strategy, we often deal with contradictory situations. Some of them, such as production growth vs. environmental impact and automation vs. employment, are very complex issues. Developing countries' capacities are challenged in finding ways to simultaneously address efficiency and productivity, job creation, wage growth, added value, inequality, and environmental degradation and integration. While efficiency and productivity are critical to wage growth, it often leads to the adoption of advanced technology that reduces labor demand. To counter the role of labor-saving technology, often developing countries agree to environmental issues.

Pro-ecological activities observed in the global economy force the search for new solutions limiting the use of harmful technologies in industry. At the same time, along with the growing awareness of people about the negative impact of fossil fuel technology on the environment, any action to improve the surrounding environment is well perceived by the public. The use of entirely natural raw materials, consistent with the principles of sustainable development and "zero waste", is an important criterion in the production of modern products [34]. The new industrial age with paradigm of Industry 4.0 [91] offers the opportunity to deal with these variables simultaneously. For example, waste can be reduced or recycled profitably by using advanced digital production methods (ADP) that can address both competitiveness and the environment at the same time. To take advantage of this opportunity, it is time to focus on the right strategy.

There are some ways of solving conflicting goals in creating an industrial economy, including the following: (a) redesigning existing products and processes for their production, so as to reduce the material and energy requirements for their production. Such activities are usually aimed at reducing production costs and at the same time reducing the energy consumption of production processes [92]. A good example is the digital advancement used in the operation of a power plant, which can increase service life by up to 30% [93]. Designers more and more often try to reduce energy consumption by products throughout their life cycle. To achieve a significant reduction in energy consumption, it is important that energy considerations are taken into account in the product design phase as most of the product's environmental impact is determined at this stage [94]. Green products that use less energy and resources during production, generate less waste and pollution in the final stages [95]. (b) Redesigning products to lower operating costs, improve safety, and reduce environmental impact. By developing green products that use less energy and resources in production, generate less waste and pollution in the downstream stages to reduce the environmental impact throughout the product life cycle, companies create their own environmental design guidelines, listing the factors to be taken into account from the design stage to create safe, environmentally friendly products and carry out a qualitative and quantitative analysis. These factors include the following: reduction of environmental pollution, resource conservation and energy conservation, sustainable use of natural resources, use of recycled resources, and simplified processing and disposal of waste.

5. Conclusions

The future of the energy system is a multifaceted path leading to a low-carbon or zero-carbon economy. For this purpose, enterprises implement the latest technological, IT, and mechanical solutions. The most important aspects presented in the article are Industry 4.0 technologies (machine to machine and IoT), digitization, and increased use of state-of-the-art technologies, including virtual technology (VPP and AR). The research has shown that modern, innovative solutions used in other sectors of the economy (e.g., in the aviation industry) are also starting to be implemented in energy companies. As a response to distributed energy, energy companies should implement more decentralized systems (blockchain) and digital-twin scenarios that will provide an opportunity for enterprises to achieve the required transition architecture to solutions that meet environmental, economic, and social expectations. Digital transformation is an aspect on which all enterprises, including energy companies, focus, as shown by the presented research. Digitization allows one to accelerate the development of companies and adapt to new market trends. The presented research results showed that the economy needs cheap and reliable energy supplies, produced in an ecological, environmentally friendly way. Moreover, the method of implementing the environmental requirements required in the provisions of EU documents was presented. It also discussed what measures should be systematically implemented to reduce energy consumption and achieve energy independence. The research results indicate the direction in which the energy sector should develop in order to meet technological, environmental, and social requirements. For decision makers, both at the political level and at the level of management boards of companies, it is an indication of solutions that energy companies are facing.

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Abbreviations

ADP	advanced digital production
AMI	advanced metering infrastructure
AMT	additive manufacturing technologies
AR	augmented reality
CEP	Clean Energy for All Europeans Package
DSOs	distribution system operators
ESCO	energy saving/service company
GDP	gross domestic product
HEVs	hybrid electric vehicles
IEA	International Energy Agency
IoT	Internet of things
M2M	Machine to machine
ML	Machine learning
Mtoe	Million tons of oil equivalent
RES	renewable energy sources
RFID	radio frequency identification
TSO	transmission system operator
VPP	virtual power plant

References

1. Varela, I. Energy Is Essential, but Utilities? Digitalization: What Does It Mean for the Energy Sector? In *Digital Marketplaces Unleashed*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 829–838.
2. Sheveleva, A.; Tyaglov, S.; Khaiter, P. Digital Transformation Strategies of Oil and Gas Companies: Preparing for the Fourth Industrial Revolution. In *Digital Strategies in a Global Market Palgrave Macmillan*; Springer: Cham, Switzerland, 2021; pp. 157–171.
3. Kueppers, M.; Pineda, S.N.P.; Metzger, M.; Huber, M.; Paulus, S.; Heger, H.J.; Niessen, S. Decarbonization pathways of worldwide energy systems–Definition and modeling of archetypes. *Appl. Energy* **2021**, *285*, 116438. [CrossRef]
4. Borowski, P.F. Adaptation strategy on regulated markets of power companies in Poland. *Energy Environ.* **2019**, *30*, 3–26. [CrossRef]
5. Borowski, P.F. New Technologies and Innovative Solutions in the Development Strategies of Energy Enterprises. *Hightech Innov. J.* **2020**, *1*, 39–58. [CrossRef]
6. Rot, A.; Sobińska, M.; Hernes, M.; Franczyk, B. Digital Transformation of Public Administration Through Blockchain Technology. In *Towards Industry 4.0—Current Challenges in Information Systems. Studies in Computational Intelligence*; Hernes, M., Rot, A., Jelonek, D., Eds.; Springer: Cham, Switzerland, 2020; Volume 887. [CrossRef]
7. Manfren, M.; Sibilla, M.; Tronchin, L. Energy Modelling and Analytics in the Built Environment—A Review of Their Role for Energy Transitions in the Construction Sector. *Energies* **2021**, *14*, 679. [CrossRef]
8. Recalde, M.Y. Which aspects may prevent the development of energy service companies? The impact of barriers and country-specific conditions in different regions. In *Energy Services Fundamentals and Financing*; Academic Press: New York, NY, USA, 2021; pp. 293–315. [CrossRef]
9. The Polish Industrial Sector is Increasing Investments in Renewable Energy and Energy Efficiency (In Polish). Available online: https://www.innogy.pl/pl/duze-przedsiebiorstwa/artykuly/2020/polski-sektor-przemyslowy-zwieksza-inwestycje-w-oze-i-efektywnosc-energetyczna (accessed on 22 March 2021).
10. Silvestre, B.S.; Ţîrcă, D.M. Innovations for sustainable development: Moving toward a sustainable future. *J. Clean. Prod.* **2019**, *208*, 325–332. [CrossRef]
11. Chang, C.P.; Wen, J.; Zheng, M.; Dong, M.; Hao, Y. Is higher government efficiency conducive to improving energy use efficiency? *Evidence from OECD countries. Econ. Model.* **2018**, *72*, 65–77. [CrossRef]
12. Safarzadeh, S.; Rasti-Barzoki, M.; Hejazi, S.R. A review of optimal energy policy instruments on industrial energy efficiency programs, rebound effects, and government policies. *Energy Policy* **2020**, *139*, 111342. [CrossRef]
13. How the State Supports Energy Efficiency (In Polish). 2020. Available online: https://www.nik.gov.pl/aktualnosci/jak-panstwo-wspiera-efektywnosc-energetyczna.html (accessed on 12 February 2021).
14. Wojdalski, J.; Krajnik, M.; Borowski, P.F.; Dróżdż, B.; Kupczyk, A. Energy and water efficiency in the gelatine production plant. *AIMS Geosci.* **2020**, *6*, 491–503. [CrossRef]
15. The Act of May 20, 2016 on Energy Efficiency, Dz.U.2020.264 (In Polish). Available online: https://sip.lex.pl/akty-prawne/dzu-dziennik-ustaw/efektywnosc-energetyczna-18315509 (accessed on 9 January 2021).
16. Energy Efficiency—Getting More from Less. Available online: https://unece-modl.dotsoft.gr/DAM/energy/se/pdfs/Booklet_Dec2015/Booklet_Energy.Efficiency_Dec.2015.pdf (accessed on 9 January 2021).
17. Fokeer, S.; Subbotnitskiy, D.; Clara, M. *Industrial Policy Measures for Industrial Energy Efficiency Improvements*; Department of Policy, Research and Statistics, Working Paper 23/2018; UNIDO: Vienna, Austria, 2018.
18. Tvaronavičienė, M.; Lisin, E.; Kindra, V. Power Market Formation for Clean Energy Production as the Prerequisite for the Country's Energy Security. *Energies* **2020**, *13*, 4930. [CrossRef]
19. Borowski, P.F. Zonal and Nodal Models of Energy Market in European Union. *Energies* **2020**, *13*, 4182. [CrossRef]
20. Stephenson, J.R.; Sovacool, B.K.; Inderberg, T.H.J. Energy cultures and national decarbonisation pathways. *Renew. Sustain. Energy Rev.* **2021**, *137*, 110592. [CrossRef]
21. Seroka-Stolka, O.; Fijorek, K. Enhancing corporate sustainable development: Proactive environmental strategy, stakeholder pressure and the moderating effect of firm size. *Bus. Strategy Environ.* **2020**, *29*, 2338–2354. [CrossRef]
22. EU External Investment Plan. Available online: https://ec.europa.eu/info/sites/info/files/external-investment-plan-factsheet_en.pdf (accessed on 28 March 2021).
23. Record Investments in Renewable Energy (In Polish). 2020. Available online: http://wise-europa.eu/2020/06/17/rekordowe-inwestycje-w-oze-w-2019-r-nowy-raport-wiseeuropa-zrodla-finansowania-i-potrzeby-inwestycyjne-w-sektorze/ (accessed on 12 February 2021).
24. World Energy Balances: Overview. 2020. Available online: https://www.iea.org/reports/world-energy-balances-overview#world (accessed on 9 January 2021).
25. Progress in the Areas of Energy Efficiency and Renewable Energy in Selected Countries of the UNECE Region. Available online: https://unece-modl.dotsoft.gr/DAM/energy/se/pdfs/geee/pub/ES_59_2019/ECE_ES_59_E_pdf_web.pdf (accessed on 9 January 2021).
26. Seroka-Stolka, O. The development of green logistics for implementation sustainable development strategy in companies. *Procedia-Soc. Behav. Sci.* **2014**, *151*, 302–309. [CrossRef]
27. Winch, S. Cultural determinants of leadership in enterprises—research results. *Cent. Eur. Manag. J.* **2011**, *19*, 102–113.
28. Charkha, P.G.; Jaju, S.B. Decision Support System for Supply Chain Performance Measurement: Case of Textile Industry. In *New Paradigm of Industry 4.0*; Patnaik, S., Ed.; Studies in Big Data; Springer: Cham, Switzerland, 2020; Volume 64. [CrossRef]

29. Maksimchuk, O.; Pershina, T. A New Paradigm of Industrial System Optimization based on the Conception "Industry 4.0". In MATEC Web of Conferences. EDP Sciences. 2017. Available online: https://www.matec-conferences.org/articles/matecconf/abs/2017/43/matecconf_icmtmte2017_04006/matecconf_icmtmte2017_04006.html (accessed on 8 March 2021).
30. Medic, N.; Anisic, Z.; Tasic, N.; Zivlak, N.; Lalic, B. Technology Adoption in the Industry 4.0 Era: Empirical Evidence from Manufacturing Companies. In Proceedings of the IFIP International Conference on Advances in Production Management Systems, Novi Sad, Serbia, 30 August–3 September 2020; Lalic, B., Majstorovic, V., Marjanovic, U., von Cieminski, G., Romero, D., Eds.; Springer: Cham, Switzerland, 2020; Volume 591. [CrossRef]
31. Industrial Development Report 2020. Available online: https://www.unido.org/resources-publications-flagship-publications-industrial-development-report-series/idr2020 (accessed on 9 January 2021).
32. Annual Report 2019. Available online: https://www.unido.org/annualreport2019 (accessed on 9 January 2021).
33. United Nations Industrial Development Organization. *Industrial Development Report 2020*; Industrializing in the digital age. Overview; United Nations Industrial Development Organization: Vienna, Austria, 2019.
34. Żelaziński, T. Properties of Biocomposites from Rapeseed Meal, Fruit Pomace and Microcrystalline Cellulose Made by Press Pressing: Mechanical and Physicochemical Characteristics. *Materials* **2021**, *14*, 890. [CrossRef] [PubMed]
35. Hernes, M.; Rot, A.; Jelonek, D. *Towards Industry 4.0—Current Challenges in Information Systems*; Springer: Cham, Switzerland, 2020; Volume 887.
36. Rokonuzzaman, M. Industrial Strategy in the Advanced Digital Age, The Financial Express. 2020. Available online: https://thefinancialexpress.com.bd/public/views/industrial-strategy-in-the-advanced-digital-age-1579013765 (accessed on 2 January 2021).
37. Kościelniak, H.; Łęgowik-Małolepsza, M.; Łęgowik-Świącik, S. The Application of Information Technologies in Consideration of Augmented Reality and Lean Management of Enterprises in the Light of Sustainable Development. *Sustainability* **2019**, *11*, 2157. [CrossRef]
38. Simpson, J.; Haley, J.; Cramer, C.; Shafer, O.; Elliott, A.; Peter, B.; Love, L.; Dehoff, R. Considerations for Application of Additive manufacturing to Nuclear Reactor Core Components. ORNL/TM-2019-1190, Oak Ridge National Laboratory. 2019. Available online: https://tcr.ornl.gov/wp-content/uploads/2019/09/M3CT-19OR06090123-Considerations-for-AM-of-Nuclear-Components.pdf (accessed on 22 February 2021).
39. Sun, C.; Wang, Y.; McMurtrey, M.D.; Jerred, N.D.; Liou, F.; Li, J. Additive manufacturing for energy: A review. *Appl. Energy* **2021**, *282*, 116041. [CrossRef]
40. Energy Sector Management Assistance Program. Funding the Sun: New Paradigms for Financing Off-Grid Solar Companies. 2020. Available online: https://www.esmap.org/Funding_the_Sun (accessed on 22 February 2021).
41. Bai, H.; Miao, S.; Ran, X.; Ye, C. Optimal dispatch strategy of a virtual power plant containing battery switch stations in a unified electricity market. *Energies* **2015**, *8*, 2268. [CrossRef]
42. Virtual Power Plant (VPP). Available online: https://www.next-kraftwerke.com/vpp/virtual-power-plant (accessed on 12 January 2021).
43. Wang, H.; Riaz, S.; Mancarella, P. Integrated techno-economic modeling, flexibility analysis, and business case assessment of an urban virtual power plant with multi-market co-optimization. *Appl. Energy* **2020**, *259*, 114142. [CrossRef]
44. Exchangees: At the Core of the Future Energy Market. Our Vision for an Evolving Energy Sector. Available online: https://www.europex.org/position-papers/exchanges-at-the-core-of-the-future-energy-market-our-vision-for-an-evolving-energy-sector/ (accessed on 22 February 2021).
45. Navarra, A.; Ross, A.; Toro, N.; Ayala, F.; Marín, T. Quantitative Methods to Support Data Acquisition Modernization within Copper Smelters. *Processes* **2020**, *8*, 1478. [CrossRef]
46. Borowski, P.F. Innovative Processes in Managing an Enterprise from the Energy and Food Sector in the Era of Industry 4.0. *Processes* **2021**, *9*, 381. [CrossRef]
47. Li, Y.; Dai, J.; Cui, L. The impact of digital technologies on economic and environmental performance in the context of industry 4.0: A moderated mediation model. *Int. J. Prod. Econ* **2020**, 107777. [CrossRef]
48. Sima, V.; Gheorghe, I.G.; Subić, J.; Nancu, D. Influences of the industry 4.0 revolution on the human capital development and consumer behavior: A systematic review. *Sustainability* **2020**, *12*, 4035. [CrossRef]
49. Ahmad, N.; Shamsuddin, A.; Aslinda, A.S. Industry 4.0 implications on human capital: A review. *J. Stud. Manag. Plan.* **2018**, *4*, 221–235.
50. Chaudhuri, A. Transformation with trustworthy digital: Policy desiderata for businesses in post Covid-19 worlds. *EDPACS* **2021**, *63*, 1–8. [CrossRef]
51. Digital Wind of Change (In Polish). Available online: https://transformacja2050.pl/project/cyfryzacja-w-energetyce-analiza/ (accessed on 29 January 2021).
52. Mahdin, H.; Abawajy, J.; Yaacob, S.S. Energy Efficient Approach in RFID Network. In Proceedings of the IOP Conference Series: Materials Science and Engineering, Bali, Indonesia, 19–20 March 2016; IOP Publishing: Bristol, UK, 2016; Volume 160, p. 12090.
53. Su, J.; Sheng, Z.; Leung, V.C.M.; Chen, Y. Energy Efficient Tag Identification Algorithms for RFID: Survey, Motivation And New Design. *IEEE Wirel. Commun.* **2019**, *26*, 118–124. [CrossRef]
54. Radio Frequency Identification (RFID). Available online: https://sites.google.com/site/impactofictonthelogistics/home/the-role-of-lct-in-warehousing/radio-frequency-identification-rfid (accessed on 10 February 2021).

55. Küfeoglu, S.; Liu, G.; Anaya, K.; Pollitt, M. *Digitalisation and New Business Models in Energy Sector*; University of Cambridge: Cambridge, UK, 2019. [CrossRef]
56. Andoni, M.; Robu, V.; Flynn, D.; Abram, S.; Geach, D.; Jenkins, D.; McCallum, P.; Peacock, A. Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renew. Sustain. Energy Rev.* **2019**, *100*, 143–174. [CrossRef]
57. Benisi, N.Z.; Aminian, M.; Javadi, B. Blockchain-based decentralized storage networks: A survey. *J. Netw. Comput. Appl.* **2020**, 102656. [CrossRef]
58. Son, Y.-B.; Im, J.-H.; Kwon, H.-Y.; Jeon, S.-Y.; Lee, M.-K. Privacy-Preserving Peer-to-Peer Energy Trading in Blockchain-Enabled Smart Grids Using Functional Encryption. *Energies* **2020**, *13*, 1321. [CrossRef]
59. Di Silvestre, M.L.; Gallo, P.; Guerrero, J.M.; Musca, R.; Sanseverino, E.R.; Sciumè, G.; Vásquez, J.C.; Zizzo, G. Blockchain for power systems: Current trends and future applications. *Renew. Sustain. Energy Rev.* **2020**, *119*, 109585. [CrossRef]
60. Wang, S.; Taha, A.F.; Wang, J.; Kvaternik, K.; Hahn, A. Energy Crowdsourcing and Peer-to-Peer Energy Trading in Blockchain-Enabled Smart Grids. *IEEE Trans. Syst. Man Cybern. Syst.* **2019**, *49*, 1612–1623. [CrossRef]
61. Heo, K.; Kong, J.; Oh, S.; Jung, J. Development of operator-oriented peer-to-peer energy trading model for integration into the existing distribution system. *Int. J. Electr. Power Energy Syst.* **2021**, *125*, 106488. [CrossRef]
62. Tushar, W.; Yuen, C.; Saha, T.K.; Morstyn, T.; Chapman, A.C.; Alam, M.J.E.; Hanif, S.; Poor, H.V. Peer-to-peer energy systems for connected communities: A review of recent advances and emerging challenges. *Appl. Energy* **2021**, *282*, 116131. [CrossRef]
63. Jiang, A.; Yuan, H.; Li, D. A two-stage optimization approach on the decisions for prosumers and consumers within a community in the Peer-to-peer energy sharing trading. *Int. J. Electr. Power Energy Syst.* **2021**, *125*, 106527. [CrossRef]
64. Tushar, W.; Saha, T.K.; Yuen, C.; Azim, M.I.; Morstyn, T.; Poor, H.V.; Niyato, D.; Bean, R. A coalition formation game framework for peer-to-peer energy trading. *Appl. Energy* **2020**, *261*, 114436. [CrossRef]
65. Lan, T.; Liu, X.; Wang, S.; Jermsittiparsert, K.; Alrashood, S.T.; Rezaei, M.; Al-Ghussain, L.; Mohamed, M.A. An Advanced Machine Learning Based Energy Management of Renewable Microgrids Considering Hybrid Electric Vehicles' Charging Demand. *Energies* **2021**, *14*, 569. [CrossRef]
66. Zhang, X.; Xu, Q.; Lu, J.; Xu, J. Conceptual characteristics and analysis of typical application scenarios of energy blockchain. In *Journal of Physics: Conference Series*; IOP Publishing: Bristol, UK, 2021; Volume 1738, p. 12113.
67. Wang, Q.; Su, M. Integrating blockchain technology into the energy sector—from theory of blockchain to research and application of energy blockchain. *Comput. Sci. Rev.* **2020**, *37*, 100275. [CrossRef]
68. Mrowiec, D.; Sołtysik, M. Examples of possible blockchain technology applications in the power engineering sector (In Polish). *Zesz. Nauk. Inst. Gospod. Surowcami Miner. Pol. Akad. Nauk* **2018**, *103*, 133–144.
69. Maesa, D.D.F.; Mori, P. Blockchain 3.0 applications survey. *J. Parallel Distrib. Comput.* **2020**, *138*, 99–114. [CrossRef]
70. Digitalization and Energy. Available online: https://www.iea.org/reports/digitalisation-and-energy (accessed on 29 January 2021).
71. Booth, A.; Patel, N.; Smith, M. Digital Transformation in Energy: Achieving Escape Velocity. 2020. Available online: https://www.mckinsey.com/industries/oil-and-gas/our-insights/digital-transformation-in-energy-achieving-escape-velocity (accessed on 9 January 2021).
72. The Future of Digitization in the Energy Sector (In Polish). Available online: https://transformacja2050.pl/project/cyfryzacja-w-energetyce-analiza/ (accessed on 29 January 2021).
73. GE Digital, Digital Twins: The Bridge Between Industrial Assets and the Digital World. Available online: https://www.ge.com/digital/blog/digital-twins-bridge-between-industrial-assets-and-digital-world (accessed on 23 January 2021).
74. Digital Twin: The Challenge of Nuclear Power Plants. Available online: https://www.corys.com/en/steps/article/digital-twin-challenge-nuclear-power-plants (accessed on 23 January 2021).
75. Hou, L.; Wu, S.; Zhang, G.K.; Tan, Y.; Wang, X. Literature Review of Digital Twins Applications in Construction Workforce Safety. *Appl. Sci.* **2021**, *11*, 339. [CrossRef]
76. Teng, S.Y.; Touš, M.; Leong, W.D.; How, B.S.; Lam, H.L.; Máša, V. Recent advances on industrial data-driven energy savings: Digital twins and infrastructures. *Renew. Sustain. Energy Rev.* **2021**, *135*, 110208. [CrossRef]
77. Directive of the European Parliament and of the Council on Common Rules for the Internal Market for Electricity and Amending Directive 2012/27/EU. Available online: https://data.consilium.europa.eu/doc/document/PE-10-2019-INIT/en/pdf (accessed on 9 January 2021).
78. Bevilacqua, M.; Bottani, E.; Ciarapica, F.E.; Costantino, F.; Di Donato, L.; Ferraro, A.; Mazzuto, G.; Monteriù, A.; Nardini, G.; Ortenzi, M.; et al. Digital twin reference model development to prevent operators' risk in process plants. *Sustainability* **2020**, *12*, 1088. [CrossRef]
79. Di Nardo, M.; Madonna, M.; Murino, T.; Castagna, F. Modelling a Safety Management System Using System Dynamics at the Bhopal Incident. *Appl. Sci.* **2020**, *10*, 903. [CrossRef]
80. Di Nardo, M.; Gallo, M.; Murino, M.; Santillo, L.C. System dynamics simulation for fire and explosion risk analysis in home environment. *Int. Rev. Model. Simul.* **2017**, *10*, 43–54. [CrossRef]
81. Can Digital Transformation Reduce Business Costs. Available online: https://retaintechnologies.com/en/can-digital-transformation-reduce-business-costs/ (accessed on 21 March 2021).
82. Digital Twins as a New IoT Milestone: How Do They Work? 2019. Available online: https://hqsoftwarelab.com/blog/digital-twins/ (accessed on 12 February 2021).

83. 4 Top Digital Twin Startups Impacting The Energy Industry. Available online: https://www.startus-insights.com/innovators-guide/4-top-digital-twin-startups-impacting-energy-industry/ (accessed on 23 January 2021).
84. The Revolutionary Impact of Digital Twin in the Energy Sector. 2020. Available online: https://www.cigniti.com/blog/digital-twin-eu-energy-utilities/ (accessed on 23 January 2021).
85. Energy Consumption of EU Member. Available online: https://www.eea.europa.eu/data-and-maps/figures/energy-consumption-of-eu-member (accessed on 23 January 2021).
86. Publications Office of the European Union. *Clean Energy for All Europeans*; Publications Office of the European Union: Luxembourg, 2019.
87. Energy.Instrat.pl. Available online: http://energy.instrat.pl/oil_prices (accessed on 24 March 2021).
88. Energy Production and Imports. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_production_and_imports (accessed on 23 January 2021).
89. Bylok, F.; Jelonek, D.; Tomski, P.; Wysłocka, E. Role of Social Capital in Creating Innovative Climate in Enterprises: The Case of Poland. In Proceedings of the ICICKM 2019 16th International Conference on Intellectual Capital Knowledge Management & Organisational Learning, Sydney, Australia, 5–6 December 2019; p. 73.
90. Bratnicki, M.; Dyduch, W. Understanding Cognitive Biases in Strategic Decisions for Value Creation and Capture. In *Contemporary Challenges in Cooperation and Coopetition in the Age of Industry 4.0*; Zakrzewska-Bielawska, A., Staniec, I., Eds.; Springer Proceedings in Business and Economics; Springer: Cham, Switzerland, 2020. [CrossRef]
91. Di Nardo, M. Developing a Conceptual Framework Model of Industry 4.0 for Industrial Management. *Ind. Eng. Manag. Syst.* **2020**, *19*, 551–560. [CrossRef]
92. Żelaziński, T.; Słoma, J.; Skudlarski, J.; Ekielski, A. The rape pomace and microcrystalline cellulose composites made by press processing. *Sustainability* **2020**, *12*, 1311. [CrossRef]
93. Pozo, O. How Digitalization can Help the Energy Sector to Reduce Their Costs? Available online: https://www.linkedin.com/pulse/how-digitalization-can-help-energy-sector-reduce-costs-oliver-pozo (accessed on 22 March 2021).
94. Seow, Y.; Goffin, N.; Rahimifard, S.; Woolley, E. A 'Design for Energy Minimization'approach to reduce energy consumption during the manufacturing phase. *Energy* **2016**, *109*, 894–905. [CrossRef]
95. Camarsa, G.; Toland, J.; Eldridge, J.; Potter, J.; Stephen Nottingham, S.; Marianne Geater, M.; de la Paz, C.; Martínez, E. *Life and Circular Economy*; Publications Office of the European Union: Luxembourg, 2017. [CrossRef]