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Conceptual Paper

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Opportunities and threats to shaping energy security in the conditions of development and use of new technologies

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Abstract: This article aims to show the areas in which technological changes will take place to bring about energy security, and the prerequisites and costs. It has been assumed that technological progress will contribute to the development of energy markets and increase the level of energy security. Changes in energy markets are a necessity. Energy is a source of economic competitiveness. The ability to produce cheap energy and in quantities adequate to needs is a social and economic development factor. The opportunities for change will be the need for new energy sources, instability in the energy markets, as well as technological progress. New technological solutions allow for better energy demand and supply management and preparing forecasts for increases/decreases in the energy demand. The threats are high costs of introducing new technologies and the necessity of implementing many investments at the same time, which require changes in entire systems. Investments require a long period of time and anticipation of trends.

Keywords: energy markets, energy security, new technologies
JEL Classification: O13, O14

1 Introduction

Energy security [Cziomer, 2008; Kaczmarski, 2010; Młynarski, 2011; Pach – Gargul, 2012; Pronińska, 2012; Ruszel, 2014] is taking on a new meaning. The issue is no longer solely about the level of supply relative to demand, but increasingly about the types of energy carriers, the technology, the availability of energy at a given time and place and, most importantly, the price.

Energy [Górka, 2014; Sharma, 2010] has become the most important factor for economic and social change, and continues to be a tool for political influence. Thus, the role of energy in countries' economies is a crucial element of civilizational progress and a determinant of development.

Searching for energy independence and, at the same time, seeing this search as a source of benefits for positive change is now becoming one of the most important social, economic, and political expectations. However, it requires significant capital expenditure not only to implement new technologies, but also to adapt existing systems and facilities to meet the challenges of the future.

This article aims to show the areas in which technological changes will take place to bring about energy security, and the prerequisites and costs.

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2 Methodology

The literature [Snyder, 2019] distinguishes three types of reviews: systematic, semi-systematic (narrative), and integrative. These three types of literature reviews are characterized by different methodological approaches and differ in terms of their purpose, research questions, analysis and evaluation, and examples of contribution. The literature review presented in this article is semi-systematic. This methodological approach was chosen based on the nature of the analyzed problem. The article aims to provide an overview showing the areas in which technological changes will take place to bring about energy security, and the prerequisites and costs.

The research question is specified broadly, as the intention is to identify all opportunities and threats, rather than to synthesize studies on a particular research question or relationship between new technologies and energy security.

When it comes to selection of publications, the search strategy is non-systematic in a sense that the intention was not to cover all articles ever written on the analyzed topic, but rather identification of the most relevant and influential and new studies in the field of interest. The objective was to select publications that had the highest impact on the development of research in the field.

Analysis and evaluation of research are qualitative in nature. The intended contribution of this article is to synthesize the state of knowledge on the impact of new technologies on energy security, and identify the possible opportunities and threats.

3 The concept of energy security

The concept of energy security is an essential element of national security and, as such, should be the subject of in-depth analysis in the economic, social, and political contexts. Until now, energy security has been identified with ensuring energy self-sufficiency [https://inwestycje.pl/gospodarka/strategicznym-celem-rzadu-jest-samowystarczalnosc-energetyczna-polski/; https://ourworld.unu.edu/en/energy-self-sufficiency-a-realistic-goal-or-a-pipe-dream] (the energy self-sufficiency index is the ratio between the amount of energy produced in a country and the amount of energy consumed in a given period), which was part of the state's activities and constituted an expression of its international policy. Such a standpoint resulted from political conditions and sovereign actions of the state and from internal conditions, that is, environmental, technical, and economic, whose limitations or possibilities determined the conditions of shaping energy security.

Changeability of the external and internal environment, technological progress, limited resources of energy resources, and the progressive process of globalization force changes in the way this issue is perceived and new conditions for its shaping.

Ensuring energy security is no longer just an element of state security but an element of economic security [Niedziółka, 2021]. This shift in emphasis is due to the role of energy and the fact that the economy's competitiveness largely depends on primary and secondary energy prices, energy policy, climate policy, the country's level of economic and social development, and historical circumstances.

The multitude and complexity of energy security factors ultimately determine their level and cost of achieving it. That is why it has become so important nowadays to define what energy security is and how it can be ensured. The role of energy security in overall security is an inherent feature of all states. However, in terms of economic, social, and technical security, it depends on the specifics of the energy market, the structure and size of the economy, the population and consumption patterns, and the nature of international ties.

The issue of energy security becomes critical in the case of countries that are strongly interconnected or whose historical past has many implications for the current shaping of energy access conditions. Common technical infrastructure, strong trade links, and limited energy supply on the market are just some of the consequences of strong ties between countries that were historically a single national territory, for example, the USSR and Yugoslavia. Today, a group of countries within the post-Soviet area must and are establishing

new forms of cooperation or sovereignty in terms of shaping energy security. Owing to its multifaceted nature and the need to incur significant financial outlays to implement new infrastructure projects and operate in a setting of often sensitive international politics, the process is lengthy and costly.

Highly developed countries also face energy security challenges, since they lack energy raw materials. At the same time, due to the structure of their economies and the level of energy consumption, they have significant energy requirements as regards the generation of electricity and mechanical energy in particular. Ensuring a sufficient supply of energy determines the standard and quality of life of citizens and the ability of the economy to produce the industries and services that define a country's position and stature in the international arena. Such countries include the countries of the European Union as well as the other countries making up the Economic Triad.

Last but not least, energy security is an important element of advantage building for developing countries. Their ability to compete, create conditions for the inflow of direct foreign investment, increase the volume of production or initiate new forms of activity, develop socially, and urbanize strongly depends on the quantity and cost of energy supplied. In the countries of Southeast Asia and South America, energy demand is closely correlated with the size of the population, their income, and changes in the size and structure of their GDP.

4 Evolution of the concept of energy security

The concept of energy security is defined in very different ways. It is most often perceived as a state of non-threat or as security of supply [Directive 2004/67/EC concerning measures to safeguard security of natural gas supply, April 2004; The Green Paper on security of energy supply]. Meanwhile, this category has a much broader scope, as it can be identified with the creation of conditions for the supply of energy carriers (natural gas, crude oil and hard coal) to producers and domestic consumers, as well as the supply of secondary energy (electricity, heat) to consumers. The creation of energy security can therefore be developed both nationally and internationally.

Energy security can be considered politically, economically, and technically and even ecologically [Ruszel, 2014].

The political prism of energy security of the state and its institutions means uninterrupted energy supply to the basic sectors and institutions of the state, including communications and transport, health, defense system, and finance and banking. In this context, the burden on state institutions of responsibility for ensuring continuity of supply or creating a situation in which there is no risk of interruptions in access to energy sources is highlighted. Such a solution often requires the participation of other states and/or organizations in the security system. It underlines the responsibility of certain energy market participants for security conditions.

In turn, the economic aspect considers the need to financially justify the implementation of certain investment projects. The issue of cost is fundamental to this approach. Energy security requires the choice of the right, economically justified energy source. The pressure is on the level of competitiveness and the related growth rate of national income. Hence, the cost of domestically produced and/or imported energy, the structure of energy production, the shape of energy policy, and the technology used are of primary importance. For example, the uncertainty of regulation related to the allocation of free CO_2 emission allowances and CO_2 emission allowance prices, and the cost of purchasing a wind or solar installation in the face of uncertainty of legal decisions.

In this sense, energy security is affected when, as a result of interruptions in energy supply or its irregularity, as well as sudden and significant increases in the prices of primary energy carriers, the dynamics of economic development is impeded: the growth rate of national income is reduced or slowed down, the standard of living of the population is lowered, and there are many other negative effects on the economy and the population. Energy security is also undermined when electricity, heat or fuel prices reach levels unacceptable to society [Kaczmarski, 2010; Młynarski, 2011; Pach – Gargul, 2012; Ruszel, 2014].

In contrast, the technical approach to energy security mainly refers to the elements of infrastructure, that is, the physical capabilities of facilities, equipment, and technologies and the compatibility of elements. Thus, it is more comprehensive in the operational part of energy security, focusing on the technical condition and efficiency of infrastructure elements for energy generation, distribution, transmission, and at present, increasingly on monitoring the volume and timing of energy demand. Threats or risks to technical energy security are evidenced by blackouts, failures in the transmission of raw materials, or restrictions on access to data for predicting energy demand.

The evolution of the concept of energy security occurs not only through the prism of the adopted perspective but also the meaning it has for shaping state security. In the early years, that is, in the 19th century when electricity markets were established, their scope for economic impact was severely limited [Niedziółka, 2018]. The markets were local. Countries remained self-sufficient in meeting their energy needs. The volume of energy production was determined by access to domestic coal, oil, or natural gas deposits, the technological capabilities available, and consumers' wealth. The 20th century was a time of great change. The strong industrialization of countries led to an increase in the demand for electricity and at the same time to numerous changes in the conditions for its generation. After World War II, countries changed their policies to recognize the strategic nature of the energy sector. That is why there has been a series of decisions aimed at nationalizing entities or creating consolidated entities whose position on the market would guarantee energy security. At the same time, technological advances facilitated the electrification of even territorially vast countries, the use of new sources of primary energy, and installation of the largest generating units [Krawiec 2015].

This century is bringing changes to energy markets. The process of globalization is not limited to changes in the trade in goods and the range of services provided, but determines the intensity and scale of change in energy markets. Liberalization, privatization, and deregulation processes are taking place. In parallel, opening up energy markets promotes their integration and multifaceted interconnection. Modern energy markets are no longer defined by national borders but are becoming attractive areas for investment and economic activity. This aspect is particularly important considering that energy markets are taking on characteristics typical of commodity markets. They become a place for competition, for the play of supply and demand, for assessing profitability and growth prospects, and a place for new stakeholders.

Technological progress is shifting the raw material barrier, increasing the flexibility of demand and supply, the size of the market is expanding, and the existing structure is changing. The main rationale for the operation of energy markets is that they are economically beneficial. This is accompanied by a growing environmental awareness, which is changing the structure of the energy carriers used and influencing the conditions of energy security {Krawiec 2012}. The growing role of renewable and/or low-carbon energy sources requires technological changes to ensure the efficient operation of the power engineering system. It also requires skillful anticipation of changes in energy supply that depend on an unstable energy source and, at the same time, the operation of units in a so-called base.

Thus, energy security is becoming considered as a state of the economy that is able to meet the current and future needs for fuels and energy in an economically and technically feasible manner while meeting environmental protection requirements.

With the multiplicity and intensity of international links, energy security is increasingly perceived globally. Where the global dimension is a source of threats and creates conditions for their elimination or mitigation, it is difficult to make assumptions for energy security without considering the energy policies of neighboring countries and/or those forming regional agreements.

5 Technological changes in energy markets

Technological changes determine not only the possibility of introducing new products and services into the market, but above all, they change the conditions of business activity. They determine the scale and size of the market, and the dynamics and intensity of the processes. Technological trends contribute to a change

in operating philosophies, consequently influencing the conditions and price of energy and the shape of energy security.

Noteworthy technological changes include those relating to the use of renewable energy sources, energy storage, electromobility, or data management.

Data acquired at high frequency show economic activity at different scales. The ability to acquire and collect data and the technical advances that accompany metering influence the decisions of energy producers and suppliers. The data are also a source of information for its consumers and a determinant of their behavioral changes. For example the "My meter" app, which allows you to monitor your power consumption in detail and start saving [https://energa-operator.pl/dla-konsumenta/licz-z-moim-licznikiem].

Technological progress in data collection affects the operation of distribution network operators. Information on the volume of energy consumed determines the volume of energy imports. Applications make it possible to calculate accurate wind forecasts and further optimize trading strategies. The applications use machine learning and automatically make updates. This enables the analysis of demand for specific services or energy volumes to provide commercial recommendations and allows them to be continuously adapted to market conditions. The solutions used include smart energy platforms, a platform where owners of solar power plants, heat pumps, and energy storage system or electronic charging stations can connect their infrastructure and optimize energy supply [https://www.controlengineering.pl/technologie-big-data-zrodlem-ogromnych-oszczednosci-energetycznych/].

Renewable energy development has made it necessary to document and account for electricity flows between sellers, consumers, and prosumers. The local nature of weather conditions, rapid changes in supply and demand in the energy market, or the load on the system by electric vehicles require monitoring energy markets, electronic contracting, and fast settlement. For these tasks, there are dedicated platforms. Most often, there is a system based on the blockchain network. The platform uses tokens for settlement [https://www.controlengineering.pl/technologie-big-data-zrodlem-ogromnych-oszczednosci-energetycznych/]. At the end of the settlement period, the liabilities to the supplier or producer are calculated.

Owners of local solar, wind, hydro, or biomass power plants can sell electricity directly to end consumers. The range of feasible trade is determined by the geographical scope, nowadays primarily local. Such solutions also contribute to making consumers more active in developing or overseeing their own energy mix. A proactive attitude favors the popularity of certain energy carriers and, in the long term, translates into an increase in their market share. At the same time, it raises the role of the local provision of energy needs. This not only gives a boost to entrepreneurship in the local energy market but also influences qualitative changes. Consumers' decisions to choose wind or solar power are an expression of support for such technological solutions and climate awareness. The increasing popularity of local solutions allows decentralization of the power engineering system. For example, Longyangxia Dam Solar Park is the largest photovoltaic farm in the world. Located in the desert of China, it consists of more than 4 million photovoltaics panels. Its installed capacity is 850 MW. The power of such plants is comparable to coal-fired power plants.

Another type of platform like Green Accelerator [https://smartgreen-accelerator.de/https://accelerategreen.ie; https://filarybiznesu.pl/transformacja-w-energetyce-czy-nowe-technologie-wejda-na-polski-na-rynek/a6560] provides intermediary services for standardized contracts to purchase and sell energy from renewable energy storage (RES). Auctions precede the contract system. Both parties achieve their objectives. The seller has the opportunity to mitigate energy price risks, and the buyer can decide on the share of renewables and the cost of energy.

A platform for gathering market information can also be used. In Poland, TGE Information Platform (Giełdowa Platforma Informacyjna [GPI]) has been developed [http://gpi.tge.pl/informacje/gpi], where structured and transparent data on the power system—planned and actual power demand, as well as information on planned and unplanned availability of generation capacity, availability of consumption facilities—is placed. Data published on the platform can influence the price level in the wholesale energy market and the decision-making of energy market participants. This is because basic price indices and energy trading volumes are published.

6 New technological solutions

An important element of innovation is a technological change in energy production. This topic is particularly relevant in view of the development of renewable energy sources, whose characteristic feature is the variable amount of energy generated depending on environmental conditions. This variation in potential can be seen in both onshore wind farms, offshore wind farms, which have much higher wind speeds, and in photovoltaic power plants.

One of the expected technological solutions is the construction of photovoltaic farms using high altitudes and specific natural conditions.[1] Placing the farms [https://www.gramwzielone.pl/energia-sloneczna/102773/panele-fotowoltaiczne-na-alpejskiej-tamie-2500-mnpm] in mountainous areas makes it possible to take advantage of the altitude and exposure to the South and the diurnal temperature differences. Low temperatures allow for module cooling in such technologies. The new locations provide the opportunity to use the snow cover to reflect the solar radiation. Such technical solutions increase the volume of energy generated by up to half. The development of RES generation affects the reduction of hydrocarbon consumption. It diversifies the structure of energy carriers used, but at the same time, requires the application of solutions stabilizing the system and enabling the introduction of energy to the grid without disturbing its operation.

New technological solutions used in solar power plants, such as ultralight solar modules, make it possible to expand the possibilities of application in buildings whose load-bearing capacity has so far made such installations impossible.

Technology innovation reduces installation costs while increasing module performance.

Technical solutions also allow the use of artificial intelligence and robots to automate the installation processes of photovoltaic panels. This makes it possible to improve work safety, shorten project deadlines, and reduce investment costs [https://globenergia.pl/czy-roboty-zastapia-instalatorow-oze-jeden-z-nich-pomaga-montowac-moduly-pv/].

Technological progress introduced in the power industry has brought, among other things, the possibility of monitoring the condition of technical infrastructure [https://businessinsider.com.pl/technologie/nowe-technologie/tauron-testuje-drony-do-monitorowania-stanu-sieci-energetycznych/516rdlm; https://megadron.pl/pl/blog/drony-z-kamera-termowizyjna-a-fotowoltaika-powietrzne-wsparcie-dla-oze-1584624172.html; https://pgeeo.pl/aktualnosci/Drony-pomoga-monitorowac-wiatraki-i-elektrownie-wodne-PGE-EO; https://swiatoze.pl/drony-monitoruja-systemy-oze/]. Owing to their remote control and small size, drones can reach vertical shafts in power plants, equalization tanks, pressure tunnels, or catchment areas. Using drones makes it possible to obtain frequent and regular images of the technical condition of infrastructure elements and document it. Maintenance inspection with drones and other devices also reduces hitherto planned breaks and shutdowns of production lines or equipment, increases operational safety, and reduces employee involvement.

7 Energy storage

Energy storage facilities [https://www.tauron.pl/dla-domu/urzadzenia/magazyn-energii; https://wysokienapiecie.pl/66380-jaki-magazyn-energii-dla-prosumenta; https://enerad.pl/magazyny-energii; https://www.scupower.com/energy-storage/?gclid=EAIaIQobChMI9qqByvCq9wIVCZiyCh2pIAHGEAAYAiAAEgJjFvD_BwE; Chena et al., 2009; Malko and Wojciechowski, 2015; Yanga et al., 2018] are an important part of building new energy, facilitating the integration of RES, supporting the construction of modern energy, and increasing the flexibility of the power engineering system.

On the one hand, energy storages facilities include system power plants, which limit their range of operation due to their location, and on the other hand, battery storages. The latter offer a greater opportunity

1 An example is a planned investment in the Alps, at an altitude of 2,500 m above sea level. Six thousand photovoltaic panels will be installed on the existing dam at this location.

to locate in areas of increasing energy demand or excess supply and in the vicinity of wind turbines or photovoltaic farms.

Energy storage is in the early stages of developing new technological solutions. Energy storage is an element of the energy infrastructure that will be successfully developed by companies involved in automation, IT, telecommunications, and data transmission.

Transmission and distribution system operators are also showing interest in energy storage. Investments in storage facilities are motivated by the possibility of energy supply and are also an alternative to investments in the expansion and modernization of the network.

Storage facilities will also constitute an essential element of the energy infrastructure, contributing to the optimization of energy consumption within groups of energy producers (clusters and cooperatives) or as investments by individual entrepreneurs. The role of energy storage facilities will increase as electricity prices rise and a power surcharge is introduced. [https://www.energetyka-rozproszona.pl/media/magazine_attachments/4816-Tekst_artyku%C5%82u-21516-2-10-20220428.pdf].

Energy storage facilities will be important for RES generators [Malko and Wojciechowski, 2015; Yanga et al., 2018]. The fact that it is impossible to feed as much energy into the grid as they produce or that there are limitations on the amount of connection capacity available will become a rationale for storing energy. The functionality of storage facilities is also recognized by the consumers. Particularly, by consumers for whom the equipment used in production processes or the provision of services must have specific energy quality parameters. A storage facility is then an object that changes/improves the parameters of the transmitted energy and, consequently, has an impact on reducing the risk of failure or damage to equipment. Storage facilities are also a desirable technological solution for prosumers, whose overproduction of energy in relation to their own current needs creates a situation for energy storage.

At the same time, technological progress is contributing to the development of civic energy, energy cooperatives and groups of active energy producers. Installations using RES for electricity and heat production can increasingly be promoted as an applied solution for individual or local use. In parallel, modern grid solutions create technical and technological improvements that improve the functioning of electricity networks despite the introduction of intermittent energy from RES. New solutions facilitate the coordination and complementarity of diversified and decentralized energy sources. Consequently, this not only allows smaller units to increase their market share, but above all, contributes to an increase in entrepreneurship among local governments, property owners, and local communities, providing the opportunity for greater self-reliance and even energy autonomy for the region; for example, conditions for Mazovia's energy self-sufficiency [https://mazovia.pl/pl/wrds/aktualnosci/mozliwosci-energetyczne-mazowsza.html].

8 Technologies in power engineering and mobility

Energy markets belong to strategic sectors of particular importance to the economy. Their development is based on increased demand but with consideration for energy security, environmental protection, and increased competitiveness. Innovation in the energy sector is focused on conventional energy, renewable energy, transmission and distribution networks, and new products and services, in particular on increasing energy intensity, reducing energy intensity, reducing the level of emissions generated by enterprises in this sector, and increasing the share of RES.

The pace of development of energy technology is impressive. In the first 15 years of the 21st century alone, the capacity of RES installations increased worldwide by 117%, and in Germany even by 480% [Zawada et al., 2015]. The capacity of offshore wind turbines has increased by more than 100% in a decade.

Innovations [Innowacje w sektorze przemysłu energii odnawialnych – jak to robią w innych państwach Europy? [Innovation in the Renewable Energy Industry – How Do They Do It in Other European Countries?] PARP, Warsaw, 2010] in electricity generation are occurring in reducing coal combustion pollution and CO_2 emissions, through the use of new high-efficiency, flexible, and low-carbon coal technologies. One of

these is CO_2 sequestration, capture, and mineralization technology [https://www.cire.pl/artykuly/serwis-informacyjny-cire-24/enea-innowacje-norweska-spolka-captico2-captico-rights-oraz-leczynska-energetyka-podpisaly-porozumienie-dotyczace-technologii-wychwytu-co2; https://naukaoklimacie.pl/aktualnosci/geologiczne-magazynowanie-co2; Gładysz et al., 2021] based on cryogenic capture and encapsulation of CO_2 in a stable chemical compound. The high efficiency of CO_2 capture and transportation and storage capacity can contribute to reducing negative environmental impacts.

Another known method of capturing CO_2 is to absorb the compound even at low concentrations without using chemical or thermal processes and therefore without expending additional energy. The energy capture device not only stores CO_2 but also transfers the gas to food production, such as carbonated beverages [https://naukawpolsce.pl/aktualnosci/news%2C79294%2Crewolucyjny-system-wychwytywania-co2.html].

Technological developments have made significant changes in the mechanical energy and propulsion of vehicles. Electromobility deployment necessitates an increase in the number of vehicle charging stations and, above all, demands a reduction in charging times. This is to be achieved through technological changes and the installation of 350 kW charging stations. Batteries play a key role in this respect. Developments over the past decade have enabled the mass deployment of electric cars. The development of chemical technologies and their application in batteries has reduced their size and weight and lowered their production costs, affecting the availability of electric cars.

Technical innovations involving the greater use of alternative fuels are significant in the process of increasing energy efficiency. These include electricity, hydrogen, biofuels, synthetic and paraffinic fuels, liquefied petroleum gas (LPG), natural gas, including biomethane in the form of compressed natural gas (CNG), liquefied natural gas (LNG) or gas to liquid (GTL).

Technological development is advancing not only in the field of vehicle propulsion, but also in the field of navigation and road safety equipment. These include sensor units, cameras, radars used for distance control and monitoring, and navigation equipment. The future belongs to autonomous vehicles. The combination of various advanced technological solutions will influence the use of driverless vehicles. Solutions already known, such as on-board computers, traffic control sensors, and driving recorders, will integrate these vehicles into freight traffic and partly eliminate road transport.

9 Limitations of shaping energy security based on new technologies

The main barrier to innovation [Wilson et al., 2012; Thon, 2014] is the high cost and high risk of project implementation. Costs include research, design, construction, modeling, testing, and final production. As the majority of projects consist of technical infrastructure elements, the cost of their production is very high and requires special financing. New technological solutions used in energy markets are solutions that not only revolutionize the secondary sector of the economy, but also constitute a civilizational advance that changes the conditions under which the sectors operate. A scale of influence and a role attributed to new solutions in energy markets is often compared with changes equal to the waves of civilization. Technological solutions are not only applied in energy generation technology, but also in industrial production and provided services. Meanwhile, the risks accompanying the implementation of innovation arise from the difficulty of composing elements into already functioning complex systems. Changing one component often requires simultaneous adaptations or changes in other systems parts. The risk is also growing, considering the importance of energy markets from the political and economic perspective of the state.

Another barrier is the low participation of private investors in research and development, which prolongs the process of design and implementation into production, and limits competition. It also changes the perspective of expectations and needs. Diverse stakeholders in the market have different perspectives, but also, as it appears, different levels of involvement in innovation, which in many cases is caused by the high cost of doing it.

Time is an important barrier. Innovations in the energy markets, whether in new carriers such as deuterium, new ways of exploiting shale gas or unconventional oil, or technologies to replace hydrocarbons, are needed here and now. Meanwhile, in many cases, they are called the solutions of the future.

Sometimes the barrier comes from public opinion opposing the use of new solutions or being reluctant to adopt innovations. Changes in the perception of technology as synonymous with positive change require the spread of knowledge, experience, and economic incentives.

10 Conclusion

Technological innovation plays a key role in shaping the conditions for energy security. They change the type of primary energy carriers used and their share in the energy mix at the national, regional, and global levels. They determine the level of profitability of investment projects and ultimately the cost of energy produced. They increase the level of security of functioning equipment, reducing the risk of blackouts. New technological solutions allow for better energy demand and supply management, preparing forecasts for increases/decreases in energy demand. Lastly, the security threshold is shifted to a level appropriate to current social and economic needs through the ability to store energy.

However, investment in innovation is extremely costly and lengthy. The changes taking place in the energy markets are both fundamental and revolutionary. The degree of impact on the energy sector and other sectors and industries necessitates multifaceted changes. Moreover, it is subject to the interests of many stakeholders and is influenced by political, institutional, and economic factors. The degree to which innovations resulting in changes to the conditions for shaping energy security are implemented is therefore closely correlated between needs, opportunities, and cost-effectiveness.

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