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Blockchain technology and peer-to-peer energy trading

Abstract: The article describes new legal regulations in Poland and the EU, which are to introduce the possibility of peer-to-peer trading in electricity. The text presents the possibility of using blockchain technology for this purpose. It describes how blockchain can revolutionize the traditional energy model, enabling direct trade between producers and consumers, eliminating intermediaries. It presents the advantages and challenges in this area, explains the key features of the technology, and discusses its potential applications in the energy sector, focusing on peer-to-peer trading (P2P) of energy from renewable sources.

Streszczenie: Artykuł opisuje nowe regulacje prawne w Polsce i UE, które wprowadzają handlu partnerskiego energią elektryczną. Tekst przedstawia możliwość wykorzystania do tego celu technologii blockchain. Opisuje, jak blockchain może zrewolucjonizować tradycyjny model energetyczny, umożliwiając bezpośredni handel między producentami a konsumentami, eliminując pośredników. Prezentuje zalety i wyzwania, wyjaśnia kluczowe cechy technologii, oraz omawia jej potencjalne zastosowania w energetyce, skupiając się na handlu peer-to-peer (P2P) energią z odnawialnych źródeł. (**Technologia blockchain i handel partnerski energią elektryczną**)

Keywords: electricity trading, blockchain technology, peer-to-peer trading, electricity
Słowa kluczowe: handel energią elektryczną, technologia blockchain, handel partnerski, peer-to-peer handel, energia elektryczna

Introduction

Energy trading in decentralized electricity markets is a revolution in the way electricity can be bought and sold. By using blockchain technology, traditional models of central management and intermediation are being replaced by distributed networks that can enable direct trading between energy producers and consumers.

In the traditional energy model, energy is produced by large producers, transmitted through the distribution network to consumers and settled by central institutions such as electricity suppliers. The development of blockchain technology can enable the creation of decentralized energy markets that enable direct trade of energy between producers and consumers, without the intermediation of traditional institutions. In decentralized energy markets, energy producers, such as owners of home photovoltaic panel installations or small wind farms, can offer excess energy for sale to other market participants. For the consumers, this gives them the opportunity to buy energy directly from local producers, which often translates into lower costs and can increase flexibility in choosing energy sources [1,2,3].

The procedure cited above, in great simplification, describes the amendment to the Act of 28 July 2023 amending the Energy Law Act [4] and certain other acts (Journal of Laws of 2023, item 1681). The amending Act implemented a number of European energy law acts into the Polish legal order, in particular Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market in electricity [5] and Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, the so-called "RED II Directive" [6], and amending Directive 2012/27/EU, the so-called market directive. Among the most important changes introduced on the basis of the above-mentioned amendment to the Act, the following should be mentioned:

- creation of a civic energy community,
- possibility of peer-to-peer trading in energy from renewable energy sources,
- obligation to conclude only comprehensive contracts with recipients of gas fuels or electricity in households;
- increasing the availability of direct line institutions for recipients;
- creation of an electronic comparison tool for offers from electricity sellers for recipients;
- changes in the functioning of the Central Energy Market Information System (CSIRE);
- extension of the competences of the President of the Energy Regulatory Office, and others [1].

As you can see, there are many changes, all of which are dictated by European law. One of them, in which, due to the possibility of using blockchain technology, great hopes are placed, is the aforementioned partner trade, which can introduce completely new possibilities and a new order to the energy sector.

Key Features of Blockchain Technology in the Energy Sector

Blockchain is a decentralized and distributed data recording technology that enables the creation of an immutable and transparent blockchain, where each transaction or piece of information is cryptographically secured and linked to the previous ones. This makes the data tamper-proof and fraud-proof, and the network functions without the need for a central governing body, as participants jointly verify and confirm records.

Key features of blockchain include:

- Decentralized structure – the possibility of no central control unit.
- Peer-to-peer (P2P) transactions – direct exchange of resources or information between network participants, the so-called “each with each other” concept.
- Cryptographic security – data is protected against unauthorized changes.
- Immutability – once added, information is practically impossible to remove or modify.
- Transparency – each network participant has access to the full transaction history [7].

Blockchain technology is used in many areas, such as finance (cryptocurrencies), energy, logistics, supply chain management and electronic voting. In the light of the currently applicable directives and the above-mentioned amendment to the act, these features perfectly fit into the assumptions of the changes, providing the possibility of creating decentralized databases and carrying out transactions between prosumers and electricity consumers [8].

In addition to its basic features, blockchain technology has several additional key aspects that have a significant impact on its operation and applications in the energy sector. These include the lack of trusted intermediaries. Blockchain can function without the need for intermediaries (e.g. banks, government institutions, sales agents) in processes such as financial transactions, data transfer or trade agreements. This allows transactions to be made directly between parties (peer-to-peer), which reduces the costs and risks associated with trusting a third party. An important element is the use of consensus mechanisms, which are based on an algorithm that allows network participants to agree on the state of the ledger without the need for central supervision. Another feature is the aforementioned transparency, to which the auditability feature can be added. Each P2P transaction recorded in the blockchain is visible to all network participants, which increases transparency. This makes this technology ideal for applications where it is crucial to track the origin of data or products, e.g. in the supply chain (tracking products from source to consumer). Although blockchain is often associated with transparency, many solutions offer mechanisms to ensure transaction privacy. There are also private blockchains that allow controlled access to data only for selected participants [9]. Another key aspect of blockchain technology that is applicable to electricity transactions is speed and automation through the use of smart contracts. Smart contracts are programs running on the blockchain that automatically execute agreements or transactions when certain conditions are met. This allows for the automation of complex processes without the need for human intervention. Examples include automatic settlements, insurance systems or even self-governing organizations (DAOs). Resilience to attacks and failures is also an important feature of the distributed nature of blockchain. The network is much more resistant to failures and attacks than centralized systems. Even if some nodes go down, the rest of the network remains operational and data is still available. The last feature of this technology is the possibility of multi-sector applications, in various industries and business models. Blockchain is a technology with a wide range of applications that also go far beyond finance. It covers sectors such as:

- Finance and cryptocurrencies: The most well-known applications of blockchain are cryptocurrencies such as Bitcoin or Ethereum. Blockchain enables safe, fast and cheap transfer of funds without intermediaries such as banks.
- Supply chain: Blockchain allows products to be tracked at every stage of production and distribution, which increases transparency and helps fight counterfeiting. The origin of raw materials can be traced, and the quality of products can be monitored, which is particularly important in the food, pharmaceutical or fashion industries.
- Intellectual property protection: Blockchain allows copyrights and intellectual property to be registered in an immutable way, making it easier to prove the rights to works or inventions.
- Electronic voting: Blockchain enables safe and transparent voting, which eliminates the risk of manipulation of results and increases trust in democratic systems.
- Identity management: It allows for the secure storage and management of digital identities, eliminating the need for central institutions to store personal data.
- Energy: Blockchain supports peer-to-peer energy trading, micro-energy pool management, and automated settlement based on smart contracts, as we discussed earlier [10].

The cited features and properties of blockchain technology are the answer to the question of whether this technology finds its application in the energy sector of the economy. Of course, one cannot forget about the limitations. For example, about the efficiency of the system. Blockchain requires significant computing resources and energy to maintain the network, which can be a challenge with a large scale of applications. Costs cannot be ignored either, because the implementation of blockchain systems in the energy sector is associated with high implementation and maintenance costs, which may be a barrier to the wide use of this technology.

Despite the above (and other) limitations, there are arguments in favour of using this solution, which allow for more efficient, transparent and safe management of energy flows and settlements of its purchases and sales between market participants, thus also supporting the development of decentralised renewable energy production.

Electricity trading market

Currently, the Polish electricity trading market is complex, dominated by regulations, several key entities and the dynamically developing renewable energy sources (RES) segment. That is why such great hope is seen in the use of blockchain technology in this sector of the economy. In Poland, electricity trading takes place on several levels and differs depending on the type of entities participating in the market. The market structure can be divided into two main segments, i.e. the wholesale market - a place where large producers and recipients (e.g. companies) trade energy, and the retail market - where individual consumers and small and medium-sized companies buy energy. The main entities on the energy market are producers, operators and distributors of energy. In Poland, producers are both large state-owned energy companies such as PGE, Tauron, Energa, Enea, as well as smaller private producers, including wind farm and photovoltaic installation operators. Transmission of energy is the responsibility of transmission and distribution system operators - Polskie Sieci Elektroenergetyczne (PSE). Energy distribution is handled by distribution companies, which transport energy to end users. The next market participants include energy sellers – companies offering energy to end users, both businesses and individual consumers, and end users – consumers of electricity, including households, industry, the service sector, and others.

Transactions of purchase and sale of electricity take place mainly thanks to the Polish Power Exchange (TGE), where energy is traded in the form of futures contracts and on the spot market (short-term energy trading). We have at our disposal the Day-Ahead Market, where transactions for energy delivery take place the day before the actual delivery, and the Intraday Market, where transactions for energy delivery are possible during the same day on which the energy is consumed. Energy can also be purchased on the basis of bilateral contracts, i.e. where large companies can enter into direct contracts for the supply of energy with producers under the so-called bilateral agreements (PPA - Power Purchase Agreement). The above explanation is of course brief and does not present the entire spectrum of market mechanisms. It is important to mention the fact that on the electricity market in Poland, an important role is played by the institution of URE and PSE, which are to some extent regulators of activities. The transformation towards renewable energy sources and the development of technologies such as energy storage and smart grids also operate according to their regulations, thus influencing further changes in the market structure and the way it functions [11].

Currently, the Polish Power Exchange (TGE) does not use blockchain technology on a large scale in its electricity trading operations. TGE relies on classic IT and market solutions. However, in the recent years, due to international political decisions (European Union directives), the growing interest in blockchain technology does not seem to be waning, which directly translates into its development and possible markets for its implementation.

Peer-to-peer trading in electricity

The role of blockchain technology is strengthened in relation to the provisions of the above-mentioned directives ((EU) 2019/944 of 5 June 2019, (EU) 2018/2001 of 11 December 2018), which stipulate that the Member States are obliged to ensure that prosumers have the right to produce renewable energy, including for their own needs, store and sell their surplus energy production, including through peer-to-peer trading arrangements. In relation to such a provision, and in particular to ensuring the possibility of peer-to-peer trading, the features of blockchain technology seem to correspond perfectly.

In accordance with the directives, the amendment to the Polish legal system (the Act of 10 April 1997 - Energy Law) introduced many new institutions, also expanded the competences of the President of the Energy Regulatory Office (URE), and introduced a number of regulations related to the need for the Central Information System on the Energy Market (CSIRE).

One of the significant changes in the law and thus a strong reference to the possibility of using decentralized databases is the introduction of the possibility of partner trade in energy from renewable energy sources (peer-to-peer, P2P). Its definition is given in the amended art. 3 point 55c of the Act of 10 April 1997 - Energy Law (consolidated text: Journal of Laws of 2023, item 295, as amended; hereinafter: "p.e."). Peer trading is a new formula for selling energy generated by a prosumer or collective prosumer to other system users based on an agreement specifying, in particular, the conditions for automated execution of the transaction and payment for it directly between the parties to the agreement, or through a third-party system user or a company operating a commodity exchange. As it can be interpreted, "the purpose of the draft regulations is to leave P2P trade participants the greatest possible margin of freedom in deciding whether to participate in this form of energy trading, choosing the method of organizing P2P, or finally choosing the provider of the electronic platform enabling trading. In the opinion of the drafter, such an approach will allow for gathering the necessary experience in a relatively limited local "environment" of P2P market participants, which at a later stage may result in extending the scope of P2P trading and adapting the appropriate regulatory instruments to it" [1, 2, 4].

As the authors of the amendment to the RES Act explain, the peer-to-peer concept is an element of a new model of operation of the power system, which is based on the exchange of energy between two or more users and, as a consequence, on the constant and short-term switching of recipients between different suppliers. The divergence of this concept from the previously established relations occurring in the electricity market means that it does not correspond to the current state of law and regulations in the field of energy. Considering the above, it is therefore necessary to enable the design of the necessary communication and control networks that could guarantee the possibility of P2P trading between individual entities in local micro-networks or between them, via dedicated national or regional internet platforms and appropriate technologies, the role of which will be similar to the role of the seller in the electricity sector [4]. Such an interpretation of the law absolutely composes the system to use blockchain technology and market decentralization and the use of smart contracts to execute energy purchase and sale orders. The introduction of a new energy trading model should provide prosumers with "additional opportunities, while also constituting another element of activation of the usually passive energy recipients, and also allow for the initiation of cooperation between the most important participants of the energy market, such as active recipients and aggregators[1] [4].

Such an assumption is nothing more than Peer-to-Peer (P2P) Trading, i.e. P2P platforms enabling direct trade in electricity between producers and consumers, bypassing the traditional structures of suppliers and distributors. Such a possibility is far from the above-described procedures of the Energy Exchange, such a possibility is in a way allowing prosumers who are not legal entities to enter the market. P2P electricity trading can therefore be compared to purchases at online auctions available to everyone. Blockchain technology supports such initiatives by its assumptions, also enabling tracking and authorization of transactions [1]. It can therefore be expected that blockchain technology, properly promoted and implemented, will open up new possibilities of action and improve the system [12].

Perspectives and opportunities for peer trading

The idea of peer trading described above has the potential to enable owners of small renewable energy source (RES) installations, e.g. photovoltaic panels, to directly sell surplus energy to other network users. Thanks to the amendment and appropriate legal provisions, prosumers could more easily conclude P2P agreements, sell energy on the local market or use digital platforms that facilitate transactions. As a result, it will increase the number of prosumers and local energy producers, which also supports the development of civic energy and reduces dependence on large producers.

The possibility of peer trading and blockchain also means the possibility of dynamic energy exchange between entities in real time, which contributes to better management of demand and supply in the energy system. Introducing appropriate regulations facilitating such transactions could help stabilize the network, especially in the context of the increase in the number of RES sources, which are characterized by production variability. The effect of such actions may be to improve network stability and reduce the costs of balancing the energy system [3].

There is also great hope for change in direct transactions between energy producers and consumers, where, thanks to the use of blockchain technology, costs resulting from the elimination of intermediaries and reduction of the costs of energy transmission over long distances could be reduced. The amendment enabling the development of partner trade could also affect the diversification of prices depending on location and time, which could bring tangible benefits to consumers [13].

The amendment to the act also supports the development of digital platforms and tools enabling P2P energy trading. These platforms could use technologies such as blockchain to automate and secure transactions. The introduction of appropriate regulations would also encourage investments in

[1] Aggregator - activity consisting in combining the volume of power or electricity offered by recipients, electricity producers or owners of electricity storage facilities, taking into account the technical capabilities of the network to which they are connected, in order to sell electricity, provide system services or flexibility services on electricity markets.

this type of innovative solutions. New technologies also mean the development of new business models and the integration of modern technologies, which supports the digitalization of the sector [14].

The use of the idea and the possibility of partner trade could thus significantly affect the development of the energy sector in Poland and Europe. It would facilitate the integration of renewable energy sources, it would be possible to promote local energy production and consumption and reduce costs for consumers. P2P trade is also an opportunity to participate in the energy market for consumers and prosumers who are private persons - this fact seems very promising. However, it should not be forgotten that such activities would of course require the development of modern infrastructure, transmission networks and the creation of a new legal framework that will balance the interests of various market participants.

Summary

To sum up, the Act of 28 July 2023 amending the Energy Law and certain other acts (Journal of Laws of 2023, item 1681) implementing Directive 2019/944 into the Polish legal system introduces a number of changes and new institutions (the entry into force of which has been extended in time). The provisions found in the law encourage the possibility of using blockchain technology. The aspects that speak in favor of this are the fact that blockchain technology is known for its high transparency, security and decentralization, so it has the potential to revolutionize the way energy is sold and consumed, especially in the context of dynamically developing distributed energy and renewable energy sources (RES).

Blockchain enables direct transactions between energy producers and consumers without the participation of intermediaries, which is crucial for the development of partner trade. Thanks to smart contracts, transactions can be carried out automatically, which increases efficiency and reduces the risk of errors. This technology also enables tracking the origin of energy, which supports the development of green energy and increases consumer trust.

The paper also discusses the current energy trading model and the challenges related to blockchain implementation, i.e. the need to modernize energy infrastructure, create an appropriate legal framework and ensure data security. Despite these challenges, the use of blockchain in P2P trading has the potential to significantly impact the energy transformation by reducing transaction costs, supporting local energy production and integrating renewable energy sources in energy systems.

To sum up, blockchain technology can play a key role in the future of the energy market, especially in the peer trading model, offering a new quality in energy management and enabling decentralization and democratization of the energy sector.

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