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BLOCKCHAIN TECHNOLOGY IMPACT ON THE ENERGY MARKET MODEL

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Abstract

Rapid development of distributed energy resources technologies, along with network constraints, plus few consumer-oriented business models, has led to a search for radically different power system configurations. This is the basis for exploring an energy market model which meets the requirements of the changing environment. This model could be referred to as a transactive energy model whose main focus is on trading energy by a peer-to-peer principle, where the power company is replaced with a fully trusted trading platform based on distributed ledger technologies, i.e. blockchain technology. The aim of this paper is to analyze energy sector solutions related to the use of blockchain technology. The emergence of these solutions indicates, on the one hand, the need for verification of the existing energy market model and, on the other hand, the need to modify the approach towards the changing environment. Blockchain technology not only means the use of cryptographic mechanisms to build trustworthy agreements without intermediary institutions between the unfamiliar users of transactions: it is also a new philosophy of life based on trust.

Introduction

Blockchain is a decentralized database technology based on cryptographic security. Its application is not only in digital currency, but also in almost every part of our lives, with particular emphasis on finances, public administration, pharmacy, health care, energy, logistics, entertainment, and much more. Hundreds of startups, governments, and the largest world corporations are working on blockchain technology solutions.

This new technology foreshadows a revolution primarily in the financial market. However, its innovative nature may bring about a radical change in thinking about different markets, therefore, it may be expected to step into the energy market, too.

The dynamically growing market of distributed energy resources, photovoltaic systems, storage, and microgrids have shifted the balance of power from centralized enterprises to a place where citizens can exercise control over many processes. And it is not only a question of controlling energy costs; it is also a matter of people's desires that their energy resources are more sustainable, socially responsible, more resilient, and more democratic. This reflects everything that is needed to initiate a revolution in the energy trade model that is taking control of the big players in the market and making citizens responsible for the energy future they co-create. Currently, it seems, this part of the economy is witnessing a revival in research on how to apply both new technology and the blockchain philosophy. The possibilities of using this technology in the highly regulated energy sector may lead to a revolution at a much larger scale than the current changes which have only introduced minor adjustments in the existing market model (Power Ledger 2017: 8-10).

Taking the above into consideration, one should pose the question: will the next revolution in the power sector result in changes in the current energy market model? If so, how deep will these changes be? Will they only focus on selected segments of the energy market or will they give grounds for building a new energy market model?

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Blockchain can offer a reliable and cost-effective way of carrying out financial transactions or trading operations that will be recorded and validated within a distributed network without a central authority. As in the case of finances, this capacity is a stimulus for research with the thesis that one day blockchain can replace some public utilities and contribute to the end of third party interference in transactions also in the service industry. This problem, however, is complex, as there is a lack of understanding that there may be a change in the already existing rules and regulations based on trust generated by the cryptographic mechanisms creating smart contracts on the Ethereum platform.[2] In the face of such radical changes, the future energy market model is expected to be based on a decentralized blockchain technology.

The development of blockchain ideally goes in line with the times we live in, when widespread surveillance and the loss of confidence in large, centralized institutions is a daily matter. Blockchain, contradicting the above model and being a viable alternative, fits the needs of the 21st century. Apart from being a new approach to payment and a new kind of technology used in programming, it is also a philosophy that defines the approach to the reality which surrounds us.

The paper analyzes blockchain technology projects in the power sector. The analysis begins with a brief indication of where the blockchain idea came from, how it evolved, and to which walks of life or the economy it could be adapted. Based on such knowledge, examples of blockchain technology in the electricity industry have been analyzed. Furthermore, an attempt has been made to identify its impact on the current electricity market model, indicating possible changes in its shape.

This new technology implies a profound change in our everyday environment; at the same time, it is characterized by a high degree of complexity which determines the need for research aimed at an in-depth analysis of all elements that will have a significant impact on the energy market. Given this, the basic scope of the study which is worth exploring is indicated at the end of this paper. It may enable more effective revolution in the energy sector, with the highest diligence in pursuit of the good of all energy market participants.

The philosophy of blockchain technology

For years economists have been exploring people's behaviors: how we make decisions, how we act in groups or as individuals, in what ways we exchange values. The subjects for study are those institutions that facilitate our trade: legal systems, corporations, marketplaces. Yet, there is a new technological institution that will fundamentally change the way we exchange values. It is called the blockchain. Although blockchain technology is relatively new, it should be viewed as a continuation of the history of economics.

As humans we look for ways to reduce uncertainty about each other to exchange our values. Nobel economist Douglass North was one of the first to explore the idea of institutions as

[2] Ethereum is a decentralized platform that runs smart contracts: applications that run as programmed without any possibility of downtime, censorship, fraud or third party interference. This is an open source blockchain platform combining Smart Contract, offering decentralized virtual machine to handle the contract, by using its digital currency called (Iuon-Chang L., Tzu-Chun L.,2017: 655).

an economic tool for lowering such uncertainties so that we can thoroughly conduct a trusted trade. He pioneered in the so called "new institutional economies"; what he meant by institutions were real, formal rules such as a constitution. However, there are also informal restrictions, e.g. bribery (North D.C. 1991:97-98). These are those institutions which make the functioning of economic principles and the study of their development through the years possible.

While developing, our society has become more and more complex with its expectations of trade and transactions. This has led to the creation of more formal institutions. These institutions help us manage our trade and decrease our personal control (North D.C. 1993: 9-10). Eventually, we have moved these institutions into the Internet. We have built up a platform marketplace like Amazon, Allegro, eBay, all of which are much faster and function as intermediaries to facilitate human economic activity.

These institutions are a tool for lowering uncertainty, so that we can combine and exchange all kinds of values in society. Now we are entering a further and radical evolution of how we interact and trade, because for the first time we can lower our uncertainty not just with political and economic institutions, but also with the use of technology itself - blockchain technology (Rosati P., Nair B., Lynn T. 2016).

Blockchain database architecture was first proposed in 2008 by the creators (also known by their pseudonym Satoshi Nakamoto) of the first digital currency – Bitcoin (Nakamoto S. 2008: 2). Bitcoin is the first global system of digital buy and sell operations not based on trust in a central institution, as in the case of traditional currency, where the role of the institution is fulfilled by a central bank responsible for creating and controlling the money supply into the economy (Bonneau J., 2015: 112).

Blockchain technology is a decentralized database that stores its registry of assets and transactions through a peer-to-peer network. In other words, it is basically a public registry of those who own and perform transactions. Transactions are secured through cryptography and, with time, their history gets locked in blocks of data that are then cryptographically linked together and secured. This creates an immutable, unforgettable record of all the transactions within the network. This record is replicated on every computer that uses the network. It is not an application, not a company: we can think of it as an open infrastructure that stores many kinds of assets. The registry is not controlled by one, but by all users of the decentralized system. Blockchain technology is characterized by the irreversibility of its transactions. It stores the history of custodianship, ownership, and the location of assets like digital currency - Bitcoin and other digital assets. It could be a certificate, a real world object, a contract, even personal identifiable information (Zheng H., 2016: 4-7).

The Economist magazine has described blockchain as 'trust machine'. The distributed system architecture enables each user to view a full transaction history, providing anonymity at the same time. Two basic types of blockchain technologies, called public and private systems, are also worth considering. These systems differ in the level of trust between the system users. Thus, it leads from a total lack of trust in the public system to a high one in the private system;

this is the public system which is a truly decentralized blockchain solution, where anyone can be a user. What is important in this system - there is no possibility of modifying historical data. On the other hand, a private blockchain solution is fully controlled by one organization and can't be considered decentralized. Nevertheless, in this kind of system, historical data may be modified, if it is the will of all the system users. The above set does not exhaust all the details characterizing blockchain technology, but it is the basis for understanding this philosophy and its operational mechanism (Berkley J., 2015).

Blockchain applications

Blockchain technology can be applied where there is a need for any activity of intermediaries, centralized data registers, or institutions entrusted with confidence. This primarily refers to the financial market (banking), but also to the business sector. A survey conducted by IBM in 2016 shows that 15% of banks and 14% of financial institutions are going to introduce a blockchain solution in 2017 (Hablen M., 2016). Implementation of this type of technology is identified in the context of improving efficiency in speeding up transactions, reducing operating costs in banking, and increasing confidence in the financial sector, whose reputation is subject to continuous testing due to the disclosure of irregularities.

The future of blockchain technology is difficult to predict due to its short track record. Most projects are either in a beta testing stage, midway through an initial pilot, or have just completed a pilot. For sure, technology is effective at enabling secure virtual currencies, but it is still too early to tell whether other applications will have staying power. While blockchain technology proponents tend to assume that centralized solutions are always 'second best', this may not be the case. The most likely outcome is that the frenzy of interest in blockchain-based solutions will evolve in the same manner as the dot-com bubble[3], with most companies failing to achieve liftoff while a select few create business models that transform the sectors they operate in (Pisa M., Juden M., 2017).

As for the enterprise sector, one basic prospect of the implementation of this technology is the possibility of broadening cooperation between different companies. By optimizing coordination between co-operating companies, cost optimization throughout the supply chain is seen (Goertzel B., Goertzel T. 2017: 65-73). Additionally, blockchain-based solutions would provide a powerful tool for verifying the origin of the individual components of a product. In other words, control would take place at every stage of the supply chain, also over the quality of the proposed components. This means that the specific application of the technology can also be used for quality certification (White G.R.T., Holden J. 2016: 3).

Some other implementations of blockchain technology may cover fast confirmation of identity, compliance of user-submitted data, acceptance of financial transactions, even loans or investments, issues of securities, and digital currencies (Bashir I. 2017: 415). Irving (Irving G.,

[3] The dot-com bubble was a historic economic bubble and a period of excessive speculation that occurred roughly from 1997 to 2001, a period of extreme growth in the usage and adaptation of the Internet by businesses and consumers. During this period, many Internet-based companies, commonly referred to as *dot-coms*, were founded, many of which failed (https://en.wikipedia.org).

Holden J. 2016:1-6) also points out that technology can be used in the medical sector as a tool to prevent the manipulation of clinical trial results – which means an increase in trust and elimination of social acceptance for low clinical efficacy or a low safety profile.

In the blockchain literature, there are a number of other suggestions for using this technology to protect privacy in the sense of data ownership or personal property (Halicki M., Lustofin P. 2017: 37-39). This includes the registration of buildings, land, and patents. The blockchain solution is highly resistant to manipulation of the data contained in the encoded chain of blocks, which is of fundamental importance in the context of sensitive and confidential data stored in the above registers (Zyskind G., Nathan O., 2015: 180-184).

Blockchain in the power sector

Although it is a new technology, the market for its applications is growing day by day utilizing solutions based on it in different areas of life. Thus, the energy sector cannot be excluded from this development, either. These are projects based on the rules of the shared economy phenomenon. Some of them are identified as the most important in the context of creating a new energy market model, e.g., sharing and clearing of charging stations for electric vehicles, flexible management of the electricity grid, electricity trade, and the possibilities of its application in microgrids and energy clusters. The above issues are complementary to each other, consequently they include both generating (especially from renewable sources), trading in energy, its distribution, and other services available on the energy market.

Sharing and clearing of charging stations for electric vehicles

It would be worth mentioning here a project by innogy SE[4] and a start-up, Innovo Innovation Hub Share & Charge, which provide access to charging stations for electric vehicles. According to this project it has been possible to create more than 1,200 charging stations based on blockchain technology; therefore, the start-up is thought to be the first company in the world to be involved in such a large-scale project promoting the development of blockchain technology (Lielacher A., 2017).

The central registration platform for electric car owners and charging station operators is the Share & Charge application, which is available to users free of charge. Companies and persons who have their own charging stations can make them also available for electric car drivers, decide on rates, or even create their own tariffs for friends and acquaintances. They can also share and charge for parking spaces at the charging stations. Such a model of behavior creates a completely new economy based on the sharing economy - in this case using the public platform Ethereum as a transaction layer. In addition, owners of electric vehicles have the opportunity to search for a charging station using an interactive map. This solution allows electric car owners to charge their vehicles at any of the new charging stations configured by the start-up as well as at existing charging points, by making digital payments. The Share & Charge application provides all participants with a transparent and secure payment system using blockchain,

[4] innogy SE is an established European energy company.

which by decentralizing databases does not require a central computer. At the time of charging, in real-time, revenue is charged to the owner of the station and the cost of purchasing it to the electric vehicle user. This virtual wallet in the form of mobility tokens, which are digital tokens, and the currency of settlement being the Euro, can be completed by credit card, PayPal system, or transfer. Each transaction is invoiced, which is also stored in the system and the user has the possibility of accessing, downloading, or printing it at any time. The mobile application allows everyone to use a secure, cryptographic platform without technical details, making it as easy to use as any other mobile solution. In addition, it provides the automation, immutability, or durability of a transaction history, plus a lack of intermediaries, significantly reducing costs, and creating unprecedented peer to peer services. It is worth noticing that the charging service in this case is done without the presence of the distribution system operator and the energy trader (innogy, 2017, 50).

Flexibility grid management

More and more, power consumers will play an increasingly important role in transforming the status of passive electricity consumers into active, conscious, energy market participants (Mirowski T, Sornek K., 2015, 77). Connecting distributed and unpredictable sources of energy brings significant challenges for performing basic responsibilities in the management and maintenance of the electricity grid. A new role for the network operator is to ensure that each network realizes its goals. This change requires increasing the dynamics of the network, where it is crucial to maintain both high quality and reliability of the electricity supply, secure and stable network operations, and create a level playing field for innovative services. This transformation poses a number of technical challenges, as the current network is not yet ready to work with a large number of distributed sources – it was designed for one-way flows. In addition, it is neither ready for new types of receivers such as charging stations for electric vehicles nor energy storage, nor for the actual activity of consumers in terms of controlling their own consumption. Supporting all user behavior of the system is *sine qua non* of the issues of network flexibility. This extremely complex mechanism, which uses a huge amount of data processed in real time, can be effectively managed by using the blockchain solution. In the future, an additional advantage of this solution should be a technology with elements that use machine learning (Merz M., 2016: 20).

For today, there are few projects that rely on blockchain technology test solutions for managing grid flexibility. Typically, these are projects in the initial phase, one that has not yet generated measurable results from its implementation, since operations began in 2017. One such project is being created by the British company Electron, which has received government funding for the development of a new blockchain transactional prototype platform. Its primary task will be to manage network flexibility at the DSR (Demand Side Response) level. The company's application for funding was supported by the National Grid and Siemens, which will participate in the project. Electron claims that its platform will use blockchain technology in a way that allows multiple parties to coordinate and share the value of individual consumer

behavior in managing their demand. Applying this large-scale solution means that the company will maximize the overall value and liquidity of the flexibility market, while at the same time enabling individual buyers to have the flexibility to participate in revenue sharing as well as cost. The company refers to this concept as a trade based on collaboration, in other words on the economics of sharing, according to the assumptions of the blockchain, and in this case we are dealing with a way to enter into a transaction without a central authority. This allows the defining of new collaboration models on an efficient, fully trusted platform (Cummings D., 2017).

As renewable electricity generation is increasingly involved in the overall supply of energy, the electricity grid is becoming unstable. This situation is most evident in Germany, where in the coming years it is forecast that there will be situations in which conventional energy sources will not be able to fully satisfy the stability of the network. With the above, TenneT, Sonnen, Vandebron, and IBM have joined forces to develop a blockchain power management solution. This innovative technology is the next step for decentralized energy sources to play an active role in power management and flexible services. In early November 2017, there was the first launch of a pilot project in Europe, which uses decentralized network home energy storage systems with blockchain technology to stabilize the grid. The TenneT transmission system operator uses these home energy storage systems as storage for stabilizing network performance. Thanks to this, after several months of preparation, TenneT and the world's largest energy storage company, Sonnen, started a pilot phase of the project, which is to be continued until mid-2018. Then, the decentralized energy storage systems will be integrated into the TenneT network through blockchain technology. The blockchain solution was developed by IBM; Sonnen provides the proper number of home energy storage systems to create a network serviced by Sonnen's e-Services. Intelligent management of energy storage systems meets individual requirements to fit into the particular situation in the TenneT network. As a result, network resources of energy storage systems can take or give power within a few seconds, when needed, to help reduce network bottlenecks. This project is part of a wider TenneT initiative to improve flexibility through increased use of data and the development of new flexibility options that will allow the network to meet the challenges and opportunities associated with energy transformation (Kastelein R., 2017).

In addition, as part of a wider digital transformation program, TenneT is exploring a network based blockchain technology that uses the Hyperledger Fabric[5] solution to integrate flexible services provided by electric vehicles and power warehouses. This means that owners of electric vehicles can also help keep the network frequency at the required 50 Hz. In this pilot project, Vandebron will work with customers who own electric vehicles to share the capacity of their car batteries to balance the local area. This also guarantees customers access to their cars to satisfy their own needs. Blockchain allows each vehicle to participate by recording its availability and performance in response to signals from TenneT. To manage and store all billing and charge data, a fully automated, worldwide authentication charging and billing system without

[5] Hyperledger Fabric is a platform for distributed ledger solutions, underpinned by a modular architecture delivering high degrees of confidentiality, resiliency, flexibility and scalability (Hyperleger, 2017).

intermediaries is being created by using a computer chip in the charging station, smartphone interface, and blockchain applications (03.ibm.com, 2017).

Electricity trade

Powerpeers, a startup developed with the involvement of the Dutch energy company N.V. Nuon Energy allows for direct electricity trading between any registered users. Blockchain applications enable the marking of every unit of produced and consumed energy, automatically save each transaction, and settle bills in a virtual wallet. This means that a part of the surplus generated energy coming from, e.g. photovoltaic panels installed on the roof of a neighboring house, may be sent to a different location. This method allows identification of the source of purchased energy. Hence, a company that produces organic food can prove to its customers that it has bought energy from a nearby hydro or wind power plant. This peer-to- peer identification and trading system is possible thanks to intelligent metering of customers and producers participating in the project.

Time-consuming activities related to the energy trading in a traditional model such as contract signing, change of the seller, or settlement, are extremely simplified or absent. Most of these functions are implemented by the application and its owner – that is, Powerpeers (which holds a concession for energy and gas trading). Power infrastructure is used locally, and the reliability of the supply and preservation of the network is maintained by the distribution system operator. In essence, it implements the idea of an energy cluster without special regulation. Such a system works only in the Netherlands, where Nuon and Vattenfall are gaining valuable experience in this business model, bearing in mind that it represents a huge potential for development on a large scale (IEA 2015).

Another example is the Dutch Oneup start-up, which has developed and tested a similar prototype of a decentralized electricity transaction (trading) system with the use of energy data from ten households. Households within the same neighborhood produce electricity using photovoltaic panels. Any energy not consumed by the household itself is delivered to its neighbors and settled by a system based on blockchain technology. All transactions in the project are realized through smart contracts. Each building also has a smart meter connected to a Raspberry Pi computer, which, turn, is connected to the network. The computer is configured in such a way that enables real-time verification of whether the terms of the agreement are being met; secondly, it collects and processes signals that individual households are able to provide a sufficient amount of energy and whether there is demand for that energy. The software automatically initiates the supply of the energy and the corresponding payments through its own cryptocurrency. It is also important that the cryptocurrency can be exchanged for euros (PwC, 2016, 22).

One of the most challenging ideas for blockchain use in the energy sector is certainly a project set up by 25 European energy trading companies whose aim is to assure wholesale market participants that they can trade freely and directly with energy as well as with other goods within a private blockchain. That means the absence of any central platform or settlement institutions does not require transaction fees (Merz M., 2016: 19).

Microgrids and Energy Clusters

In April 2016, a joint venture between LO3 Energy and ConsenSys called TransactiveGrid launched a pilot project called Brooklyn Microgrid. The project tests the integration of buildings with distributed generation systems in a decentralized peer-to-peer network. This means that the use of blockchain technology is explored here in the context of direct energy sales between neighbors. The technology used in the project is based on the Ethereum blockchain. Ten buildings were connected in a microgrid, five of which are equipped with photovoltaic panels. All unconsumed energy by the buildings themselves is sold to the five neighboring households. All the buildings are connected via a conventional power grid, and transactions are managed and stored using a central blockchain. This configuration shows how it could look. In this way there is the opportunity to see if consumers actually benefit from the possibility of exchanging energy among themselves (PwC, 2016, 21). With this new technology, the market can reach a point where one person with a single solar panel can participate in the end-user market. This is a chance for prosumers, which allows them not only to supply excess energy to the network, paying a fixed fee but placing it on the market individually. The plans provides for all renewable energy resources to be owned by the community itself and that members will jointly decide how to catch and share revenue. This means that the current electricity sales model would have to change in a way that would allow such transactions.

From the beginning the concept of energy clusters, supported by the Ministry of Energy, has attracted great interest as well as doubts about its practical implementation. The most obvious doubts are those about the manner of settlement, responsibility for network management, demand balancing, quality of supply including network losses, break times, voltage. The above pilot project demonstrates that by using blockchain technology, building a functional application layer and an information and marketing campaign, it is possible to implement the cluster idea in an effective way. In addition, the application of solutions presented in the projects on network flexibility, storage, or integration and billing of electric car charging stations has great potential for the development of local communities, changing fundamentally the shape of the current energy market model.

Energy market model

The current energy market model is based on provisions that require energy companies to separate network activities (regulated activities) from energy trading (competitive activities). Customers are entitled to choose freely a supplier. Free choice in this context means that customers can only choose from suppliers authorized to run such activities.

The implementation of a decentralized market model based on blockchain technology is likely to change the currently functioning market roles and connections between participants in this market. In theory, using smart contracts, transactions could be made directly, i.e. a customer in the energy market would not need to choose a supplier who would buy energy on his behalf and conduct its settlements. Blockchain technology enables direct establishment of contractual

relations between consumers and producers. Of course, the direct sales model does not exclude the existence of a supplier, aggregators, or other entities that will be entitled to provide such services. It is the client who decides about his future relations with existing entities on the market.

However, it should be remembered that the omission of intermediaries in energy trading may lead to a fall in energy prices as a result of greater competition associated with the entry of new participants onto the market. One of the main benefits of the blockchain transaction model is that all electricity supplied to the network can be clearly assigned to individual customers. In addition, this assignment may be implemented in small time-units (e. g. 15 minutes). This means that all produced and consumed energy can be very precisely distributed and managed in accordance with the economy of dynamic prices - which will significantly reduce costs for consumers. It is worth noting that the physical flow of energy will be carried out to the end user directly from the nearest generator. Settlements for the purchased energy, including payments made in the blockchain technology, would enable making direct payments in real time without an intermediary, like a bank.

To implement such a solution, it will be necessary to install smart meters to all interested entities and recipients. The role of the DSO operator, which in the current energy market model is responsible for the measurement data will change. These data will no longer be collected and recorded in local databases, as all the data on consumption and transactions will be exchanged automatically in a way that guarantees the correctness of data via blockchain (smart contracts). The transactional data necessary to set network tariffs will also be available in the blockchain network.

Distribution system operators will have information about the transactions they need to charge customers for network costs. Provided that the decentralized transaction model is fully implemented, transmission system operators will no longer require data for billing purposes, as all transactions will be executed in real time and settled solely on the basis of actual consumption. What is more, after the implementation of smart meters (which is a prerequisite), the functioning of the blockchain as a distributed transaction data register can be used to create a comprehensive archive of all electricity billing data.

The method of calculating network rates in reality, based on blockchain technology, still remains the issue. Since it will be possible to trade between neighboring clients (prosumers), the model of setting these rates must change so that it takes into account the actual costs of such supplies.

Conclusion

The process of changing the seller, integrating smart home devices, making graphics of generating units, reporting to the transmission network operator, or balancing the distribution system to allow network flexibility, are only some selected applications of blockchain technology – conceivable, but not fully tested. The catalog of analyzed solutions may not be large, but it clearly indicates the direction of future changes in energy sector projects implemented

all over the world, which are more and more willing to engage in the implementation of new solutions based on blockchain technology, seeing in it great potential for the future operation of the power sector. However, the implementation of projects requires both smart meter technology and blockchain software with integrated functionality of an intelligent contract. Intelligent meters are needed to record the amount of energy produced, blockchain software to carry out transactions between neighbors, and intelligent contracts to conduct and register transactions in an automatic and secure manner. Additional applications thanks to which the entire system can be controlled, are also needed, e.g. by defining certain parameters, such as prices, which are to be purchased from producers or simply neighbors. All transactions must then be carried out fully automatically in accordance with pre-established rules. It is also necessary to integrate the above solutions with the entire power system to ensure stability and security.

It should also be remembered that the implementation is to take place comprehensively, simultaneously, in all areas of life. To make it possible to implement in an effective way, it is necessary to cooperate with business, science, regulatory creators, government agencies, and ordinary people. We must begin to prepare ourselves now if we want to confront a world in which dispersed, autonomous institutions will play a key role in the economy of every country. Further development will depend on technological progress and competitive technologies as well as on regulatory and government practices in individual countries. Yet, one can assume that blockchain technology will promote the emergence of new innovative business models in various industries.

One should also be aware that different, non-standard approaches can have a destructive impact in the future and should be subject to additional regulatory intervention. With this in mind, for the correction of the negative impact that may accompany the development of technology, future research should focus on such issues as:

- identification of the whole energy architecture and identification of blockchain entry points,
- designing blockchain system architecture to deliver different government, industry and consumer objectives (e. g. grid balancing vs product innovation),
- importance of data privacy and governance in a public and permitted blockchain,
- demand Side Response identification and authentication using smart metering and IoT sensing, actuation and control,
- designing transactive energy schemes to maximize consumer engagement,
- identifying social, psychological, and financial value to consumers,
- working out how to equitably socialize the cost of a robust universal energy service,
- avoiding social marginalization arising from product differentiation and energy gated communities,
- designing one platform that delivers multiple value streams (social, psychological, and financial),
- classification of barriers to the introduction of a public blockchain platform,
- identification of potential threats and benefits for the individual as well as for the entire economy resulting from the development of blockchain technology,

- study of the economic environment characteristics in which it will be possible to introduce blockchain technologies in the sector,
- initiation of the regulation and development of a new strategy for the development of companies that are actually based on blockchain.

The involvement of serious players of the energy sector in exploring and developing blockchain technologies is strong evidence that they are considered to be prospective and potentially revolutionary. And this will ultimately change the currently applicable energy market model into a decentralized one in which the main role is played by active consumers.

To sum up blockchain technology's impact on the energy market model, it should be pointed out that the final shape of the market will depend on future regulations, primarily at the national level. These regulations will certainly take into account the aspects related to treats brought about by the development of this type of technology. Importantly enough, this type of regulation currently cannot be properly defined, due to the lack of thorough analyses of projects still in the development phase. However, it is possible to review areas that should be regulated to provide customers in the energy market with security in terms of transactions while maintaining the stability of the energy system. These issues are broad enough to require future research

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THE EFFICIENCY OF FINANCIAL INCENTIVES IN THE DEVELOPMENT OF THE ELECTROMOBILITY SECTOR IN THE NETHERLANDS

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Abstract

The purpose of this paper is to analyse the Dutch electromobility sector in terms of the effectiveness of applying financial incentives and to investigate the hypothesis that the key to using them is not the amount of subsidies for customers to purchase vehicles or to build charging stations, but to properly coordinate time in their application. In addition, the scope of subsidies should be changed from time to time, which will allow the gradual development of various types of electric vehicles. The second hypothesis which will be examined is the claim that the effective use of financial incentives does not necessarily imply a heavy burden on the budgets of central and local administration.

Introduction

The Netherlands is a country characterized by one of the most developed sectors of electromobility in the world. This is evidenced both by the number of electric cars on the roads and by the number of charging stations. The purpose of this paper is to analyse the Dutch electromobility sector in terms of the effectiveness of applying financial incentives and to investigate the hypothesis that the key to using them is not the amount of subsidies for customers to purchase vehicles or to build charging stations, but proper time coordination in their application. In addition, the scope of subsidies should be changed from time to time, which will allow the gradual development of various types of electric vehicles. The second hypothesis which will be examined is the claim that the effective use of financial incentives does not necessarily imply a heavy burden on the budgets of central and local administration.

Considering the above, the following questions should be posed to the task of verifying the justness of these hypotheses: which conditions determine the development of the electromobility sector in the Netherlands?; which financial incentives have been implemented to increase the number of electric cars and the number of charging stations?; what effects did they bring?; when was the most rapid increase in the number of electric cars and the number of charging stations and from which did such sudden increases result? Answering these questions will allow examination of the correctness of the hypotheses set in this paper.

In this paper, the scope of research has been narrowed to the period after 2010. Since then, key financial programs have been implemented. Moreover, the aim of these programs was to encourage the purchase of electric vehicles. Additionally, due to the analysed subject, the following analysis focuses exclusively on financial incentives. Issues related to other incentives, such as the creation of low emission zones in cities, were omitted. In order to achieve the aim of the research, firstly it is reasonable to examine the conditions for the development of the Dutch electromobility sector. That's why the determinants had the greatest influence on the shape of the policy which was implemented. Subsequently, it is necessary to analyse the mechanism of coordinating the implemented policy. This is important because the adopted structure allowed

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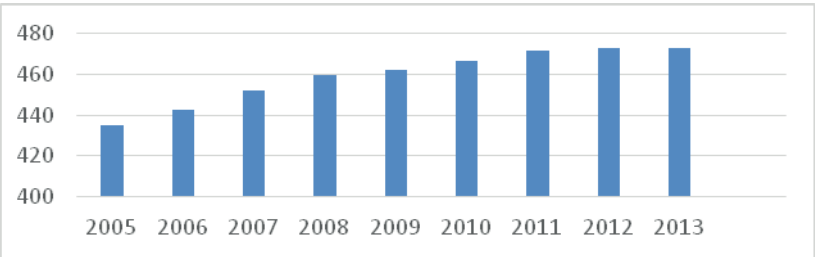
for implementing synchronized activities at many levels of governance and to realise the interests of many parties. The remaining part of the paper focuses on the analysis of financial incentives applied in the Netherlands and their effectiveness.

Conditions for the development of electromobility in the Netherlands

The analyzed country is very well conditioned in the development of new technologies in the transport sector. The Netherlands is almost entirely a lowland country, with the largest population aggregation in the west, in particular in the north and south provinces and also in Utrecht. The factors that significantly affect the level and pace of economic development are very high population density - less than 17 million inhabitants live in an area of 41 543 km^2, which gives a value of around 403.9 inhabitants per square kilometre. However, in only the Randstad agglomeration (7.1 million population), the population density is approximately 1,500 people per 1 km^2. As a result, the Netherlands is the most densely populated country in Europe. The population density and the surface area of this country, combined with a very high level of economic development (GDP in PPP at the level of 752,139 billion USD- data for 2015), cause that the Netherlands is characterized by a very high rate of urbanization. Approximately 90% of the population there live in cities (Wojtowicz 2014).

The above values have a strong impact on the shape of the Dutch transport sector. The transport infrastructure of the Netherlands is one of the most developed in Europe. This is evidenced by the omnidirectional connections between cities and neighbouring countries, a very good condition of inland waterways and port infrastructure, which allow for example for the effective provision of transhipment services. Because of its geographical location, the Netherlands is a very important element of the European transport system. However, from the viewpoint of the subject of this analysis, land transport is a key segment of the transport sector in the Netherlands. The current road network has about 139 thousand kilometres while the railway network is about 3.3 thousand kilometres. Due to the high level of urbanization of the country and relatively small distances between the largest cities, in the Netherlands road transport is the most common mode of transportation. This is evidenced by the fact that the typical Dutchman daily travels by car between 15 and 30 km (Fajczak-Kowalska 2014: 252-254). At present, there is a clear upward trend in the number of owned cars per 1000 inhabitants. This state is illustrated by the chart below.

Chart no. 1 Number of passenger cars in the Netherlands per 1,000 inhabitants



Source: own elaboration based on: Eurostat, Energy, transport and environment indicators. 2016 edition, p. 97, [Internet:] http://ec.europa.eu/eurostat/documents/3217494/7731525/KS-DK-16-001-EN-N.pdf/cc2b4de7-146c-4254-9521-dcbd6e6fafa6 (access: 10.1.2018)

While in 2005 this amount was 435 cars per person, in 2011 it was already 472. Since then, the above trend has been turned, which can be justified by the gradual development of car sharing and car-pooling services that are often associated with the resignation of owning a private car. There are now over 8 million cars on Dutch roads, which is an increase of around a quarter compared to the beginning of the 21st century (Ministerstwo Spraw Zagranicznych 2017).

The Netherlands is also a country with a high level of energy security. However, it should be noted that the above does not mean that there is sustainable economic development. This is a result of a very high share of fossil fuels in the energy balance of the state. In the overall structure of primary energy production, gas accounts for 39% and oil for 38%. On the other hand, coal has a share of 15%. One should also note the very low use of the Dutch potential in the segment of producing energy from renewable sources. However, the Netherlands has well diversified the direction and sources of energy supplies. What's more, this country is the largest natural gas trading centre in the European Union and one of its largest exporters. As a consequence of the analyzed factors, the Netherlands is very well conditioned in the development of new technologies in the transport sector, in particular electromobility (International Energy Agency 2017).

Policy coordination of the development of electromobility in the Netherlands

The development of the electromobility sector is related to the need to conduct a coherent policy in many socio-economic fields. This means that the intervention of the state in all areas of electromobility development should proceed in parallel. This is because actions taken in one area usually imply changes immediately in the other areas. For example, exemption from registration fees during the purchase of an electric vehicle results not only in the reduction of revenues of the local government unit, but also involves the necessity of making adequate legal changes. Additionally, in order to stimulate the development of electromobility in those sectors, the Netherlands has applied many incentives which can be divided into two categories: direct (i.e. financial) and indirect. Very important to highlight is that the development of the electromobility sector could have happened in the Netherlands despite the lack of functioning of a highly developed domestic automotive industry. To make it possible, it was necessary to use both direct and indirect incentives, and what is more, it was necessary to implement and apply them at all levels of management. As was mentioned above, taking into account the scope and the objective of this analysis, it is appropriate to focus only on the direct encouragement for buying electric vehicles (Van der Steen, Van Schelven, Mulder 2014: 9).

In the Netherlands, institutions functioning at all levels of governance were responsible for implementing the development policy of the corresponding sector, both at the central as well as regional and local levels. What is a kind of special feature of this country is that the centre of gravity of implementing a policy was evenly divided between the above levels of public administration. As a result, the actions taken were mutually complementary and, depending on their nature, could be appropriately distributed among various entities (Van der Steen, Van

Schelven, Mulder 2014: 27-28). In the Netherlands, the political system for the development of electromobility consists of various levels of institutions and other parties, which are responsible for the development and implementation of activities in a given section of the electromobility chain, as is shown in the table below:

Table no. 1 Parties interested in the development of electromobility in the Netherlands

Interested party	Responsibilities
Government	setting a framework for activities carried out by other entities, coordinating function, setting new directions of development
Business	providing knowledge determining the desired directions of development
NGO's	supporting and supplementing activities, drawing the attention of the authorities to areas often overlooked from the central perspective

Source: own elaboration

To sum up, in this country the organization and coordination of the undertaken activities was in line with the assumptions of the principle of subsidiarity. Taking these observations into account, the model of central coordination of development policy of electromobility in the Netherlands can be portrayed as follows:

Table no. 2 Central coordination of the development policy of electromobility in the Netherlands

Institution	Responsibilities
Formula E-Team	Strategy development, lobbying, overcoming barriers, industry integration, communication
Netherlands Enterprise Agency	Consulting, financial instruments, communication, information activities
Ministry of Infrastructure and Water Management & Ministry of Economic Affairs and Climate Policy	Policy coordination, setting the course of action

Source: own elaboration

The adopted structure allows avoidance of competency disputes and precisely defines the needs of all parties involved in the development of electromobility. The institutions mentioned above were also responsible for the development and implementation of financial incentives whose purpose was to encourage consumers to purchase electric vehicles. This is important because such a model of cooperation between many parties ensures better coordination of adoption of the incentives. However, it should be also emphasized that the key to their application was not the amount of subsidies to buy a car, but the methodology of their application.

Financial methods for developing electromobility in the Netherlands

In the Netherlands direct financial incentives have focused on increasing sales of electric vehicles and encouraging the construction of charging stations. Therefore, the main instrument used was exemption or relief for purchasers of low emission vehicles from the purchase tax and registration charge of a car or motor (Bpm). The amount of this tax was determined by the level

of CO_2 and other pollutants produced by the car (e.g. NOx) as well as the value of the vehicle. For cars emitting up to 50g CO_2 per kilometre, the regulation provided for a full exemption from the necessity to pay tax. Importantly, this regulation also referred to the production and operation of components dedicated to these vehicles, for example to fuel cells. In turn for each gram of CO_2 for low-emission vehicles in the range of 1 to 81g of produced carbon dioxide per 1 km, the fee amounted to 6 €. With regard to the amount of this tax we can conclude that, taking into account the wealthiness of Dutch society, this amount is not excessive. This is particularly evident when we realise that with an emission level between 83 and 110 g CO_2/ km, it was necessary to pay an amount of 69 € for each gram. In turn, for high-emission vehicles (i.e. up to 180 g CO_2/ km), rates increased up to 434 € for each gram of produced carbon dioxide. It should be added that such a distinction between the amounts of the fee is an expression of the state policy for strengthening the share of BEV cars in the electromobility market. As a result the amount of their total cost of ownership has reduced. What is more, the amount of rates and criteria have changed over the years. However, it is worth highlighting that key to this instrument was the progressive methodology of calculating the tax reduction, which was more important than its amount (Government of the Netherlands 2017).

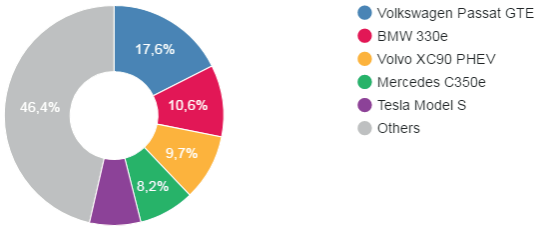
The above conclusion is clearly visible on the example of another popular instrument. In the Netherlands, for entrepreneurs who use company vehicles for private purposes (if private use exceeds 500 km per year), the income tax rate has been reduced. Its amount is calculated by adding to the tax 14% to even 25% of the value of the vehicle leased. A zero tax rate was applicable until the end of 2013 and from the beginning of 2014 the tax was calculated in the amount of 7%, 14%, and 20% according to the fuel type and CO_2 emissions if the cars are fuel efficient (Belastingdienst 2017). In relation to electric cars these values were 7% (for BEV) and 14% (for PHEV). It is estimated that the estimated savings associated with the use of EV vehicles is even around 2,000 € per year. Another attractive instrument was that the cars emitting maximum 50g CO_2/km are exempt from the annual circulation tax. Until 2016, the exemption included both new and operating cars. However, the scope of this relief has changed since 2016 and currently it includes only fully electric vehicles.

In addition to the above, two systems have been introduced which allow relief of costs of an electric vehicle against taxable profits. These programs are MIA (Environmental investment rebate) and VAMIL (Arbitrary depreciation of environmental investments). Through the MIA all entrepreneurs in the Netherlands who pay income or company tax can deduct up to 36% of the investment costs for an environmentally friendly investment on top of their regular tax deductions for investments (Van der Steen, Van Schelven, Mulder 2014: 32-33). In other words, entrepreneurs can receive rebates and subsidies, for example, for the purchase of electricity or installations necessary for the construction of a charging infrastructure. The deduction covers such costs as: costs of purchase, production, modification and/or purchase costs of new elements, as well as environmental consultancy (Nederland Elektrisch). It is also possible to exempt from taxation the profits from owned electric cars. Thus, the VAMIL

allows entrepreneurs to decide themselves when to write off these investment costs. Both programs are conducted at the central level, by the Dutch Ministry of Finance, Infrastructure, and the Environment and its direct implementation is the responsibility of the Dutch Enterprise Agency (NEA) and the Tax and Customs Administration(Netherlands Enterprise Agency 2014).

Financial incentives were also used in the Netherlands at the regional level, although these were rather rebates and subsidies than tax exemptions. Amsterdam, for example, introduced additional payment of 5 000 € to purchase an electric vehicle for business purposes and up to 10 000 € (currently reduced to 5 000 €) to purchase an electric car, a small delivery van, or a taxi. Additionally, purchase of a truck or bus can be associated with obtaining a surcharge of 20% of the purchasing price up to 40,000 € per vehicle (amsterdam.nl). Obviously, the last instrument is mainly an incentive for large entrepreneurs. Similar subsidies for the purchase of a private car or for business purposes were or are also available in Rotterdam, Utrecht, or Tilburg. In addition, some cities grant subsidies for scrapping old cars. However, considering the cost of an electric vehicle, we can realize that surcharges do not even cover the difference between this cost and the price of a traditional car. It is worth quoting here the data in the light of which in 2016 the best-selling electric car in the Netherlands was the Volkswagen Passat GTE, which was bought by 18% of drivers.

Chart no. 2 Best-selling electric car in the Netherlands in 2016



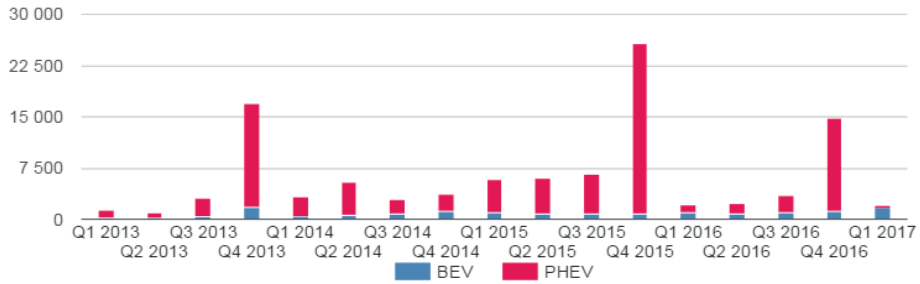
Source: European Alternative Fuels Observatory, Netherlands, [Internet:] http://www.eafo.eu/content/netherlands (access: 10.1.2018) and CBS Statistics Netherlands

The cost of this vehicle at the time was about 45,000 €, so even with these subsidies the car was much more expensive. The same observations can also be applied to other popular cars. Incidentally, the Volkswagen Passat GTE is a hybrid car, just like the BMW 330e, which was purchased by just over 10% of the Dutch. This shows that in the first phase of the electromobility development PHEV (plug in hybrid electric vehicles) cars are more popular.

The incentives analyzed above do not entail high costs of state administration. This is because those instruments usually concern tax exemptions instead of direct subsidies for customers. From the point of view of the development of electromobility, the use of these instruments has brought the expected results. The Netherlands has managed to achieve a desired increase in demand for EV cars with a relatively low burden on the central budget. However, what is important is that the amount of the subsidies was variable every few years. This means that price "manipulation" is crucial, because it affects consumer demand.

In the Netherlands the most dynamic development of electromobility took place at the beginning of the second decade of the 21st century. As a result of the activities initiated at that time, a significant increase in the number of newly registered electric cars was achieved. However, implementing the incentives analyzed above would not have been effective without their effective application. The key remark at this point is that in the Netherlands the financial incentives were limited in time. The graph below shows the growing number of newly registered electric cars between 2013 and the first quarter of 2017.

Chart no. 3 Number of newly registered electric cars (BEV & PHEV) in the Netherlands in quarterly terms 2013-2017

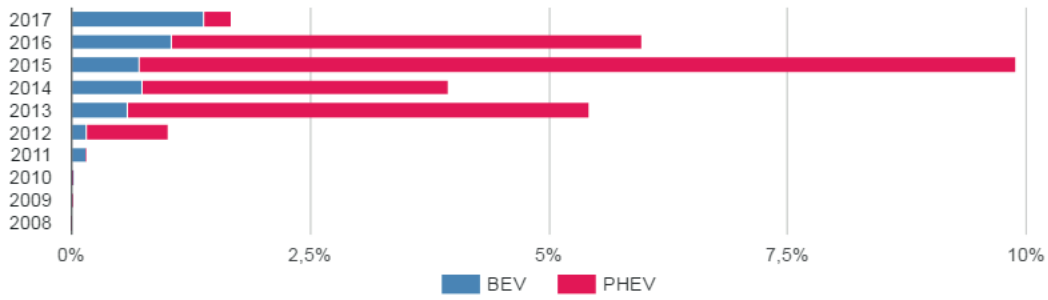


Source: European Alternative Fuels Observatory, Netherlands, [Internet:] http://www.eafo.eu/content/netherlands (access: 10.1.2018) and CBS Statistics Netherlands

The graph above clearly shows that PHEV cars are definitely more popular in Dutch society. We can also indicate three moments in which there was a very large increase in the number of newly registered electric cars. Moreover, all three moments were at the ends of the years 2013, 2015, and 2016. Noteworthy also is that throughout this period the Netherlands had various financial incentives to purchase electric cars. However, each of them ended at the end of the given years. For example, in the last quarter of 2013 there was a huge increase in the number of vehicles sold. While in 2012, 4,326 PHEVs and 828 BEVs were registered, one year later it was respectively 20,164 and 2,441. The explanation of this state is that it was related to the tax concession program and additional payment for customers purchasing electric cars, which ended with the end of 2013. Some kind of social fear of losing the chance to reduce the costs of acquiring a new vehicle led to a very large increase in the number of electric vehicles sold. A similar process can be observed between the third and fourth quarter of 2015. The number of newly registered electric vehicles between July and September 2015 was 5,964 (PHEV) and 707 (BEV). In turn between October and December 2015 it was already respectively 25,024 (PHEV) and 767 (BEV). The scale of fluctuations in the number of registered electric cars is an example of the skilful influence of the government and other institutions on society. Thanks to that policy it was possible to increase the demand for new technologies even in the month to month perspective. Thus, the state maintains some kind of control over the market, making it much easier and more effective to implement policy as well as to monitor the effectiveness of actions taken to develop electromobility.

Another example of the effectiveness of the electromobility development policy is in influencing the popularity of particular types of electric cars. As was mentioned above, during the first phase of the implementation of emobility, PHEV cars were definitely more popular in Dutch society. That's because they are characterized by the parallel operation of an internal combustion and electric engine. Their biggest advantage is their range, which reaches up to 1000 km. PHEV cars are also much cheaper than the BEV type. At this point it should also indicate the level of market share by BEV and PHEV cars. This is shown in the chart below.

Chart no. 4 Shares of BEV and PHEV cars in the electric vehicle market in the Netherlands on an annual basis



Source: European Alternative Fuels Observatory, Netherlands, [Internet:] http://www.eafo.eu/content/netherlands (access: 10.1.2018) and CBS Statistics Netherlands

The conclusion that can be deduced from the above data is that the development of hybrid cars is an intermediate step on the road to building a fully developed BEV car market. In the Netherlands during the first phase of the implementation of emobility the government supported the development of both types of vehicles. But, for the reasons mentioned above, PHEV cars were more popular. However, in the second phase the government decided to stop supporting PHEV cars and to promote only fully electric vehicles. As a result 2017 was the first year when BEV cars had more sales. Once again, it shows how government can influence society. To summarise, it is necessary to conclude that the methodology of implementation and usage of the financial incentives is definitely more important than their amount.

The level of development of the electromobility sector is determined not only by the number of electric cars that were sold, but also by the number of charging stations and the density of their system. In the Netherlands, these two parameters were growing in parallel, which is an expression of the coherence and complementarity of the implemented policy. In order to encourage entrepreneurs to build and install charging stations on their premises, the possibility of using MIA and VAMIL systems has also been opened before them. What's more, in the province of Friesland a Drive4Electric program operates, under which there have been introduced subsidies for entities undertaking such activities. They take various forms, such as discounts in using other stations and vouchers of up to 500 €. A similar program also works in Rotterdam – the Rotterdam Electric Program. It supports the first 1,000 electric car owners with their own charging station, the building of which is supported by the city. Rotterdam has installed further

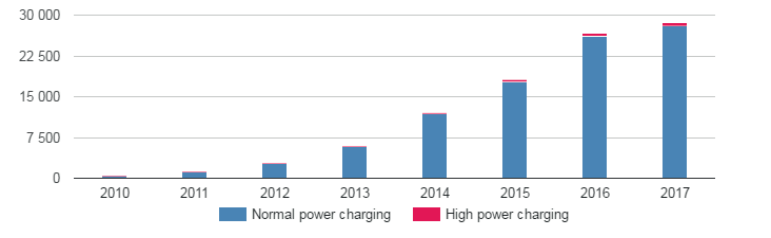
charging points in strategic locations in the city centre and popular parking places (Van der Steen, Van Schelven, Mulder 2014: 37).

A characteristic feature of the electromobility infrastructure development policy is its reliance on various forms of cooperation between state-owned institutions operating on various levels of governance and private entities, which have taken the form of public private partnership (PPP). One example of the cooperation in PPP form was the partnership established between the state-owned operator power network (TenneT) and regional network operators within the E-laad foundation. This consortium in the period of the most dynamic development of charging infrastructure, the years 2010 – 2014, had a budget of about 25 million euro. This allowed building during those four years about 3,000 charging stations. What is important is that due to the inclusion into the investment process of entities from outside the public sector, the above mentioned development was reconciled with the spatial demand for such installations and the possibilities for their construction.

On the other hand, the above analysed cooperation of many entities from various governance areas facilitated the process of identifying and overcoming barriers during the process of the developing the electromobility infrastructure. In the Netherlands, the development of charging stations is largely financed by the central government. Most often local government units are responsible for implementing programs and managing spending. They can also apply for financial support from the central administration. Importantly, such subsidies are almost exclusively provided for investments carried out jointly by local authorities and the private sector, which contributes to building partnerships between them. One example of such cooperation is Schiphol airport near Amsterdam. There is an ensemble of charging stations, which is also one of the largest in the world for that type of installation. It was created thanks to deep cooperation between the central government, the local government, and the airport authorities. As a result, construction costs of the system were evenly distributed.

The consequence of the above activities is that during the analyzed period in the Netherlands there was a multiple increase in the number of charging stations, including the so-called fast charging station, as shown in the chart below:

Chart no. 5 Development of charging stations in the Netherlands (2010-2017)



Source: European Alternative Fuels Observatory, Netherlands, [Internet:] http://www.eafo.eu/content/netherlands (access: 10.1.2018) and CBS Statistics Netherlands

While in 2010 in the Netherlands about 400 stations were installed and none enabling fast charging, there now exist about 28,000 stations with normal voltage and 640 fast-charging stations. In the above chart it is worth paying attention to two key moments: the periods between 2012 and 2013 and between 2013 and 2014. In these intervals there was more than a twofold increase in the number of charging stations per annum. While in 2012 the Netherlands had 2,782 stations, in the following year the number was 5,770. Over the next twelve months, drivers could use as many as 11,860 charging stations. Such large differences result from the fact that at the end of the years with the largest increase in the number of charging stations, the support programs for its builders were to be ended. Thus, in society, a similar phenomenon as when buying electric cars could be observed. There was a kind of social fear of losing the chance to reduce construction costs. It is also difficult not to notice that the aforementioned situation in 2013 coincides with the period of the largest increase in the number of electric cars being sold. This is an expression of the consistency of policy. However, cooperation within the PPP was also attractive. To sum up, taking into account the area of the Netherlands, population density, and the number of land roads, it should be concluded that in this country there is a very dense, highly developed network of charging stations for electric vehicles.

Conclusion

To summarise the above analysed issues, it must be noted that in the Netherlands there is a highly developed electromobility market. This is evidenced by the increase every year in the number of newly registered electric vehicles, as well as the increasing density of the charging infrastructure. Planning actions in this area, various authorities have emerged with the correct assumption that the pursued policy must be connected with the skilful use of financial incentives. First of all, as was shown above, the key was not the amount of the subsidy. The crucial thing was the temporary limitation of their use. Therefore, the main research hypothesis set in this paper was confirmed. Moreover, the incentives should be changed from time to time. The point is that in the first phase of the development of emobility, PHEV cars are definitely more popular in society than BEV cars. It can be said that the road to popularity of fully electric cars leads through the development of plug-in cars. In the first years it is worth supporting both types of vehicles, and after a few years to stop supporting hybrids.

Secondly, the Netherlands has managed to achieve the desired increase in demand for electric cars, with a relatively low burden on central and local budgets. This is important because it shows that the financial incentives do not have to be “expensive”. Thus, less wealthy, ambitious countries can afford to use them. So countries like Poland can also try to develop their own electromobility markets. As a result, the second hypothesis was confirmed. The additional conclusion that results from the analysis above is that financial incentives are the most effective element of the electric vehicles sector’s development. Without them, the pace of development of electromobility may not be satisfactory.

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REGULATION OF PUBLIC CHARGING STATIONS IN PROPOSED POLISH LAW ON ELECTROMOBILITY AND ALTERNATIVE FUELS

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Abstract

Transport, as the core of the regional, national, and, undoubtedly, global economies, requires for undisturbed functioning a developed infrastructure; places where vehicles can be fueled, especially filling stations, are one of the most essential elements of this infrastructure. Electromobility, which is certainly becoming step by step the future of the wholly understood transport sector, will also need, like conventional transport, a specific infrastructure which will permit the refueling of electro-vehicles, too. Easily accessible public charging stations seem to be the most important element in developing electromobility in common transport. To assure such, complex legal regulations are necessary. The Polish legislature has responded to this necessity and is now pursuing work on laws regarding electromobility and alternative fuels. This article has two main emphases - analyze the proposed regulations in the matter of public charging stations and pinpoint the principal tasks in this score. The author hopes that this article will initiate larger interest in this developing institution in Poland.

Introduction

The assertion of the growth of ecology requires nowadays the development of environment-friendly inventions which can thereafter be used by every economic sector. Transport is an indispensable element of the whole economy. Currently, one of the best compounds of environmentally friendly transport is electromobility. Electromobility may be defined as a road transport system based on vehicles that are propelled by electricity (Grauders, Sarasini, Karlström 2014: 10). The electricity to propel these vehicles may derive from clean sources, so electromobility is potentially a fully ecological means of road transport.

The efficient functioning of such areas as electromobility certainly needs state-based regulation, which should create the most essential institutions and procedures. As every conventional vehicle has to be cyclically fueled, running electric vehicles also have to be charged when necessary. As was already mentioned above, the goal of establishing the legal scope of electromobility is the enhancement of ecology in transport and fighting the harmful effects of polluting the environment. However, even the most environment-friendly means of transport will not run correctly without a well-developed and accessible infrastructure. As to electromobility and its common popularity, probably the most important factor is a network of public charging stations.

This article will broach the question of the legal basis of public charging stations, with focus on the proposed Polish law on electromobility and alternative fuels and its conformity with European Union law. Also, there will be undertaken an assay of indicating the general key elements that should be considered by state bodies in the creation and development of public charging stations infrastructure.

Public charging stations – definition, types, and brief history

The description of public charging stations deserves reference to the opinions of researchers in this domain. Firstly, it is worth mentioning the general definition of public charging stations. J. Wirges defines public charging stations as charging stations which are

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publicly accessible to EV [electrovehicles - author's note] drivers (not taking required membership, a specific service provider, or similar limitations of use into account), usually set up at public curbsides (Wirges 2016: 88). J. Wirges considers that within the category of public charging stations semi-public charging stations should also be included, which can be characterized as charging stations accessible only to parts of the public, for instance the clients of a business, e.g. stations located in publicly accessible parking garages of supermarkets, cinemas, and other venues, that are open to the public (Wirges 2016: 88).

The history of charging stations is strictly connected with the history of electric vehicles. As the first electric cars were introduced in the 19th century (the first practical electric car was presented in 1884 by the British inventor Thomas Parker), so the need to create facilities permitting their charging was already present. C. D. Anderson and J. Anderson write, that "In 1895, a firm in London displayed a sign indicating it was prepared to charge 'accumulators' of all sizes at any hour of the day or night. At the same time, *L'Energie Électrique* in France painted a glowing picture of the future of electric vehicles, with charging stations being available at any of the 10,000 establishments that had electrical plants. By 1906 a battery exchange system had been developed in Hartford, Connecticut. A customer could purchase a vehicle without a battery and would then pay a flat fee for service and battery exchanging. The Philadelphia/Baltimore area, for example, had twenty-seven charging stations" (Anderson, Anderson 2010: 8).

Although it seemed that electric vehicles would dominate the market of means of transport, in the 1920s, due to a series of technological and economic developments that incentivized the deployment of gas-powered vehicles, the popularity of electric vehicles started to decline (Safak Bayram, Tajer 2017:5). And it was until the 1990s when a revival of interest in electric vehicles could be observed; societal reasons for the revival of electric vehicles (EV's) are the monetary cost of energy and its cost in national dependence, coupled with the more recent focus on the environmental damage inflicted by internal combustion engines (Chan, Chau 1997: 3). With the revival of EV technology, there is also a need for providing an efficient infrastructure that includes charging stations.

Currently public charging stations may fall into two fundamental contexts:

- "charging while parked", which usually means a commercial venture for a fee or free, offered in partnership with the owners of the parking lot (it can be also associated with semi-public charging stations), examples include charging stations placed in parking lots, shopping malls, etc.;
- fast charging at public charging stations with a charging force of more than 40 kW, delivering over 60 miles (100 km) of range in 10–30 minutes – these chargers may be at rest stops to allow for longer distance trips, but they may also be used regularly by commuters in metropolitan areas, and for charging while parked for shorter or longer periods. The fast charging technology is nowadays the most common type used in public charging stations.

Finally, it is legitimate to describe briefly the technology used in the chargers at public charging stations. The modern one, called "DC fast charging" or commonly "level 3 chargers" in relation to technologically lower-level chargers, are chargers which charge an EV through a 480 V and direct-current (DC) plug typically up to 80% charge of a vehicle's battery in 30 minutes (EVTown 2017). The main advantage of this technology is the drastic reduction of charge time, nearly to that of refueling a gasoline car (Northeast Utilities 2017).

Proposed regulation of public charging stations in Polish law on electromobility and alternative fuels

The Polish legislature, in reference to the usual position of EU institutions, has decided to regulate the matter of public charging stations in the national law. The proposed law on electromobility and alternative fuels (in a version from 22.11.2017) sets norms concerning the area of creation, functioning, and other essential issues in article 2 points 6, 7, 8, 28, 30 and in chapter 2 subsequently. These regulations will be in turn analyzed in the below mentioned subsections.

Basic terms

The project law on electromobility and alternative fuels envisages the setting up of a few important, in terms of the institution of public charging stations, terms, which are:

- **charging** (pol. *ładowanie*)**,** defined in article 2 point 6 on electromobility and alternative fuels project, which is electricity consumption by an electric vehicle, a hybrid electric vehicle, a zero-emission bus, a motor vehicle that is not an electric vehicle, a moped, a bicycle, or a bicycle cart within the meaning of the Act of 20 June 1997 – Road Traffic Law, carried out at a charging point, for the purpose of driving this vehicle;
- **public charging station** (pol. *ogólnodostępna stacja ładowania*), defined in article 2 point 7 on electromobility and alternative fuels project, which is a charging station available on an equal footing basis for each user of an electric vehicle, hybrid electric vehicle, motor vehicle other than an electric vehicle, moped, bicycle or bicycle cart within the meaning of the Act of 20 June 1997 – Road Traffic Law;
- **operator of a public charging station** (pol. operator ogólnodostępnej stacji ładowania), definied in article 2 point 8 on electromobility and alternative fuels project, which is an entity responsible for the construction, management, operational safety, operation, maintenance, and repair of a generally available charging station or a point of power supply for ships;
- **charging station** (pol. stacja ładowania), defined in article 2 point 28 on electromobility and alternative fuels project, which is:
  a) a construction device related to construction work, or
  b) a detached building with at least one charging point installed,
  c) equipped with software enabling the provision of charging services, including a parking stand and an installation leading from the charging point to the power connection;
- **charging service** (pol. usługa ładowania), defined in article 2 point 30 on electromobility and alternative fuels project, which is the chargeable charge for charging in a public charging station.

In the explanation to the projected law on electromobility and alternative fuels, the law's proposer, the Minister of Energy, has indicated that the introduction to the Polish legal system of these new terms will liquidate barriers to the progress of the Polish alternative fuels market (Ministerstwo Energii, 2017: 9). What is more, these definitions should contribute to the main aims of this regulation, which is low-carbon emission transport development and alternative fuel infrastructure (RCL 2017: 2).

Rules for the development and operation of alternative fuels infrastructure – specific regulation for public charging stations

Specific regulation is undoubtedly necessary for almost all legal institutions, especially for those expanding, like public charging stations. At the beginning, it is needful to mention that the Polish legislature (through the Minister of Energy) is heading to its target in this area which is "defining the path of development and construction of generally accessible charging stations for electric vehicles" which "should enable the emergence of a core infrastructure network for these fuels, and thus contribute to the implementation of the objectives set by the project promoter and the objectives of the National Framework." (Ministerstwo Energii 2017: 10). What is more, it is proposed to dissociate the regulations of public charging stations and the infrastructure for vehicles powered by natural gas - the reasons of such dissociation follow (Ministerstwo Energii 2017: 10):

- different properties of both alternative fuels, which affects different principles of particular infrastructure operation;
- differences in the number of infrastructure planned to deploy;
- various costs of building a charging station and a natural gas station;
- the different structures of the electricity and natural gas market and, what is connected with it, the different number of entities interested in economic activity related to the construction of infrastructure and the sale of alternative fuels.

The duties of an operator of a public charging station

Article 3 of the proposed law on electromobility and alternative fuels contains the main duties of the operator of a public charging station, which are the following:

- ensuring that:
  a) at least one charging service provider operates at a public charging station,
  b) a public charging station fulfills the technical requirements referred to in the regulations issued on the basis of art. 18;
- ensuring that the Office of Technical Inspection, hereinafter referred to as "UDT", conducts tests of the public charging station;
- responsibility for the proper technical condition and ensured safe operation of a generally accessible charging station;
- concluding an agreement for the provision of electricity distribution services, referred to in art. 5 para. 2 point 2 of the Act of April 10, 1997 - Energy Law;

- providing the operator of the electricity distribution system, the charging service provider and the seller of electricity, with data on the amount of electricity consumed;
- concluding a contract for the sale of electricity to ensure the functioning of the charging station;
- accounting for electricity losses resulting from the operation of the charging station;
- providing information on the rules of using this station in the public charging station and instructions for its use;
- providing charge providers with access to a public charging station on an equal treatment basis.

The next essential article in the matter of the duties of an operator of public charging stations is article 8 point 1, which restricts the use of energy from public charging stations just to charging, recharging, or replacing the battery for driving an electric vehicle, a hybrid electric vehicle, a zero-emission bus, a motor vehicle, not being an electric vehicle, moped, bicycle or bicycle cart within the meaning of the Act of 20 June 1997 - Road Traffic Law - at the charging point. This provision should be rated positively as it composes a legal norm which counteracts any eventual abuses in the public charging stations operation.

Supplier of charging service

In article 3 paragraph 2 the Polish legislature proposes creation of an entity called "supplier of charging service" (pol. *dostawca usługi ładowania*). This construction creates *de facto* a division of the wholly understood charging of electric vehicles into two activities - operating of a public charging station and supplying a charging service. It is proposed that the supplier of the charging service will have two primary duties:

- provision of the charging service;
- contract sale of electricity with an electricity seller.

The Ministry of Energy does not explain precisely this idea. Taking into consideration the objectives of the proposed law on electromobility and alternative fuels it seems that this solution is worthless, because of undue contradistinction between the duties of a public charging station operator and the supplier of a charging service, especially that article 6 provides that the operator of the public charging station, excluding the power distribution system operator, may act as a charging service provider. From the point of lucidity of the functioning of the provision of the charging service for owners of electrovehicles, i.e. the EV's fuel market, the entity of public charging stations operator is sufficient. The Polish legislator exhibits here overregulation, which will lead to many misunderstandings and even conflicts.

Other provisions

In the proposed law on electromobility and alternative fuels, Polish authorities have introduced also other regulations concerning technical and safety requirements. Many aspects, especially those constructional, are planned to be placed under the supervision of the special government's body – the Technical Supervision Office (pol. *Urząd Dozoru Technicznego*).

What is understandable, many specific issues will be concretized in delegated acts by the relevant ministers, thus the minister relevant to the energy (article 18) eventually in accord with the minister relevant to the maritime economy and the minister relevant to the inland waterway shipping (article 19).

Conformity of the proposed law on electromobility and alternative fuels with the European Union law

Accession of the Republic of Poland to the European Union on 1st May 2004 has brought a specific legal dualism, where two legal orders take effect. The laws of each Member State of the European Union has to be compatible with the acts of the EU's institutions.

In the scope of electromobility, the most important EU legal act is Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of an alternative fuels infrastructure (O. J. of the EU L 307 from 28.10.2014, p. 1). In point 25 of the preamble to this directive, where the reasons for adopting such a legal act are stated, it is indicated that "Electro-mobility is a fast developing area. Current recharging interface technologies include cable connectors, but future interface technologies such as wireless charging or battery swapping need to be considered as well. Legislation needs to ensure that technological innovation is facilitated." The EU legislation states also in point 27 of the preamble to the directive 2014/94/EU, that "Electro-mobility is an important contributor to meeting the Union's ambitious climate and energy targets for 2020." What is more, points 24 and 26 state that "Member States should ensure that publicly accessible infrastructure for the supply of electricity to motor vehicles is built up. To define an appropriate number of recharging points accessible to the public in their national policy frameworks, it should be possible for Member States to take into consideration the number of existing recharging points accessible to the public on their territory and their specifications, and to decide whether to concentrate deployment efforts on normal or high power recharging points." and "A recharging or refueling point accessible to the public may include, for example, privately owned recharging or refueling points or devices accessible to the public through registration cards or fees, recharging or refueling points of car-sharing schemes which allow access for third party users by means of subscription, or recharging or refueling points in public parking. Recharging or refueling points which allow private users physical access with an authorization or a subscription should be considered to be recharging or refueling points accessible to the public." Taking in all of the above-mentioned statements, it is necessary to conclude that the European Union organs see well the benefits of electromobility for the environment and economy. They also see that without a special surrounding infrastructure electromobility will never become as developed as desired.

The main points of the 2014/94/EU Directive essential for the public charging stations facilities are:

– shaping of the definition of "recharging or refueling point accessible to the public", which means a recharging or refueling point to supply an alternative fuel which provides Union-wide non-discriminatory access to users. Non-discriminatory access may include different

terms of authentication, use, and payment (article 2 point 7 of the directive 2014/94/EU);
– imposing of a few obligations to Member States like designation of urban/suburban agglomerations, of other densely populated areas, and of networks which, subject to market needs, are to be equipped with recharging points accessible to the public (article 3 point 1 indent 5), or ensuring that an appropriate number of recharging points accessible to the public are put in place by 31 December 2020 (article 4 point 1).

The Directive on the deployment of alternative fuels infrastructure permits the adoption of elastic regulations concerning the matter of public charging stations. As shown in the table of accordance between Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure and the proposed Polish law on electromobility and alternative fuels, the articles are not a direct implementation of the directive (RCLa 2017: 1 – 6). This method remains in accordance with the sense of the Directive and should be rated positively.

Conclusion

Current trends in environmental issues suggest that electromobility will probably become an essential part of world's economy. As it concerns the prevalent conveyances, electromobility also needs a capably functioning infrastructure in which public charging stations, like filling stations currently are one of the most important elements. However, the regulation of a public charging station, in order to be effective and ensure the success of the complete transition to electric transport, must be transparent and ancillary to the mentioned objectives. Complete analysis and evaluation of the regulation of public charging stations will be possible after implementation of the law on electromobility and alternative fuels.

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THE ROLE OF OIL AND NATURAL GAS IN THE CONTEXT OF LOW-EMISSION TRANSPORT BY 2030

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Abstract
Fossil fuels, mainly petroleum and natural gas, are dominant in the transport sector. The occurring climate changes, which are largely the result of exhaust emissions, must be slowed down. To achieve this, legal regulations have been introduced determining the development of alternative drives in transport while reducing the share of those present. The development of electromobility and clean gas technologies is a chance to reduce the share of diesel drives in the transport sector. The purpose of this article is to present the role of natural gas and crude oil in the perspective of 2030.Key words: natural gas, oil, low-emission transport.

Introduction

Oil and natural gas are the two most desirable fuels in the world. The history of these fossil fuels dates back to ancient times – a however, their true value was appreciated only in the mid-19th century. The discovery of oil and natural gas and their extraction from the world's first oil field started by Ignacy Łukasiewicz took place in 1854 in Bóbrka near Krosno (PGNiG 2017). Ignacy Łukasiewicz used oil as a fuel in a kerosene lamp, which was a milestone for the later oil sector. The great importance of that discovery is demonstrated by the fact that 160 years after that event, oil and natural gas underpin the functioning of global economies, because industry, transport, and electricity production are all based on these fuels (Fic 2015: 17). Along with global development, the demand for these fossil fuels is constantly increasing, and their extraction potential is limited. Apart from the fact that these resources are limited, the second important factor in analysing further perspectives of these fuels is emission from combustion, i.e. natural gas emits less combustion gas into the atmosphere than burning liquid minerals such as diesel oil or petrol (Sas et al. 2017: 38). It is a huge challenge for further development of the global transport sector still based on oil. Which direction will it take? Is this the end of the "black gold" era, to be supplanted by new gas technologies or electric propulsion?

The main aim of this article is to present the role of oil and natural gas in the transport sector in the context of the development of low-emission transport by 2030. With this aim in view, the authors have put forward the following hypotheses:

- the role of oil by 2030 will diminish in favour of other technological solutions;
- legal regulations effectively aim at reducing the number of combustion-engine vehicles in favour of those powered by "clean energy" by 2030;
- new gas technologies will play a leading role in individual and public transport.

In view of the above hypotheses, a few research questions which will be useful in studying the hypotheses must be formulated:

- is it possible to dethrone the leading role of oil in transport by 2030?
- how will the development of low-emission transport affect the position of oil?

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- are the assumptions of EU legal acts on climate change decreasing effectively the number of vehicles fuelled with liquid minerals?
- will electric and hybrid cars gain the passenger car market by 2030?
- how does the NGV market look in Europe and throughout the world?
- how is the infrastructure for CNG/LNG vehicles being developed in Poland?

Determinants of the development of low-emission transport

It is worth considering why low-emission transport is developing at an increasing pace and becoming so popular. There are a few factors, which mainly determine the development of this industry. The basic impulse for making the process of introducing low-emission transport more dynamic is the environment (Ministry of Energy 2016: 9). Global warming, caused by excessive emission of greenhouse gases, has had the result of passing legal regulations to prevent this problem. Countries which are members of economic and political organisations must enforce the provisions of the law, so that the problem of global warming can be dealt with globally. It seems that the European Union is a leading entity in this area, which through the national energy regulatory authorities, supervises the effects of the adopted assumptions.

Climate policy

There are three main strategies in the field of climate: *The Third Energy Package from 2007, Climate and Energy Policy Framework by 2030,* and *Low-carbon Economy in 2050* (European Commission 2017). There are three main assumptions resulting from the above mentioned strategies which, with further forecasts, will evolve appropriately. These include:

- **Limiting the emission of greenhouse gases**
  The reduction of greenhouse gases, in particular water steam and carbon dioxide, is one of the main challenges of the European Union. The importance and negative influence of the problem was recognised at the beginning of the 21st century, but only in 2007 was attention drawn to the problem by the drawing up of a legal act - *The Third Energy Package.* The industrial and transport sectors are the main sources of these gas emissions (Motowidlak 2015: 176). Therefore, in subsequent points of the abovementioned legal acts, attention is paid to the production of clean energy and increased energy efficiency, which must partially face upcoming energy challenges (ibid.).
- **Improved energy efficiency**
  Gradual improvement of energy efficiency by reducing losses and using intelligent systems, in connection with the newest technologies, allows the effects of energy production to be maximised (ibid.). In the strategy valid until 2030 efficiency is to be improved by 40% compared to the year 1990 (European Commission 2017).
- **Increased share of RES in the energy balance**
  Using more advanced solutions makes it possible to increase every year the share of renewable energy sources in the total energy balance. Hydroelectric plants, wind farms, and

photovoltaic cells are all developing rapidly - the projects are mainly financed from EU funds. Taking into account the increasing demand for electricity, it is a very good signal in terms of meeting consumers' needs (*EUCO 169/14*: 1-5).

All the mentioned assumptions help directly or indirectly to increase interest in low-emission transport. Countries are forced to reduce greenhouse gases, including car exhaust fumes. Two types of low-emission vehicles are gas and electric vehicles. The latter works to meet the next assumption – that is, increasing the share of renewable energy sources in the total energy balance.

Natural gas as an alternative to oil

Natural gas is one of the three most caloric fuels in the world along with oil and hard coal. It is what many economic branches are based on – industry, transport, services, or households (Kaliski et al. 2010: 28). The main advantage over other energy sources is its low emissions – several times lower than hard coal or oil emission. It can take different forms. It can be purified and compressed (CNG-Compressed Natural Gas), liquefied (LNG-Liquefied Natural Gas), or in case of refinery waste produced during oil and natural gas (LPG) processing, change its physical state under pressure (WNP 2017). Imposed restrictions of exhaust gas emission makes all natural gas form a very good alternative to diesel oil or petrol.

Vehicles powered with different forms of natural gas are becoming more popular and year by year their number is growing. To encourage potential customers, certain tools should be used to cause a specific reaction, namely, introducing financial instruments to encourage the purchase of this technology, favourable fiscal policies, and clear legal regulations. Development strategies for low-emission transport depend on a number of elements: forecasts for the condition of the natural environment, profitability of infrastructure construction and maintenance, and the attractiveness of the natural gas unit price compared to other fuels (Sas et al. 2017: 13). It is appropriate here to present the emission of toxic compounds based on the example of buses powered with diesel oil and CNG (Table 1).

Table 1 Emission of toxic compounds of a city bus

Exhaust compound	Exhaust emission value [g/k Wh]	
	Diesel engine	CNG engine
Nitrogen oxides	13.4	2.9
Carbon oxide	4.6	0.3
Particles	0.3	0.06

Source: Monika Orzechowska, Dominik Kryzia, Polityka energetyczna – energy policy journal, Tom 17, Zeszyt 3, Kraków 2014, s. 323.

When analysing the presented data it can be definitely stated that natural gas is more friendly to the environment. Several times lower exhaust emissions should be an impetus for intensifying

activities leading to the implementation of solutions based on natural gas. Favourable conditions – mainly of an economic nature - from the point of view of an individual customer would be a driving force for the market of clean gas technologies.

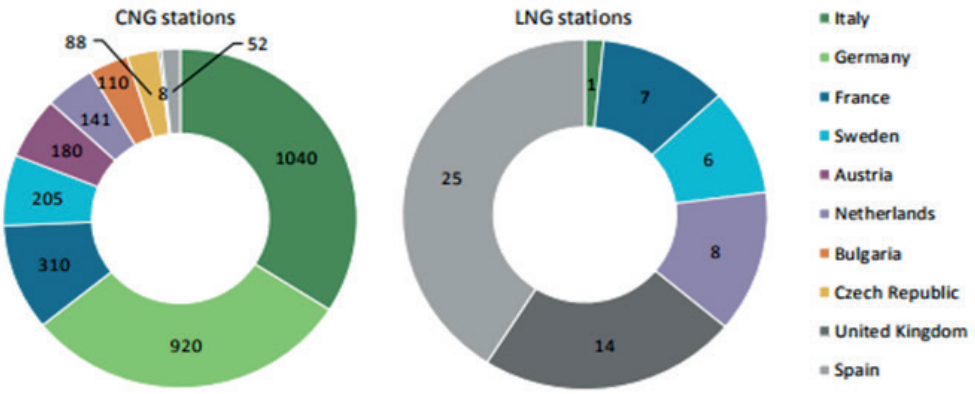
European NGV market

The European NGV market is less dynamic than the Asian or South American markets. This is the result of the policy of individual governments. Their recognition of CNG or LNG potential has resulted in domination of the market for vehicles powered with this fuel since 2009. Countries such as Iran, China, or Pakistan are leading in terms of the number of CNG cars. The largest percentage progress compared to previous years can be easily shown on the example of China, which during the last 7 years has increased its fleet almost 8-fold (ibid.). What is more, Southeast Asia has become the cradle of CNG vehicles production (CNG-LNG 2017). The trend is increasing (compared year-by-year), which is very good news from the point of view of the global development of low-emission transport, even in view of the proven technologies. In Europe, Italy is leading in terms of the quantity of vehicles and developed infrastructure. This phenomenon is determined by the base of CNG service stations opened even in the 1970's and 1980's. In the last decade the governmental programme for co-financing gas vehicles and lowering the excise on this fuel resulted in a substantial increase in the number of CNG cars by 51% (from 588,077 in 2009 to 885,300 in 2016) . The top European countries are also: Ukraine, Germany, Sweden, and Bulgaria. However, the total number of vehicles in these countries does not exceed half of the Italian CNG fleet. As far as Poland is concerned, currently 3,590 CNG vehicles are in use, which can be refuelled at 27 stations. Throughout Europe 2 million CNG and LNG vehicles are being used.

The slow increase in CNG passenger cars in Europe and Poland seems to have been caused by the small number of passenger cars available on the market as well as expensive CNG systems, which has resulted in a lack of development of the infrastructure. It seems to be a vicious circle, where poor infrastructure results in the lack of production of CNG vehicles and vice versa. For instance, in Poland, taking into account the number of CNG service stations and the number of "ordinary" filling stations, the shortage of possibilities for refuelling a car means that customers are discouraged from purchasing such vehicles (number of CNG stations - 27; number of filling stations - 6624) (PGNiG 2017). The number of stations is a very reliable indicator, which shows how the CNG or LNG transport sector is developed (Chart 1).

The situation is better in the case of public transport, where more emphasis is put on ecological public transport buses. An excellent example is Rzeszów, where 70 CNG buses are in service, making it a leader among other cities. LNG buses, 35 of which were bought by MZA Warszawa in 2015, are unique in Europe (CNG-LNG 2017).

Chart 1 Chart presenting the number of CNG and LNG stations in selected European countries in 2016.



Source: www.iea.org

Conclusion

Among the areas mentioned in the analysis, the national natural gas market looks the least favourable in the context of individual transport. The lack of appropriate infrastructure, legal regulations, or state financial tools, has resulted in only a marginal increase in interest in alternative fuels among consumers. However, EU policy requires action in this matter. To achieve the objectives of the abovementioned policy a Low-Emission Transport Fund will be launched, whose purpose will be to extend the fleet of electric vehicles and develop electric, CNG and LNG vehicles infrastructure (PAP 2017). It is a chance for Poland to use the potential of drives based on natural gas.

The public transport market seems to be more favourable, especially urban transport, which in the last 10 years has been dominated by CNG and LNG buses. It should not be forgotten that electric buses, apart from gas fuels, are part of low-emission transport. What is more, a European tycoon of urban electric communication, Solaris Bus & Coach, is a Polish company. Electromobility and buses powered with alternative fuels are a chance for the Polish public transport industry (Transport Publiczny 2017).

The prospects regarding the European market seem to be encouraging. The countries with a significant number of vehicles powered with natural gas are constantly and consistently developing in this sector. New stations are being opened, facilities for the owners of such solutions are being introduced, and automotive companies are producing more and more passenger cars with factory gas systems. The trend is increasing, both in the development of infrastructure and the number of cars.

The development of low-emissions transport on current global trends is very interesting. Rapid growth in the number of CNG cars in the Middle East and in Southeast Asia can be noticed. The very high rate of growth is caused mainly by economic aspects - the price of natural gas constitutes 10-30% of the price of diesel oil or petrol; co-financing of the conversion of vehicles – up to 90% of the costs incurred – in for example Iran; abolished customs duties on the CNG system equipment between Pakistan and Bangladesh (Sas et al. 2017: 12). If the

current growth rate is maintained, the prospects for alternative fuels in Asia are encouraging. It can be an opportunity for European companies in the context of gaining a very ready market for modern technologies.

Currently, not many African countries have vehicles with such drives. The main users of gas vehicles are residents of Egypt and Mozambique (NGV journal 2017). It is the region with the least developed gas technologies. this is caused by their general development and economic situations, but it is possible that the condition of African economies will improve and they will become more open to innovative technologies. Today it is difficult to have any prospects for Africa.

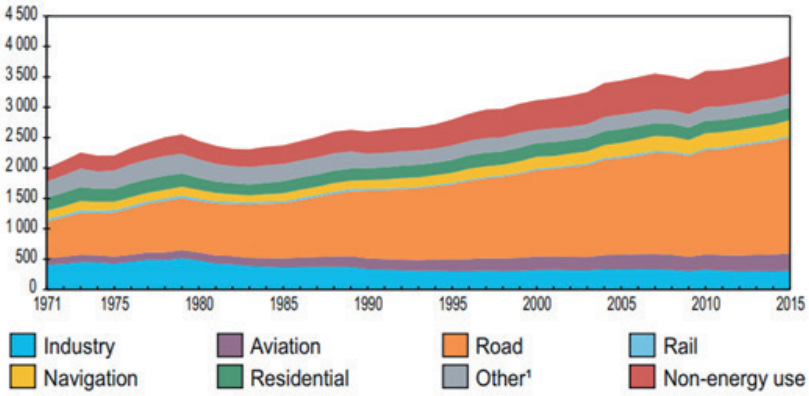
An exemplary continent with well-developed gas technologies can be South America. The number of cars powered with gas in South America constitutes about 24% of the total number of gas cars worldwide (22,335,773 pcs.) (ibid.). In the top ten countries with the most CNG vehicles, South American countries hold three places among 4 Asian countries and 1 European country.

As can be seen, the current global CNG situation is rapidly developing in two continents. Europe, after a few years of stagnation, is trying mightily to catch up and use the potential of clean gas technologies. The principles of free market and globalisation in the near future will result in natural gas becoming popular again and gas drives working in the whole world. Current trends and the rapid growth of fleets based on gas in those countries which have been developing such technologies for a long time, will drive the market. It is a very good direction taking into account current climate problems, security of supplies of other energy sources, and depletion of conventional sources.

Current role of oil

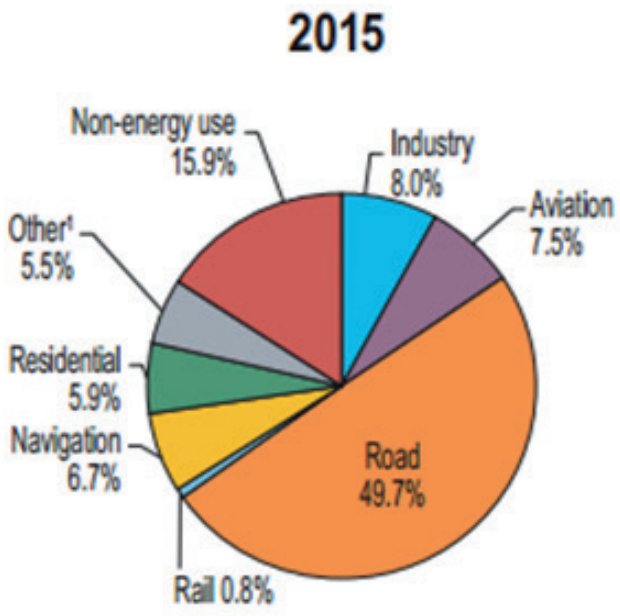
Oil is a major, if not the most important energy source of the global economy, because it accounts for almost 33% of global primary energy (Sławomir Grzelak, Państwo i społeczeństwo: 137). It is of fundamental importance as an energy resource. It is very important for the chemical industry, but above all is used to produce fuels: in global terms the transport sector utilises about 60% of produced oil. It is worth mentioning data collected by the International Energy Agency:

Chart 2 Oil Total Final Consumption from 1971 to 2015 by sector



Source: IEA, Key Word Energy Statistics 2017, p.39

Chart 3 2015 shares of world oil consumption

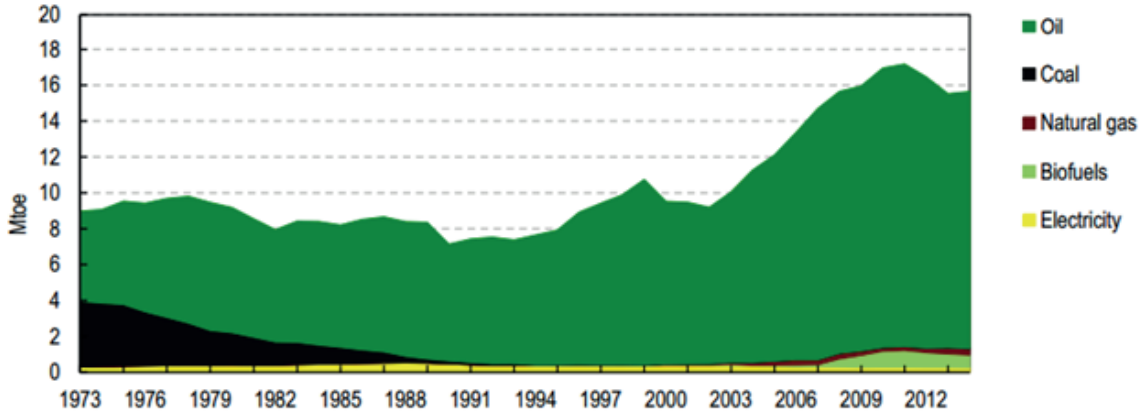


Source: IEA, Key Word Energy Statistics 2017, p.39

The above charts clearly show how important oil is in the transport sector. Road transport itself utilizes almost 50% of global oil production; together with aviation they account for 57.2%. It is clear that oil is currently the main power source for vehicles, which makes it difficult to be replaced. Analysing the chart presenting total oil final consumption from 1971 to 2015 by sector, we can also notice an increasing trend in the consumption of this energy source. In that period oil consumption in transport more than doubled. To emphasise the current role of oil, the shares of energy sources in transport are presented below.

– In Poland - in 2014 the share of oil in transport was 64.3%, clearly seen in the chart below

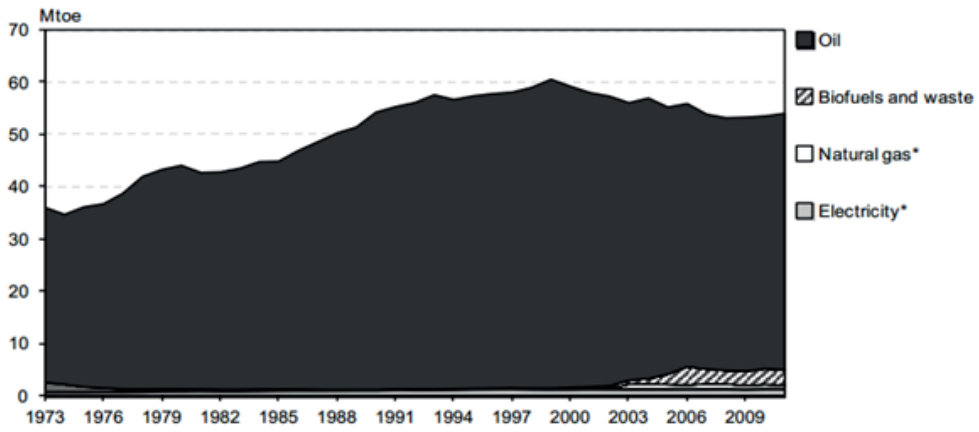
Chart 4 TFC in the transport sector in Poland by source, 1973-2014



Source: IEA Poland 2016, p.55

– In Germany - oil is also dominant, but there are also other energy sources, e.g. REN

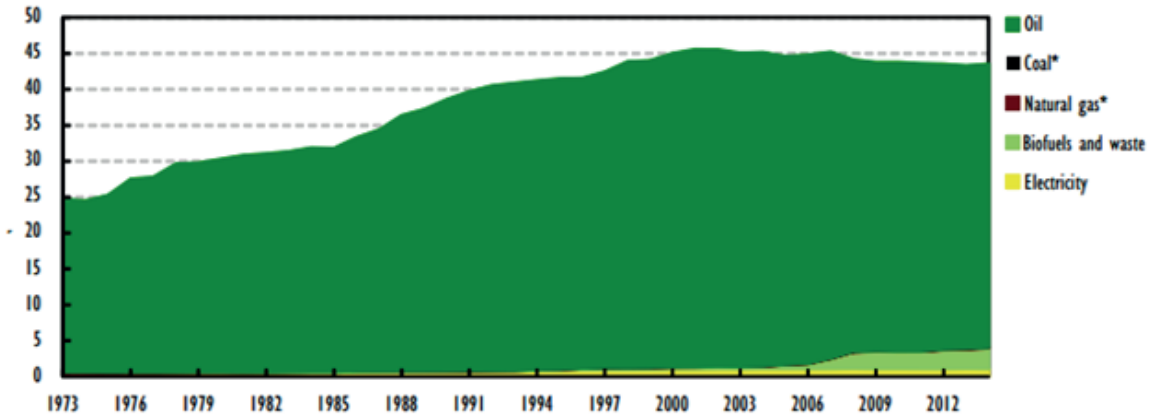
Chart 5 TFC in the transport sector in Germany by source, 1973-2014



Source: IEA, IEA Germany 2013, p.36

– In France - the sector is dominated by oil. Very slow growth of electricity in powering vehicles

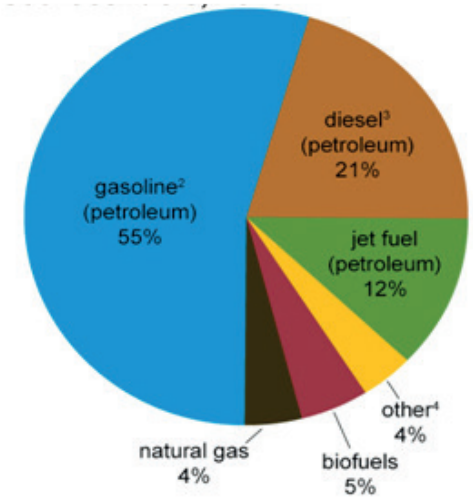
Chart 6 TFC in the transport sector by source - France



Source: IEA, IEA France 2016, p.52

– In the USA - the world's largest consumer of oil (Tomczonek 2013: 118).

Chart 7 TFC in the transport sector in the USA by source



Source: https://www.eia.gov/energyexplained/?page=us_energy_transportation

The role of oil in the context of low-emission transport by 2030 - forecasts.

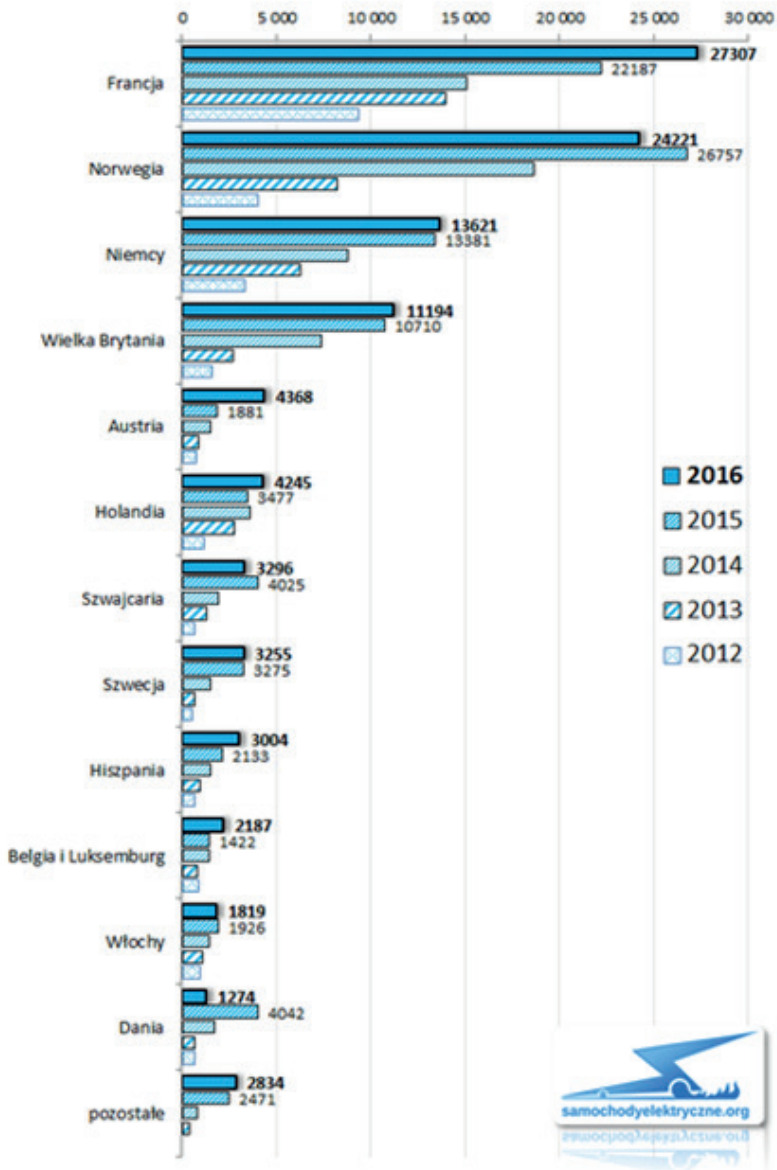
What will be the role of oil in the transport sector by 2030? This is a question asked by more and more people who study the transport sector and its related fuels. The main factor affecting directly the essence of using this material will be the pace of introducing electric vehicles onto the market. Although in the 1950's M. King Hubbert in his hypothesis on so-called peak oil predicted the decline of oil, developing production and discoveries of new reserves put this idea into question (Princeton 2017). A very accurate comment was formulated by a former minister of oil industry of Saudi Arabia, sheik Zaki Yamani: "The Stone Age did not come to an end because we had a lack of stones, and the oil age will not come to an end because we have a lack of oil" (Economist 2017). The above words clearly indicate that oil will lose its leading role in transport, but will it happen by 2030? It all depends whether another transformation will be carried out in transport. At present about 57% of global demand for oil is generated by the transport industry, and road transport itself needs 44% (Voxeu 2017). Therefore, two scenarios are presented below. The first one is based on dynamic development of electromobility and its effects on the role of oil in transport. The other one presents the role of oil when electric vehicles are slowly introduced onto the market.

Electromobility and hybrid vehicles

Electric and hybrid vehicles are also important in low-emission transport. It is safe to say that, consistently, we can see their age unfolding. Although the history of electric drives dates back to the 1830's, it is only in the 21st century that technological development has enabled such vehicles to be economically viable (Fic 2015: 55). Climate change and introduced legal norms are a catalyst for transport electrification. As a response to the transformation of this branch of the economy, many countries are preparing strategies and plans for the development of electromobility aimed at the development of infrastructure, co-financing of purchases, and fiscal policy for the owners of electric vehicles (ibid.: 16) .

In the third quarter of 2017, global sales of electric cars increased by 63% compared to the respective period of the previous year (Businessinsider 2017). According to data of the *International Energy Agency*, China is the market leader in terms of the number of electric cars. Chinese policy has created a situation where electric vehicles are almost 40% cheaper than combustion-engine cars, which is a great incentive to buy such cars. Other large markets include the USA and Europe. Despite double digit growth year-after-year in practically every market, electric cars account for about 0.2% of the total number of registered passenger and light commercial vehicles. Norway is a phenomenon on a world scale, where electric and hybrid cars account for almost 29% of all passenger cars (Obserwator finansowy 2018), and in 2017 the number of sold electric and hybrid cars constituted 51% of all vehicles sold. It is worth presenting statistical data on registration (sales) of electric cars in selected European countries in 2012-2016.

Chart 8 Registrations of electric cars in selected European countries in the last 5 years



Source:samochodyelektryczne.org/wyniki_sprzedazy_aut_elektrycznych_w_europie_w_2016r_kraje_i_modele.htm

As can be seen in the chart above, registrations of electric cars are increasing. The increase in the number of cars is cyclical and stable. It can also be noticed that most registrations took place in the most developed countries with significant capabilities in the energy production sector. Both Norway and Germany are constantly developing renewable energy sources, which enables electromobility to be developed faster, because "clean energy" is to become the main power source of these vehicles. France, on the other hand, is leading in nuclear energy production. Capabilities connected with energy production using energy sources other than the traditional ones is contributing to the gradual decrease of the role of oil in transport.

The first issue that should be tackled here, is to answer the following question: what should happen to enable the quick introduction of electromobility? Where the production of

the car itself is not an important obstacle, the possibilities to "refuel" them seem to be more problematic. First of all, it is necessary to consider where the sufficient amount of energy to power vehicles can be obtained from. It is known that fossil fuels reserves are limited. Therefore, countries implementing electromobility put at the same time emphasis on the development of renewable energy sources, which are to be the main source of energy for vehicles. However, as is well known, electricity can be produced from oil, gas, coal, biomass, nuclear energy, or RES. This creates numerous possibilities and options. Generally with the prospect of limited reserves of fossil fuels, much emphasis is placed on energy produced from renewable energy sources, but such a prospect should not hamper the development of electric vehicles. De facto the energy obtained from fossil fuels, nuclear materials or RES is the same, and can be used to power electric vehicles without restrictions. This factor calls for the possibility of rapid development of electromobility even in countries where RES are not well developed, but which have reserves of coal or gas or a developed network of nuclear plants.

Another problem to solve is the charging of electric vehicles. In order to introduce electric cars, countries are forced to build appropriate infrastructure. This is a factor which can considerably slow down the introduction of this type of low-emission transport, because it requires appropriate funds and commitment on the part of the government.

Conclusion

The aim of the study was to present the role of oil and natural gas in the context of low-emission transport by 2030. Natural gas is a very promising alternative fuel. Compared to conventional fuels, it is a low-emission and more environment-friendly substance. An appropriate form to determine prospects for natural gas is their division into three areas: the national level, European, and the world. Due to huge disproportions in development of transport based on CNG or LNG, the evolution of natural gas as a fuel cannot be unambiguously and universally determined.

The vast majority of countries in the world base their communication system on oil technologies. 2030 seems to be too short a time to dethrone oil from its leading position in transport. Obviously, numerous requirements of environmental protection spur the moving away from conventional energy sources, something happening now, but such a process is systematic. It should also be taken into account that powering low-emission vehicles requires appropriate infrastructure, the construction of which requires time and financial resources. The social factor mentioned above is also important. In many countries the cost of purchasing an electric vehicle may be too high for an average citizen, which in turn will slow down the process. Only after a few years will people be able to buy second-hand electric vehicles, because their price will fall. Countries producing oil are also worth considering. Those countries will definitely not allow sudden supplanting of the material they offer, because it could mean colossal losses for them. Those countries will probably endeavour to slow down the process of supplanting oil. To sum up, the role of oil in the perspective of 2030 and low-emission transport may decrease but

not significantly. Oil will probably remain the most popular energy source in transport, but its market share may decrease by a few percentage points.

The prospects for developing the market of electric and hybrid vehicles are very encouraging. This is backed up by legal regulations which encourage the purchasing of e-cars. An additional factor stimulating this market are subsidies that allow cars to be purchased at a lower price, because part of the price is financed by external entities. An element which does not play a leading role but has its share, is social environmental awareness, because electric and hybrid cars are zero-emission vehicles. Apart from vehicles powered with clean gas technologies, electric and hybrid cars are becoming an important alternative to the combustion-engine cars still dominant on the market. By 2030 the market for passenger cars will probably not be dominated by alternative drives, but it is estimated that their number will constitute about 25% of the total number of cars (Ministry of Energy 2016: 5).

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BOOK REVIEW: THE NATURAL GAS EXPORTS OF TURKMENISTAN. ENERGY AND GEOPOLITICAL INTERESTS IN THE CASPIAN REGION

Urs Unkauf [1]

Abstract

After the decline of the Soviet Union and the emergence of independent states, the southern Soviet republics opened their resources to international markets and began to develop their own political ambitions at the same time. Turkmenistan, as the country with the fourth largest reserves of natural gas (2014 estimated with 9.93 % of worldwide natural gas reserves) and as the most important supplier to China of this energy source takes a special place in the political configuration of post-Soviet Central Asia. In his recently published doctoral thesis, Heinrich Schulz analyses the questions why the country hasn't realized the export of natural gas to Turkey and Europe yet, and how Turkmenistan is influenced by energy political interests and geopolitics in the Caspian Region. The monograph also introduces general political issues regarding natural gas, pipeline infrastructure, and foreign trade of fossil fuels in Central Asia.

Introduction

Regarding the Caspian Region, the plurality of stakeholders in the sector of natural gas and petroleum is quite particular for this part of the world. Azerbaijan, Kazakhstan, Uzbekistan, and Turkmenistan account for 29.1% of global natural gas and 2.2% of global petroleum reserves (Abdolvand/Schulz 2013). Together with Uzbekistan, Turkmenistan was the centre of cotton manufacturing during the Soviet times. Around 80% of the country is covered by desert; most of the 5.7 million inhabitants live in a few developed centres. It seems quite evident that the exploration and production of fossil fuels has developed as the key issue of economic priorities for the states of Central Asia – especially for Turkmenistan with its huge natural gas reserves. Besides Kazakhstan and Uzbekistan, where the link goes back to the Soviet era, also the other neighbour states Azerbaijan, Afghanistan, and the Islamic Republic of Iran are important stakeholders concerning the natural gas export potentials of Ashgabat. Of course, the Russian Federation is also affected by gas trade from the Caspian Region and tries to keep control over the main pipeline connections. The national energy policy has not yet implemented solutions to overcome the resistance against Turkmenian gas exports to Europe for various reasons. Heinrich Schulz, who works as a business consultant with focus on Iran and honorary secretary of the German-Turkmenian Forum provides several explanations in his book about the interdependence of energy policy and geopolitical interests.

Turkmenistan as geopolitical stakeholder in the Caspian Region

The main question is why Turkmenistan has not yet been able to realize natural gas exports under the circumvention of Russia and why Ashgabat has an interest to export to Turkey and Europe (Schulz 2018: 28). This guiding aspect is subdivided into four hypotheses. The first one estimates the most important reasons in the geographical circumstances, confronted with the hegemonic ambitions of Russia and the containment policy of the US towards Iran at the same time. The second hypothesis refers to the second aspect of the main question and tells that there are more problems in the gas trade with Russia the more Turkmenistan develops an

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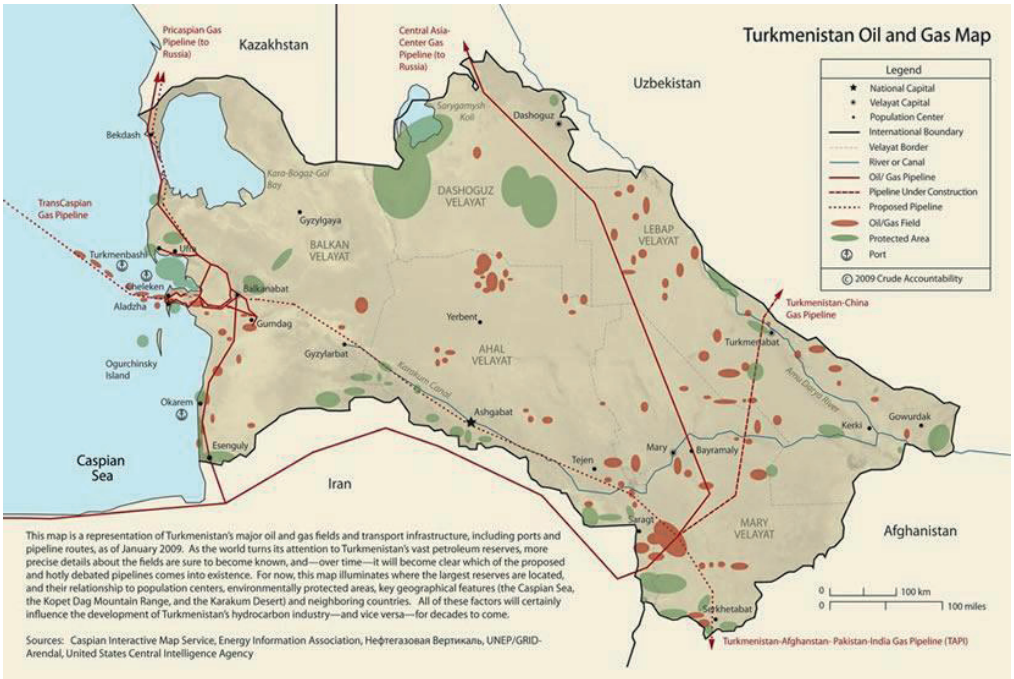
interest in exploring new markets in Turkey and Europe (Schulz 2018: 29). His third hypothesis refers to the lack of interest of cooperation from Azerbaijan, because Baku seems to be focused on its own export projects to Europe, concerning the increased importance of natural gas for this country in the last years. Finally, the fourth hypothesis indicates the Turkmenian evolution towards China, which makes development with the West impossible at the same time (Schulz 2018: 30). In consequence of the few monographs about the country, Schulz' thesis is mainly based on case studies, articles, and chapters from overview books about the Caspian Region (Schulz 2018: 23-27).

Graph no. 1 Overview of Oil and Gas in Turkmenistan



Source: EnergyPedia 2010,
https://www.energy-pedia.com/news/turkmenistan/cnpc-and-petrofac-win-gas-field-contract (access: 30.12.2017)

Natural gas as a key issue for Turkmenistan

Placing focus on the terms of analysis, the author defines energy security for Turkmenistan as the diversification of market areas, export routes, energy production, and the further processing of resources, for instance through petrochemical production (Schulz 2018: 57). The second chapter provides detailed statistics and data about the development of the Turkmenian natural gas production, infrastructure, and market demand on the regional and international level (Schulz 2018: 115-168). After summarizing also the investment potential of the country, the third chapter continues with a descriptive presentation of the Turkmenian gas trade since independence in 1991 (Schulz 2018: 169-232). An intermediate result shows already the importance of diversification as a paradigm of national energy policy concerning the stability of political power (Schulz 2018: 231).

Geopolitics through pipelines

With an analytical approach, chapter four estimates the reasons for the failure of the Turkmenistan-Iran-Turkey-Europe-pipeline project (TITE) as well as for both Trans-Caspian pipelines (Schulz 2018: 233-374). For TITE, the author sees the challenges which prevented the pipeline's construction in the resistance of the US against the project and the ambitions of Iran (Schulz 2018: 253-257). Instead, Trans-Caspian pipeline I was supported by the US, but blocked by Russia and Iran. Pipeline project II had support from the European Union as a component supplier of the Nabucco-project in the Southern Gas Corridor, but was opposed by Moscow (Schulz 2018: I 280-294, II 352-367). In general, the neighbour states of Turkmenistan have no interest in supporting Turkmenian export ambitions because of their own natural gas reserves. Afghanistan is an exception, but considering the issues of security and stability is not a preferable option for optimized export revenues (Schulz 2018: 368-375).

An additional benefit of this chapter is the comparable presentation of stakeholders' interests and their causes. Following this method, the author shows that, for instance, Russia is taking efforts to retain regional hegemony by controlling the export routes and directions. The unsettled legal status of the Caspian Sea is used by Russian politicians to preclude exports outside of their own transit zones (Schulz 2018: 265-267). The US is still trying to outline a containment strategy for Russian influence in the post-Soviet and Central Asian space and isolate regional energy cooperation with Iran (Schulz 2018: 267-269). China has a general interest in enlargement and diversification of its own natural gas imports and has tried to take a neutral position, wherever possible, for example in the case of Trans-Caspian pipeline II (Schulz 2018: 145, 153). Azerbaijan and Turkmenistan have some disagreements about their common Sea border, and Baku sees no reason for allowing Turkmenian gas exports through Azerbaijan – but is ready to negotiate in general questions concerning transit possibilities to Europe (Schulz 2018: 301, 347-351). All this shows that the diversification of Turkmenian exports to Iran and China are actually the central prospects for the development of a foreign trade infrastructure.

Conclusion

In the end, the four hypotheses underlying the guiding question will be approved. The summary of explanations, therefore (Schulz 2018: 381-386), is followed by some policy recommendations for the different stakeholders. The author considers the European Union should respect the interests of Russia and integrate Moscow into negotiations about future pipeline projects in the Caspian Region (Schulz 2018: 386-389). A possible scenario for future development of cooperation is seen in the connection of Azerbaijanian and Turkmenian offshore platforms in the Caspian Sea (Schulz 2018: 387). The role of Iran as exporter of natural gas in the context of ongoing US sanctions and high interior energy consumption is appraised critically. However, the export of Turkmenian gas to Iran and transformation to LNG is not excluded for the valorisation of European and Asian gas markets for Ashgabat (Schulz 2018: 388). The strategic question here is to establish an agreement between Turkmenistan and Iran about LNG

exportation to Europe, but as the author concludes, Turkmenistan prefers export to China under the current conditions (Schulz 2018: 389). As Hamid Reza Araki, director of the national Iranian gas company NIGC declared at the end of October 2017, Iran will not allow Turkmenian gas exports to Turkey. Finally, Turkmenistan is considered to continue the diversification of its export structure and the national economy as a whole, especially in the sectors of petrochemical industry and power generation.

Maybe the most important benefit of this publication can be seen in the focus on the interconnection between energy and geopolitics on the one hand and the global importance of the Caspian Region in the sector of natural gas on the other hand. Hopefully, there will follow other works about the perspectives of the other Central Asian states as important providers in the global market of fossil fuels to the East and the West.

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