SMART METERING AS AN INSTRUMENT SHAPING ENERGY CONSUMERS' BEHAVIOURS

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Abstract

The power system in Europe is presently experiencing a period of serious changes. Technological progress allows the consumer's role to change from being a passive customer into being an active market participant consciously managing their energy consumption and generation of energy based on microgeneration devices. Therefore, concepts arise for a new model of energy system operation, assuming the growing role of the consumer. Therefore the purpose of the article is to present the current state of knowledge about selected empirical and theoretical aspects related to the concept of "smart meters" and their importance for solving sustainable development problems. In addition, the article will attempt to answer the following research questions how can smart meters contribute to changed consumers' behaviours, and if smart metering can affect the development of the prosumer-based power industry? The basic research method used in the article is an analysis of the subject literature and the available statistical data.

Key words: Smart Metering, prosumer, Smart Grid, energy, consumers behaviour

Introduction

The beginning of the 21st century is a period when numerous countries face a huge challenge of satisfying the growing energy needs, at the same time meeting the requirements related to protection of the environment. Climate change is a fact and affects many spheres of life. It is beyond doubt that climate change mitigation by CO2 emission reduction leads to a new economic and political transformation worldwide. Therefore, new challenges appear related to more effective generation, transmission and use of electric energy. The intensity of seeking more effective energy production capacities triggers the fundamental need for transformation of economies in many countries in the world in a manner allowing development of innovative technologies. The observation of trends suggests that today a simple continuation of the current development directions with regard to the energy infrastructure that guarantees energy security becomes highly insufficient (ATKEARNEY, 2012).

The power system in Europe is presently experiencing a period of serious changes. The most important goals of these transformations are: development towards a common energy market, improvement of cross-border transmission capacity allocation flows, efficiently operating and competitive wholesale markets as well as growth in energy effectiveness and importance of demand management. On the other hand, in Europe, as well as around the world, it is possible to observe a significant growth in investment in renewable energy sources and rapid development of mobility – associated with the use of electric cars (MATUSIAK, 2016).

In July 2015, the European Commission initiated the process of public consultations on the new energy market structure. The questions asked in the mentioned document clearly indicate that the energy market in Europe has changed and still continues to dynamically change to a substantial degree. Energy consumer and prosumer have become key market participants, while local energy production and consumption management becomes necessary to improve the energy system and increase the performance of the grid and achieve high energy efficiency (MATUSIAK, 2016).

Technological progress allows the consumer's role to change from being a passive customer into being an active market participant consciously managing their energy consumption and generation of energy based on microgeneration devices. Therefore, concepts arise for a new model of energy system operation, assuming the growing role of the consumer. The consumer becomes a more and more active market participant, which is happening, among other things, because of the consumer's involvement in generation of electric power for their own needs, with the possibility of selling any generated energy surplus to external entities (ATKEARNEY, 2012). A result of microgeneration development and the growing number of prosumers is, on the one hand, the process of pushing out the system energy entities based on fossil fuels from the system, and, on the other hand, reduction in the demand for electric energy, resulting from

covering the demands partly by the prosumers themselves (KIELERZ, 2015). Also new, so far not found on a mass scale, functions streamlining and economizing our daily life are being activated, which, as a consequence, lead to the necessary expansion of the power grid (at the level of distribution and transmission) and the home grid with highly specialized elements and smart systems (ATKEARNEY, 2012).

Smart grids (Smart Grid SG) – their construction and development are necessary in order to satisfy the needs of the industry and the economy, but also the requirements of the new European policy: climate policy, environmental protection and social expectations. Smart Grid incorporates the strategic, comprehensive and complex approach attribute, one of the elements of which is smart metering. Smart Grid is planning and implementing actions that refer to all the energy market participants, at each level of their participation in the market. An intelligent metering system strengthens energy market competitiveness – strengthens the end customer's position, restricts the monopolistic position of energy companies and gives opportunities for new entities to act on the market (KIELERZ, 2015).

The level of development of the solutions and the condition of the infrastructure allowing the potential of intelligent grids to be utilized are advanced in the countries of Western Europe, USA or Japan. In Poland, projects related to installation of smart metering have only just started, as the basis for introducing new energy consumption control systems. These systems must be dedicated to the end consumer's needs, as he or she is the main participant of the future energy market (PAMUŁA, 2013).

Material and methods

The purpose of the article is to present the current state of knowledge about selected empirical and theoretical aspects related to the concept of "smart meters" and their importance for solving sustainable development problems. In addition, the article will attempt to answer the following research questions:

1. How can smart meters contribute to changed consumers' behaviours?
2. Can smart metering affect the development of the prosumer-based power industry?

The benefits that consumers can obtain as a result of using smart meters will be analysed in the article. Potential benefits depend on the implemented functionalities, and these functions should be assessed in terms of changes in social practices. The basic research method used in the article is an analysis of the subject literature and the available statistical data.

Smart metering as a precondition for the implementation of smart energy grids

The notion of smart energy grids, or smart metering systems, has not been legally defined itself, but it is assumed that smart grids are technical and organizational solutions, thanks to which it is possible for all participants of the energy market to communicate among themselves in order to provide energy services at as low cost as possible and as efficiently as possible as well as integrate scattered energy sources, including those related to RES (renewable energy sources) (BARTCZAK, 2016). SG does not have an internationally accepted definition of this notion. In the USA, SG is defined as transformations of the energy system from a centralized system, based on system-wide producers, to a decentralized system, where an active consumer plays a big role, as a result of using ICT (*Information and Communication Technology)* on a large scale (COLL-MAYOR, et al., 2007; U.S. DEPARTMENT OF ENERGY, 2010). On the other hand, in Europe, SG applies primarily to development and effective incorporation of distributed generation devices to the power system, on a so far unprecedented scale (COLL-MAYOR, et al., 2007; DIRECTORATE-GENERAL FOR RESEARCH, 2006). On both continents, however, the need to develop and implement the idea of SG has been confirmed in order to meet contemporary requirements for the power sector (KOWALSKA-PYZALSKA, 2011).

In the broad meaning, smart power grids are the whole energy grid, starting from energy generation, through the transmission and distribution infrastructure, to all categories of energy consumers (households, commerce, industry) (WOSZCZYK, 2010). Smart grid incorporates the strategic, comprehensive and complex approach attribute, it is about planning and implementing actions that refer to all the energy market participants, at each level of their participation in the market (KIELERZ, 2012).

One of the pillars of implementing the SG philosophy is common introduction of a modern metering infrastructure (Smart Metering) on the side of energy consumers, which will allow mutual connection and communication between companies producing, transmitting, distributing energy and its consumers in an IT system. Communication and connection will allow all the entities to access important, from their point of view, information, permitting the consumed energy to be better managed (ELŻANOWSKI, 2010).

The present system, to a large extent based on inductive meters, does not give sufficient information both to energy consumers and the other energy market participants. AMRs (*Automated Meter Reading),* that is, automated one-way meter readings, are also not sufficient. At present, attention is paid to the use of AMI systems *(Advanced Metering Infrastructure)* incorporating, among others, telecommunication systems, smart information, prognostic and decision-making algorithms. Thanks to

them, the metering data related to the energy consumed by particular devices can be transferred as a function of time (KOWALSKA-PYZALSKA, 2011).

An intelligent metering system is equally important for a municipal customer and for a large industry one. It leads to making most rational, economically justified decisions. It is one of the best tools to reduce electric energy consumption (KIELERZ, 2012). As shown in Table 1, electronic meters, as compared to traditional ones, are much more functional and more advanced by design. In this way, they can become more useful both for energy distribution operators and end consumers of electric energy. What differentiates smart meters from traditional ones is the possible two-way communication between them and the whole system. At the same time, this communication takes place both between the end devices, namely those that are located in the apartments of particular electric energy consumers, and meters placed in buildings, as well as between these meters and devices enabling collection and processing of diverse data and information (BARTCZAK, 2016).

Table 1. Comparison of a traditional meter and a smart meter.

Traditional meter	Electronic meter
Design stability over time, small number of modifications	High design variability
Easy installation, so it is difficult to make a mistake	Difficult installation, in which a mistake can be made easily
Energy taken from the electric energy grid, usually 2W power	Energy taken from the grid plus possible battery power
Uncertainty from class 0.2 or worse	Uncertainty class 0.1, and even better
The meter measures only active energy	The meter measures a number of various parameters
Remote readout not possible	Full remote readout, possibility to make remote changes in measurement parameters and two-way communication
Possibility of making correct measurements only in the electric energy grid and without distorted voltage and current	Correct operation for any shapes of voltages and currents
Cheap design	Simple versions very cheap, while meters with communication features are substantially more expensive than traditional meters

Source: (BARTCZAK, 2016).

The application of smart metering makes it possible to (MIROWSKI, PEPŁOWSKA, 2016):

- increase measurement precision by thickening the readout frequency, which is important mainly for the distribution system operator (DSO),
- obtain information about the daily consumption of electric energy by the analysis of daily electricity consumption in a household,
- obtain information about the household zone in which the highest consumption is observed, by analysis of electric power consumption in a specific zone,
- increase savings in a household by analysis of energy receivers' working time.

The smart meter infrastructure is only the starting point for using their functionalities in future smart grids. SG must therefore have new, relative to traditional grids, properties, such as: energy management, high flexibility in responding to the changing customer needs, the same rights for all energy market participants, reliability and ensured safety and quality of deliveries, easy and fast way of connecting subsequent users, including producers of energy from renewable sources (PAMUŁA, PAPIŃSKA-KACPEREK, 2012). W As a result, the usability of smart grids in the electric power system involves (BOREK, 2015):

- higher activity of energy consumers, who have the possibility not only to control, but also manage consumption and generation of electric energy; thanks to mobile applications, consumers can control their current energy consumption, and, in consequence, effectively manage it;
- improved quality of deliveries, resulting from the possibility of monitoring the entire energy system; thanks to devices based on smart grid solutions, in the event of a failure, a message about necessary intervention is remotely sent to the operator, contributing to a shorter time of interruptions in electric energy supply to end consumers;
- increased security of the country's power system by ensuring access to data about energy demand in real time; demand management takes place through multi-zone tariffs and offering customers higher rates for energy at the times of the highest power consumption and lower rates when energy consumption in the system does not put it under excessive load.

Benefits from the application of smart metering

Smart Grid allows many functions and technologies to be used simultaneously. It enhances the comfort of using energy and yields savings to an individual customer as well as presents environmental and macroeconomic benefits. For an energy consumer, smart grid means active management of his or her own energy demand, which will not only reduce the electricity bill, but more importantly, in the social aspect, will also bring significant environmental benefits, because, in consequence of more rational energy management, the energy demand will decrease, and therefore, the number of newly-constructed conventional power plants will be smaller (KOPTERSKI, 2010).

Benefits from launching the process of introducing smart grids are significant for Poland and include improved efficiency in managing natural resources, greater energy independence of the state without deepening problems related to the use of coal. They form the basis for efficiency-focused education of the society and limit the risk of penalties that the European Commission may impose for exceeded emission limits. A proper combination of financial incentives and well-designed legal implementation mechanisms will assist in modernizing the energy sector and strengthen the Polish economy. First of all, improvement in the quality of electric energy and reliability of the transmission grids will contribute to higher efficiency of the industry. Secondly, consumers will be able to monitor their energy consumption and actively reduce their bills. Thirdly, the functions of smart grids will make it easy for the operators to sell Polish energy on foreign markets. In addition, in this way Poland takes actions consistent with the EU directive, which focuses attention on the possibilities for introducing smart metering systems until 2020 (KOPTERSKI, 2010).

Experience of the EU member states and IEA studies indicate that the introduction of smart metering translates into energy efficiency growth by 6-10%. Tests conducted in sixteen EU countries have proved that consumers can obtain quite substantial financial benefits by using smart electric energy meters. Clearly, they may reach as much as 81%, though in many countries this level is certainly much lower. To a great extent, it depends on the range of use of these meters and the speed of their introduction to the energy market (BARTCZAK, 2016). However, in accordance with the European Smart Metering Landscape Report – "Utilities and Consumers" USmartConsumer from November 2016 and JRC Science for Policy Report "Smart grid projects outlook 2017 – Facts, figures and trends in Europe" from 2017, the following phenomena can also be observed (ŚWIRSKI, 20117):

- in some Scandinavian countries (Finland, Estonia, etc.), we can see complete digitization, where the on-line consumption readout service and electricity bill control is common for all citizens. It is connected with advanced development of the energy market and possibility to optimize bills,
- drop in research projects and total investment in smart grid, which achieved peaks in the years 2012-2014, and then fell to as low as 50-60% of the peak values, research and pilot project outlays are falling which indirectly proves very moderate success of the first research projects,
- several really operating large-scale projects, used by millions of users or even all the citizens – especially Finland, Sweden, Estonia and recently Spain, which however shows that there is a possibility of equipping all users with smart meters and the future path towards a fully digital system,
- smaller than planned growth in the application of dynamic tariffs for individual users, pilot projects in some countries, but there is no broad promotion of the programs,
- optimistic in paper reports, but rather difficult to prove possibility of easy DSR application (demand-side response profile change e.g. under the effect of price signals or special agreements) among individual users (DSR for the so-called large consumers – large customers, is a different case and there are systems that begin to operate commonly, even in Poland.
- indirectly – poor possibilities to obtain lower electricity bills (individual consumer), which was to be the primary result of all market changes, effective markets actually operate only in Scandinavia (where potential savings are also related to relatively high consumption of energy per inhabitant)
- a significant decrease in "fashion" for smart grids and smart metering – an issue which was the most interesting research area and the purpose of many grant programs several years ago now is becoming slightly common and not as attractive marketing-wise. This shows that the effects, both for customers in the form of smaller bills and companies in the form of bigger profits, are not unambiguous. It is clearly noticeable that for the time being the metering investments are supported by the regulatory framework and by transferring costs to the customer's electricity bill and not by direct profits for both sides: consumer – supplier.

Other benefits resulting from smart grids and at the same time smart metering are also stressed in the subject literature. These benefits in the functional, utility, educational and environmental aspects are presented in Table 2.

Table 2. Benefits from using smart electric energy meters in functional, utility, educational and environmental protection aspects.

Functional aspect	Utility aspect	Educational aspect	Aspect related to environmental protection
Enabling electric energy consumers, by obtaining access to current information concerning consumption and costs of this energy, to make decisions about using cheaper tariffs or restricting energy consumption at those times when it is more expensive	Customer's possibility to track information concerning the household devices that consume most energy	Legible data from the reader will allow customers to easily compare tariffs of particular energy vendors	Thanks to rational energy management by particular customers, it is possible to use this energy more effectively, and therefore reduce carbon dioxide emission to the atmosphere as well as reduce unfavourable climate changes
Constant and continuous exchange of information between the electric energy consumer and vendor	The meter can be read without the need for the customer's presence at home	The operation of smart meters contributes to changes in customers' habits and makes them expand knowledge about what to do to generate savings and limit electric energy expenses	
Adaptation of the terms of sale to individual consumption profiles of the consumers			
Quicker course of the procedures related to change of the vendor			

Source: (BARTCZAK, 2016).

The other benefits from using smart metering still include improved safety and reliability of the power system, which is possible as a result of significant reduction in pauses in supply, being a consequence of continuous supply of information about the energy consumed by smart meters. In addition, the application of these meters makes the power grid become fully (BARTCZAK, 2016):

- observable (by the metering system),
- controlled,
- automated,
- integrated with the already existing systems.

It is also necessary to add that the benefits related to the use of smart metering also include high complexity and innovation. At the same time, these benefits include practically all the profits which are noticeable for the meters in which the reading is made manually and by AMR (BARTCZAK, 2016).

Effect of the application of smart metering on the development of prosumer power industry

In Europe, the increasing social well-being of the majority of the population has caused change in the consumption model of the households, which currently goes beyond providing for the basic needs, in the case of some products and services outside the boundaries of necessary usability, and often also outside the boundaries of the environmental sustainability. Consumption models of the households are shaped by a number of economic, social, cultural and political factors. In Europe the most important of them include: growing income and greater wealth, globalization of the world economy along with opening of the markets, growing individualization of the society, new technologies, marketing and advertising activities, smaller size of the households and, in some regions, aging population. The present changes in the consumption model result in intensified adverse impacts on the environment, as expenses move to categories with a more intensive effect (for instance transport and energy consumption in households). In these two fields, the potential limitation of the impact resulting from technical progress is eliminated by growing consumption (SŁUPIK, 2011).

Prosumer power industry is an answer to the challenges of the future faced by contemporary energy markets, as it will contribute to the increased electric energy supply and supplement heavily geographically diverse locations of generation devices. This will also contribute to the growing awareness of energy consumers, who will transform from customers into aware prosumers, effectively using environmental resources. However, effective prosumer power industry requires IT systems to be introduced to supervise, manage and monitor operation of the system and its cooperation with the nearest environment, including with the energy infrastructure (CASINI, 2014; MORENO et al., 2014, WÓJCICKI, 2015).

Electric energy consumption structure is determined by many factors. The most important ones are economic considerations. The level of electric energy rates is a significant premise for all the decisions made by the consumer. In addition, the awareness concerning global processes and the effect on the condition of the natural environment may affect the propensity of consumers to take actions that are intended to protect the environment, or more broadly ensure sustainable economic development. However, a factor having huge importance, contributing to the greater awareness of customers with regard to possible methods of reducing energy consumption and obtaining cost savings related to this consumption, is the feedback they obtain. The conducted research in different countries, also in Poland, show that customers do not have sufficient information about how much and how they consume electric energy, but also how they can reduce this consumption. Simultaneously, they do not have information what is the cost of energy they consume, with breakdown into consumption times and the type of devices used. Delivery of such information to the consumers will allow them to understand these processes and possibly change behaviours (WROCŁAWSKI, ZAJDLER, 2008; EURO CENTRUM, 2018).

Smart energy grids enable to control the amount of power used, and the installation of smart meters can be described as the first important step towards rational electric energy consumption in households and various types of companies. Detailed information on the electric energy consumption profile obtained by the customers encourages them to use energy more rationally and increases their motivation for saving, which is reflected in reduced amounts of the electricity bills.

When integrating devices and systems used by individual consumers with the smart grid, three main areas of using appropriate technologies can be distinguished (PAMUŁA, 2013):

- used by household consumers – technologies intended mainly to control and manage the installed devices and partly to aggregate and transmit data outside,
- used for integrating the household with the smart grid – technologies intended mainly for connecting households into clusters and connecting them to the electric power grid, allowing exchange of information and monitoring, but also offering the possibility to take over control over the actions taken,
- used for integrating household clusters with service suppliers (energy distributors, intermediaries between groups of energy suppliers and consumers) – technologies designed for combining information generated by the household with the services offered by the supplier, allowing infrastructure monitoring and management as well as equipped with automatic decision support systems for the adopted strategies.

Smart meters allow permanent and continuous exchange of information between the energy consumer and vendor in near-real time by transmission of data from the device. Modern meters also create the possibility to transfer feedback to the customer, e.g. concerning the current energy price, but also offer complete information on its use to the customers in an available, clear manner. All this makes it possible to adjust the consumption level of power to its current price and the financial situation of the family, and further – ensure more effective energy consumption by the household (PAWŁOWSKI, 2012).

In the report about the Polish energy market and Poles' energy awareness (prepared by PTWP Group in cooperation with URE (Energy Regulatory Office) and TNS OBOP) from 2012, the vast majority of the surveyed, as much as 87 percent, claim that they try to save energy in their households (for comparison, in the recent edition of the TNS study concerning environmental awareness and behaviours among the inhabitants of Poland from 2014 as much as 96% of Poles declared energy saving). The primary energy saving motive among Poles is the desire to minimize charges, and not care for protection of natural resources or the environment. 71 percent of the surveyed directly declare that by saving energy, they try to reduce their electricity bills. The most popular way of saving energy among Poles is to switch off unnecessary lighting (67 percent). Quite often we replace light bulbs with energy-saving ones (52 percent). Slightly less than a half of the surveyed (40 percent) try to buy energy-saving household equipment, e.g. household appliances, radio and TV devices, and seal windows (42 percent). Approximately one third of the surveyed are supporters of the methods such as: switching the washing machine on only after filling the drum, not leaving chargers e.g. for phones, computers in wall sockets, thermal modernization of buildings, avoiding standby mode in household appliances. The issue raising concerns here is that only 9 percent of the surveyed answered that they use economic energy tariffs. This calls into question the previous declarations, because it shows that although in theory we know the energy saving methods well and declare that we follow them, only a fraction of the surveyed has taken the trouble to change the tariff to a more flexible one (TNS, 2014).

The installation of smart metering devices and the new technological infrastructure for handling smart grids is the turning point in the customer's contacts with the energy supplier. Two-way communication and the changed method of preparing the bills, from a forecast made on the basis of monthly readings into the real-time consumption reading, paves the way for completely new interactions of the

energy supplier with the customers. The possibility of combining data from smart device measurements with data from other sources about the customer (offer selection methods, behaviours related to the attitude towards effective energy use programs, response to different motivation methods) will deliver information to the distributors not only about how customers use electricity, but, more importantly, why they behave in the particular way (PAMUŁA, 2013).

Changes occurring on the energy market are simultaneously an impulse for developing new technologies at various points in the value chain. Particularly important are new technologies concerning smart grids and distributed generation. The development of distributed generation devices gives the consumers the possibility to generate electricity and adopt the role of prosumers. Prosumers will be able to produce electric energy to satisfy not only their own needs, but, in specific situations, to sell the surplus. New technologies also foster development of demand response management services and use of the aggregated demand response potential to offer a system service in order to support power system management.

The positive impact of electric energy generation by consumers on the development of smart measurement systems and smart energy grids involves the obligation to adjust the measurement systems to the needs of simultaneous energy collection and generation, imposed on the grid enterprises. When connecting a micro-source to the grid, the distribution network operator is obliged to modernize and adjust the connection to the needs of such operations, this involves the need to replace the meter and creates a natural opportunity to apply a more modern, more effective and more convenient smart meter, which will be useful both for the prosumer and the grid operator. The prosumer will be one of the entities most actively using new opportunities created by smart power grids, and therefore using the services provided by the data communication sector. The development of prosumption will be directly translated into the use of the most advanced data communication tools to manage electric energy generation and consumption in households as well as remote control of the whole home electrical grid (IZBICKI, 2014).

Solutions used as part of HAN (Home Area Network) may be helpful in electric energy management both to prosumers and other consumers. A home area network (HAN) can be defined as a set of devices installed in the house, mutually communicating with one another, used, among others, to manage electric energy consumption. HAN includes devices or applications used to manage electric energy consumption, active household devices, devices used for household electric energy production (scattered generation) and devices enabling communication inside the network and with other networks, in particular the AMI network. HAN allows the scope of smart grids in households to be extended beyond smart meters and energy management solutions to be built. The implementation of HAN indispensably requires the consumers' involvement. The key benefits from implementation are achieved thanks to changes in the consumers' habits with regard to electricity consumption methods and the related peak power demand. The data transferred to the consumers by the electric energy operators have a huge effect on the characteristics of energy consumption. The customers expect transparent information to be received about their own consumption profile and the resulting costs. The commonly applied system of invoices issued on the basis of forecasts often does not meet these expectations – the invoices happen to be overestimated or understated, and the confused customers lose trust in energy suppliers. In turn, the application of smart metering devices makes it possible to conduct energy settlements over short periods and on the basis of the actual consumption (EURO CENTRUM, 2018).

Summary

Considering the above, it should be stated that smart meters may significantly contribute to optimized energy consumption, namely compensate for the differences between the peak and non-peak power demand. The greatest advantage of smart meters is the path opened for launching the prosumer market, namely one in which the current energy consumer may also periodically become an energy producer. Smart metering devices have new functionalities allowing communication with the supplier and enable an immediate response to price signals as well as make it easier to control the power consuming devices. At the same time, the data gathered and collected in measurement systems offer new opportunities for running studies of customer behaviours, allowing the distributors to prepare attractive programs for effective energy use and to better adjust the offers and the services to a particular customer. Vast data collections from smart devices will allow for much more than just a detailed definition of the customer's behaviours. The installation of smart meters is thus the first step to achieve benefits from the transition from the central energy management system to the system of smart networks.

References

ATKEARNEY, 2012. *Infrastruktura Sieci Domowej (ISD) w ramach Inteligentnych Sieci (HAN within Smart Grids). Raport podsumowujący.* http://www.kigeit.org.pl/FTP/PRCIP/Literatura/025_Raport_2012_ATK_Regulacyjny.pdf (access 10.08.2018).

BARTCZAK, K. 2016. *Analiza korzyści i zagrożeń związanych ze stosowaniem w Polsce inteligentnych liczników energii elektrycznej (Smart energy meters – analysis of advantages and risks accompanying in introduction these devices in Poland*). Przegląd Elektrotechniczny, 01.

BOREK, A. 2015. *Korzyści konsumentów i systemu elektroenergetycznego z zastosowania inteligentnych sieci typu SMART GRID na rynku energii w Polsce (Energy Market – benefits of applications smart grids for consumer and energy system).* Studia i materiały Instytutu Transportu i Handlu Morskiego Uniwersytetu Gdańskiego, 12.

CASINI, M. 2014. *Internet of Things for energy efficiency of buildings*. International Scientific Journal Architecture and Engineering, 2.

COLL-MAYOR, D., PAGET, M., LIGHTNER, E. 2007. *Future intelligent power grids: Analysis of the vision in the European Union and the United States*. Energy Policy, 35: 2453–2465.

DIRECTORATE-GENERAL FOR RESEARCH – Sustainable Energy Systems, *European Smartgrids Technology Platform: Vision and strategy for Europe's electricity networks of the future*, 2006, http://www.smartgrids.eu (access 10.08.2018).

ELŻANOWSKI, F.M. 2010. *Smart grids i smart metering w procesie inwestycyjnym*. In: M. Cherka, F.M. Elżanowski, M. Swora, K. Wąsowski, *Energetyka i ochrona środowiska w procesie inwestycyjnym*, Warszawa, p. 18.

EURO CENTRUM Park Nukowo-Technologiczny, 2018. *Rynek inteligentnych sieci energetycznych w Polsce*. (*The market of smart energy networks in Poland)* http://pnt.euro-centrum.com.pl/files/post/830/Rynek-inteligentnych-sieci-energetycznych-w-Polsce.pdf (access 10.08.2018).

IZBICKI, M. 2014. Inteligentne sieci elektroenergetyczne oraz „presumpcja" jako elementy kształtujące społeczeństwo informacyjne *(Intelligent electricity grids and "presumptions" as elements shaping the information society).* In: P.A. Nowak (ed.) Innowacje 2014. Innowacyjne działania w ICT.

KIELERZ, A. 2012. *Elementy inteligentnych sieci energetycznych – Smart Grid Ready (Elements of intelligent power grids - Smart Grid Ready*). Agencja Rozwoju Przemysłu, http://www.ptzp.org.pl/files/konferencje/kzz/artyk_pdf_2012/p014.pdf (access 10.08.2018).

KIELERZ, A. 2015. *Smart Grid a stabilna praca systemu elektroenergetycznego przy wzroście produkcji energii w różnych jej źródłach (Smart Grid and sustainable electricity system with power production increase from various energy sources).* Materiały XXIX Konferencji z cyklu Zagadnienia surowców energetycznych i energii w gospodarce krajowej, Zakopane, https://se.min-pan.krakow.pl/pelne_teksty29/k29_mk_z/k29mk_kielerz_z.pdf (access 10.08.2019).

KOPTERSKI, W. 2010. *Smart Grid – sieć przyszłości (Smart Grid – network of the future).* Pomiary Automatyka Robotyka, 12.

KOWALSKA-PYZALSKA, A. 2011. K*oncepcja smart grid szansą dla rozwoju generacji rozproszonej (Smart grid as a chance for distributed generation*). Prace Naukowe Instytutu Maszyn, Napędów i Pomiarów Elektrycznych Politechniki Wrocławskiej, 65, Studia i Materiały, 31.

MATUSIAK, B.E. 2016. *Zarządzanie wymianą energii w inteligentnym sąsiedztwie- model biznesowy* (*Energy exchange management in an intelligent neighbourhood- business model).* Rynek Energii, 1(122).

MIROWSKI, T., PEPŁOWSKA, M. 2016. *Analiza symulacyjna zużycia energii elektrycznej u odbiorcy końcowego z wykorzystaniem inteligentnego opomiarowania (Simulation analysis of electricity consumption for the final consumer with the use of smart metering*). Polityka Energetyczna – Energy Policy Journal, 19(2): 81–92.

MORENO, V. UBEDA, B., SKARMETA, A., ZAMORA, M. 2014. *How can we tackle energy efficiency in IoT based smart buildings*. Sensors Journal, 14.

PAMUŁA, A., 2013. *Inteligentne sieci elektroenergetyczne – uwarunkowania rozwoju dla grupy klientów indywidualnych (Smart Grids requirements deployment for residential customers*). Nierówności Społeczne a Wzrost Gospodarczy, 36.

PAMUŁA, A., PAPIŃSKA-KACPEREK, J. 2012. *Inteligentne domy i inteligentne sieci energetyczne jako elementy infrastruktury smart city (Smart homes and smart grid as a smart city infrastructure*) Zeszyty Naukowe Uniwersytetu Szczecińskiego, 721, Studia Informatica, 29.

PAWŁOWSKI, SZ. 2012. *Inteligentny licznik prądu ma zmusić do ekologicznego myślenia (The intelligent electricity meter is designed to make you think greener)* https://www.obserwatorfinansowy.pl/forma/rotator/inteligentny-licznik-pradu-ma-zmusic-do-ekologicznego-myslenia/ (access 10.08.2018).

SŁUPIK, S. 2011. *Kształtowanie zrównoważonej konsumpcji energii w kontekście zmian klimatycznych (Formation of energy sustainable consumption in the context of climate change*). In: M. Wachowiak, D. Kiełczewskiego, H. Diefenbacher (eds.) Zrównoważona konsumpcja. Rozwój zachowań konsumentów w Polsce i w Niemczech, FEST, Heidelberg.

ŚWIRSKI, K. 2017. *Inteligentne liczniki w warunkach polskich i europejskich. Mniej innowacji a więcej zarobku dla prawników (Intelligent meters in Polish and European conditions. Less innovation and more income for lawyers)* http://konradswirski.blog.tt.com.pl/inteligentne-liczniki-warunkach-polskich-europejskich-innowacji-a-wiecej-zarobku-dla-prawnikow/ (access 10.08.2018).

TNS 2014. *Badanie świadomości i zachowań mieszkańców Polski, badanie trackingowe (Study of awareness and behavior of Polish residents, tracking research*). Raport TNS Polska dla Ministra Środowiska.

U.S. DEPARTMENT OF ENERGY 2010. National Energy Technology Laboratory, *Understanding the benefits of the Smart Grid*, 18 June 2010.

WOSZCZYK, B. 2010. *W kierunku nowej energetyki (Towards a new energy industry*). Polska Energia, 12.

WÓJCICKI, R. 2015. *Internet Rzeczy jako narzędzie wspomagające poprawę efektywności energetycznej w fotowoltaicznych instalacjach prosumenckich (The Internet of things in energy management systems for residential prosumers*). Napędy i sterowanie, 11.

WROCŁAWSKI, M., ZAJDLER, R. 2008, *Raport 4. Analiza wpływu na otoczenie społeczno-gospodarcze przedsięwzięcia (Analysis of the impact on the socio-economic environment of the enterprises).* Urząd Regulacji Energetyki, p. 45-46.