Research Article

Jarosław Kowalski*, Bożena Ewa Matusiak*

End users' motivations as a key for the adoption of the home energy management system

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Abstract: Development of renewable energy means that there is a growing demand for technology that helps to manage and consume it in an optimal way, using more energy when it is produced on sunny/windy days, preferably at the place of production, and avoiding long-distance transmission. This opens the field for solutions based on the Internet of Things (IoT) technologies, advanced demand management, and the concept of smart energy. The creation of a smart home energy management system (HEMS), which will help end users to manage the produced electricity, was the goal of the project entitled "e-balance – Balancing Energy Production and Consumption in Energy Efficient Smart Neighbourhoods". Research with potential users carried out within the project showed that the existence of such systems in the home environment redefines the concept of electricity, which becomes tangible and always present in sight. Users also expected that the system would significantly reduce their electricity bills, an expectation which is not always confirmed by economic simulations. This means that the final solution will have to take account of other types of motivation and engagement, e.g., environmental ones. The paper presents conclusions from quantitative and qualitative research conducted within the "e-balance" project in Poland, Portugal, and the Netherlands.

Keywords: Internet of Things, smart city, smart energy, energy flexibility, user motivation research JEL **Classification:** O310, Q420

1 Motivation and research methods

This paper presents the results of research performed mainly by the University of Łódź team and the National Information Processing Institute (NIPI) team, which has aimed to identify the needs and responses of the system participants and to design a business model for a new system referred to as "e-balance". It focused on managing energy efficiency and was implemented under Smartcities 2013 (FP7), a European Union (EU) research project prepared with researchers from all over Europe. As a result of the project, which stretched over 4 years (2013–2017), a system prototype was developed. It was implemented under a pilot project in the Netherlands and involved a range of pricing simulations and social studies performed among the potential future participants of the system. The project and the system itself represent an example of Internet of Things (IoT) applications and are in line with the smart grid (SG) development for the purpose of energy management in various regions, cities, and even within the national grid, which is possible thanks to a fractal approach to its development.

***Corresponding author: Jarosław Kowalski,** National Information Processing Institute, Warsaw, Poland,
E-mail: jkowalski@opi.org.pl **and Bożena Ewa Matusiak,** Computer Science Department, University of Łódź, Łodź, Poland,
E-mail: bozena.matusiak@uni.lodz.pl

In this paper, quantitative and qualitative studies and their results have been described and presented in brief. The main research questions were as follows:
- To what extent does a safer and more stable energy grid and an absence of outages provide a motivation for end users to install a home energy management system (HEMS)?
- How high the expected savings on energy bills?
- What other factors except saved money can motivate users to install an HEMS?

To answer these above questions, a research program was conducted within a project entitled “e-balance: Balancing Energy Production and Consumption in Energy Efficient Smart Neighbourhoods”.

The research program consisted of the following elements:
1) A quantitative study with electricity consumers was conducted in May and June 2017 in three countries: Poland, Portugal, and the Netherlands. The aim of the study was to gather opinions on the perception of the energy management system concept and the attractiveness of various solutions in the designed home electricity management system. The study involved individuals aged 18–79 years, either responsible or co-responsible for paying electricity bills in the household. The total sample was random quota based and consisted of 1,660 people in Poland, 1,639 in the Netherlands, and 1,545 in Portugal. To ensure representativeness in each country, the sample structure was adjusted using analytical weights to reflect the population of each country based on gender, age, education, and region of residence. At this stage, we asked people about the detailed concept of the HEMS which was prepared during the e-balance project.
2) User tests conducted in June and July 2017 in 38 households in the town of Zutphen, the Netherlands. The aim of this part was to gather real data on usage and user experience of a prototype of the HEMS. The prototype of such a technology was installed in households which were equipped with smart washing machine that allowed users to schedule the washing cycle. By using a smart Whirlpool washing machine and a smartphone, users were able to set up a time slot where the automatic system should run the previously loaded washing machine. They could also monitor the production and consumption of electricity on a specially designed graphical user interface.
3) Qualitative study: seven individual in-depth interviews (IDIs) were conducted with people who actively used the prototype of the system. The main objective of the study was to diagnose potential barriers and factors affecting the perception of the system and its adoption. The IDI method was chosen because during the interviews in real-life scenarios, when users discuss their usage experience in natural language, researchers gain the opportunity to see the system through the users’ eyes and, in effect, better understand the social context of using HEMS. Also, individual interviews allow users to better imagine and experience the consequences that the discussed system may have for their lives, which may be difficult during typical quantitative tests, i.e., concept tests.
4) Economic simulation, where the following elements were simulated for several business cases: the amount of potential income earned by grid operators/aggregators and benefits for end users. The results will be only shown to highlight the social questions about money and savings for future system users.

2 Smart cities in the era of the IoT: introduction

There are many factors that provide a foundation for the development of the idea of “smart cities”, i.e., fast progress in information and communication technology (ICT) development, new application options in various economic and social spheres, the idea of sustainable development, and the never-ending need to implement changes in order to improve social life standards in a dynamic environment with Industry 4.0 [Hermann et al., 2015]. “Smart city” is a term that has been used for many years [Deakin (ed), 2014]. In general, it implies a transformation of future cities in a way that would turn them into people-friendly places in all aspects of social and economic life (smartest cities). The assumption is that residents of cities and districts would live a comfortable life based on the sustainable development idea, whereas the cost of the city-wide system with its residents would be optimized as low as possible. The concept of costs is relative and depends on the wealth of the society finally.

A smart city also means a skillfully managed city. In order to achieve that goal, a city should be supplied with systems to measure the key subsystems responsible for its operation. The relevant literature lists the following areas that are important for city life: the administration and management system, the health-care system, information flow systems, education, transport, mobility, and logistics, waste management, energy management (public lighting, heating system and energy, including renewable energy), municipal management, public space management, culture and entertainment, etc. [Stawasz et al., 2012]. This list, however, does not encompass all areas of urban life. In its report on potential areas of IoT development [Michałowski 2018], the Sobieski Institute has listed 15 such areas, emphasizing that modern technologies, including IoT and artificial intelligence (AI) in particular, can contribute to unique progress in integrated operations of systems/public management and produce the synergy development effect [Sułkowski and Kaczorowska-Spychalska, 2018]. A smart application of these aspects will translate into a higher quality of living in both cities and smaller settlements.

The top 100 smart cities ranking prepared for 2017 [Sumara, 2018] was based on 19 criteria considered to be of importance in terms of "smartness" of the current cities. Warsaw ranks 89th on the list, but no other Polish cities were included. The analysis covered 500 cities throughout the world, with Copenhagen, Singapore, and Stockholm as top performers. The assessment criteria included the use of smartphones in various spheres of city life, availability of high-speed 4G/5G Internet, transport and mobility, the use of smart systems in road traffic and parking, car rental and car sharing apps, availability of digital services for e-administration, the use of modern technologies for energy supply and consumption, availability of city cleaning systems, etc.

As mentioned earlier, the IoT in particular, alongside AI, cloud computing, and the Big Data technology, represent challenges that currently determine the direction leading to the status of real smart cities, provided that they will be implemented in specific systemic solutions, for instance, in energy supply systems, energy efficiency management systems (EEMSs) in energy clusters or energy cooperatives.

2.1 IoT and SG on the energy market

IoT or even Internet of Everything (IoT/IoE) as well as machine learning and communication machine-to-machine (M2M) increases connectivity between people and smart things at an accelerating rate in numerous markets and areas of life [Mattern and Floerkemeier, 2010]. IoT means the network of physical devices, tools, home appliances even vehicles, and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these things to connect each other and collect and exchange data between them.

According to Juniper Report [Juniper, 2016], a total of 50 billion devices/sensors/actuators are expected to be in use by 2020, with 75 billion in 2025. The idea of IoT is being developed (from 1996 and even earlier) and applied in smart appliances in cities and districts/neighborhoods to increase security, efficiency, and safety in numerous control systems and to improve energy efficiency in energy systems. In the case of households, IoT is applied for home automation and control of all household devices. In the electricity grid, it is applied to achieve better control and monitoring services and to create new services, while in business the IoT is used in new mobile services and in many other areas. Nowadays, the contemporary information society (IS), with the IoT/IoE and SG as its components, generates a growing number of data in all the abovementioned areas.

According to Vermesan and Friess [2014], "the communication issue is the most energy consuming task on devices". It is necessary to use the Big Data technology and cloud technology for new applications that have been designed specifically to introduce new market services in the IoT environment. "Most businesses are focused on getting products to market more quickly, adapting to regulatory requirements, increasing energy efficiency, and most importantly, to innovate using the IoT. Now, this possibility is available as all smart things can be visible using smartphones, smart applications, and they can communicate with one another to understand actions taken and states in online environments" [Matusiak et al., 2015].

As regards SGs in energy systems and the use of renewable energy resources (RESs) on electricity market, new innovations have been launched for numerous new services. They call for the understanding of the new digital environment with really smart devices and a new type of awareness on the part of users.

One should also explain that SGs in energy systems are based on modern sensors, intelligent meters, and dedicated devices that intercommunicate and take the operation of the grid to a new level while also improving its efficiency, reducing the cost, and integrating all energy market participants. First official definition of SG was provided by the Energy Independence and Security Act of 2007 (EISA-2007) in USA, which was approved by the US Congress in January 2007, The first step to establish such a grid in Poland would be to install smart energy consumption meters in households (the obligation to install new, smart meters in 80% of the households by 2020) and to modernize the transmission grids, particularly the ones based on 110 V voltage (Hel Peninsula – Intelligent Peninsula project, started in 2009). Subsequent stages will involve the development of new markets, cooperating systems, SG management systems, and new business models available thanks to new possibilities, such as active demand management, civic energy, sustainable development and RES development, common energy market in Europe, etc.

To conclude, the technological transformation that took place in recent years, driven by the development of Internet technologies, resulted in a fast start leading toward the so-called Industry 4.0, i.e., the fourth industrial revolution or industry digitalization of almost all spheres of human life, including the energy sector.

For this reason, applications such as the e-balance platform for balancing energy production and consumption in smart, energy-efficient neighborhoods are proposed for consideration in this paper as an innovative solution for consumers/prosumers and as an IoT application that provides smart features to household devices as well as smart services for the neighborhood and for the energy market as a whole. It is a simple modern solution for the Industry 4.0 society.

This application is an example of IoT and Big Data-based solutions to manage new services, such as energy flexibility products provided by the users on the energy market. It is a good example of a system with a prototype developed under a 2013–2017 EU project (FP7). It introduces modern IoT-based solutions to manage active demand on the energy market saturated with unstable sources (RES). It also activates prosumers, i.e., market participants that also generate energy for their own needs to achieve savings and electricity optimization and to exchange them into specific financial benefits. Importantly, such a system is currently highly desirable for local optimization of electricity consumption and generation.

In this context, several questions have to be addressed. They mainly concern the social aspect: what exactly will this system offer to people, how will people/users be integrated with the system and how can they adapt such technology and systems? Will the system be easy to understand, will it be really useful while making them delve deeper into advanced technology? What will happen when there is an interruption in Internet supply or a major failure in communication between devices/system elements?

3 Energy demand management: What is it and why do we need it?

Energy demand management, also known as demand-side management (DSM) or demand-side response (DSR) [USEF 2016; EU Commission 2016], is a method to manage demand for electrical energy. In general, under a classical approach, electrical energy used to be perceived as a commodity that can only be managed on the supply side. That meant that the supply corresponded to the level of demand at any time when a need arose. In other words, producers had to generate as much energy as was demanded at a particular moment. Since the 1970s and the Great Recession in America, incentives and programs that impacted buyer behaviors have been introduced. They aimed to change these behaviors in terms of needs, particularly during the peak hours, which ultimately induced the DSM. DSM programs are focused on savings and on reducing participants' consumption by using or encouraging the use of energy-saving devices, such as light-emitting diode (LED) bulbs, etc. They also include modern systems that help to manage demand and create new services under the umbrella of the so-called "energy flexibility", which can be supplied to a balancing market in order to reduce the generation needs during peak hours, where there is an increased demand for electricity from the national grid.

Currently, we are using numerous sources of dispersed small generation. They constitute a scattered energy market, with wind and solar farms, and hydro energy: all the new renewable energy sources offer new production capacities. At the same time, they remain unstable, and their efficiency can vary in time. As a result, in order to ensure stability of the whole production system, the demand management through active impact is necessary, particularly during peak hours.

The e-balance system has been developed to achieve this objective.

3.1 E-balance as an energy management system

The system proposed under the e-balance project (FP7 2013–2017, www.e-balance-project.eu) is aimed at managing the active side of demand. It concerns three areas of management, i.e., (i) management of electrical energy use and consumption in the household of a single prosumer, (ii) management in the neighborhood to achieve local balancing of the needs of the local community, and (iii) community participation in the delivery of products/energy flexibility services to the market in order to increase economic efficiency and stability of the electrical energy system (www.e-balance-project.eu/deliverables (D2.3, D3.1, D3.2, D4.1, D4.2)).

The objective of the project was to develop a prototype solution/platform, run a test implementation, and develop a business model proposal for a potential future commercialization. A social survey on engaging future users in the potential use of the system was also performed under this project.

The authors formulated the following key business assumptions to develop the business model for the e-balance platform: the system would operate in a smart environment, i.e., smart meters communicating with the e-balance platform tools through a dedicated customer management unit would be mounted in a single prosumer's household and in the neighboring households. Photovoltaic panels or other dispersed small generation solutions would be installed in the households or, alternatively, users would have household energy storage devices or electric cars, which would be able to accumulate energy produced for their own needs during a specific period (e.g., at night). Users would also own household equipment of the latest generation, manageable through an exchange of information and communication with the e-balance platform. The purpose of this approach is to manage the time of their operation to ensure optimum energy efficiency and flexibility management.

3.1.1 A system of benefits for prosumers

Under the research and simulation efforts, three remuneration systems for prosumers were proposed and presented to users in surveys. A theoretical simulation test was also performed for one system based on a business case developed specifically for the needs of the project. The general idea behind the e-balance platform mechanism as well as remuneration for prosumers is as follows: the system will optimize the use and consumption of electricity in the households, depending on the operating strategies adopted by prosumers, their needs, and ability to change habits. The operation of household devices will be shifted from peak hours to periods when energy can be cheaper (peak shaving). Also, short-term forecasts of energy needs and consumption will be applied to signal changes, if any, in the user's energy use profile in the short run [more details in Matusiak and Bartkiewicz, 2018].

4 Installation of the energy management system: motivating factors

During the quantitative study, the respondents were asked what would motivate them to install a smart energy management system at home. The main reason for using an SG from the engineering point of view, i.e., a safer and more stable energy grid, was a motivating factor for about a quarter of consumers from Poland and Portugal (25% each) and for one-tenth of consumers in the Netherlands (11%) (Figure 1).

These numbers show that from potential users' perspective, the SG addresses problems and challenges that will emerge in the future, once renewable energy sources become more popular.

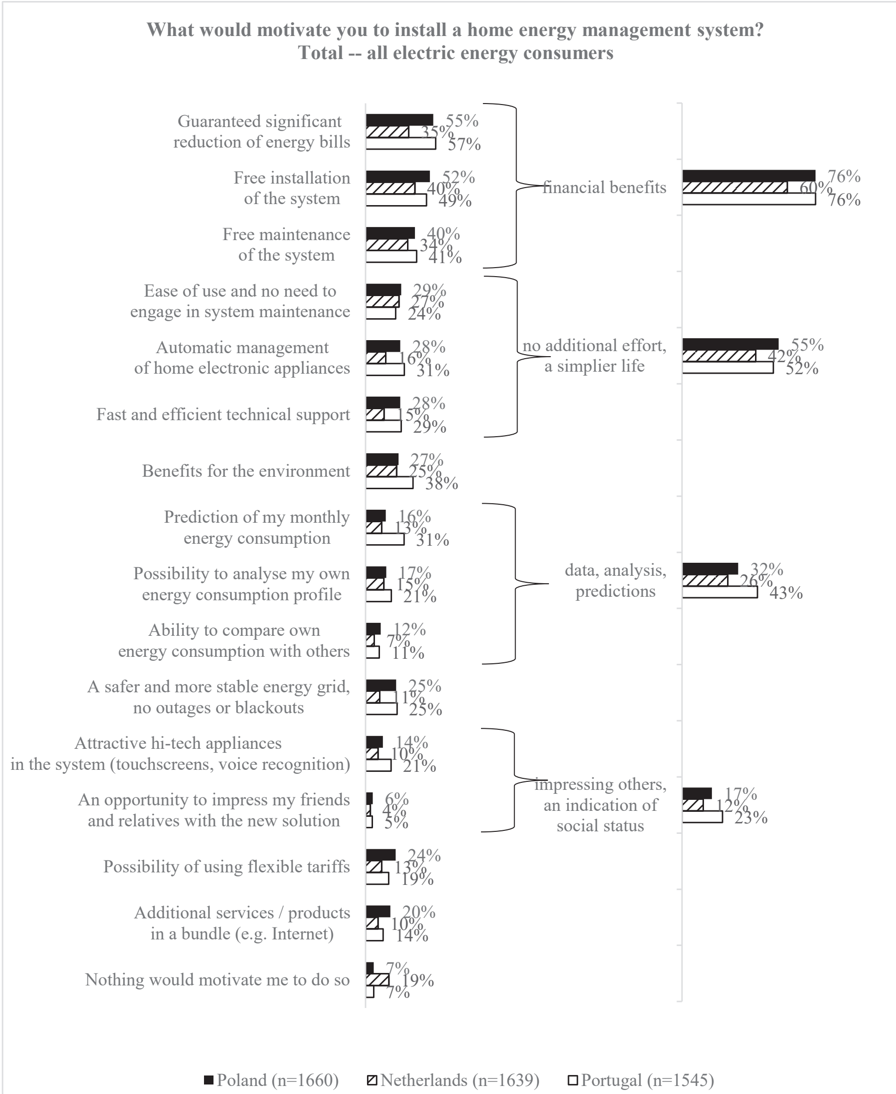

Figure 1. Motivations for installing HEMS. Base: electrical energy consumers aged 18–79 years
HEMS, home energy management system.

In each of the three countries concerned, the most motivating factors included system characteristics related to "economic aspects": guaranteed significant reduction of energy bills (indicated by 57% of consumers in Portugal, 55% in Poland, and 35% in the Netherlands); free installation of the system (49% of the respondents in Portugal, 52% in Poland, and 40% in the Netherlands) and free maintenance of the system (41% in Portugal, 40% in Poland, and 34% in the Netherlands). In total, at least one of the three aforementioned financial motivations was indicated by 76% of consumers in Portugal and Poland each and by 60% of consumers in the Netherlands. Clearly, the main expectation among potential users is related to financial benefits and no need to make major investments.

Another factor that could encourage potential users to install the system is the ease of use and no need to control the system (24% in Portugal, 27% in the Netherlands, and 29% in Poland). Consumers would also welcome automatic control of household appliances (31% in Portugal, 28% in Poland, and 16% in the Netherlands) as well as fast and efficient technical maintenance. At least one of the three above mentioned elements was indicated by 55% of the respondents in Poland, 52% in Portugal, and 42% in the Netherlands. Easy use seems to be very important because of the nature of modern life. Today, people are engaged in many activities, with many things, media, tasks, technologies, and duties competing for their time. Attention and involvement have become the most precious currency in the world of marketing. According to Harmut Rosa, we are living in an "accelerated society" [Rosa, 2015]. In these circumstances, the cognitive burden generated by new technology as well as the related new duties and responsibilities is a very important factor.

5 EMS: simplification vs. complication of life

Well, will the energy management system simplify users' lives? The answer is by no means clear. In order to gather real data on usage and user experience related to the energy management system, a prototype of such a technology was installed in a demo site in the town of Zutphen (the Netherlands). Technical tests were conducted in June and July 2017 in 38 households equipped with devices that enabled users to observe and monitor the production of electricity on photovoltaic panels (installed on the roof) and to use a smart washing machine. During the study, seven IDIs were conducted with active users of the system. The main objective of the study was to diagnose potential barriers and factors affecting the perception of the system and its adoption.

The IDI method was chosen, because when users discuss their usage experience in natural language during interviews conducted in real-life scenarios, researchers get the opportunity to see the system through users' eyes and, as a result, to get a better understanding of the social context of EMS. Also, individual interviews enable users to imagine and experience the potential consequences that the system may have for their lives, a task which may be more difficult in typical quantitative tests, such as concept tests.

From the perspective of potential users, the aforementioned system addresses problems and challenges they do not experience currently. The technological innovation in the realm of electrical energy is currently a background technology [Ihde, 1990]. Electricity is used without much reflection and is seen as abstract and elusive: it is "possessed" by electricity-operated devices. As a rule, consumers do not know how much energy their household consumes (they know more or less how much they spend, which is not the same).

The study showed that the smart energy management system redefines the concept of electrical energy. Electricity is no longer invisible and intangible: in fact, it is displayed on the graphical user interface. It turns into something that is constantly produced, consumed, and visible in the household, something like a homemade cake that household members can create at home and then watch it gradually disappear. In the new paradigm, electricity becomes a product that household members can trade in, e.g., sell back to the grid, store, or consume on their own. It involves a whole range of potential decisions that can generate a cognitive burden for users (Should I store or sell?, Did I make the right decision?, etc.). In an extreme case, such a system can complicate recipients' lives, hence the emphasis on making sure that its functionalities simplify rather than complicate everyday life.

These motivations clearly show the difference in perspectives between engineers and power system managers and ordinary users of electrical energy. The benefits of a more stable electricity network and less common blackouts are quite abstract for people who do not experience such problems very often. Thus, if end users are to make a real change in their everyday habits, this change must give them real benefits.

6 Financial benefits: expectations and simulations

What are the chances for the system to bring savings? The study shows that about a half of consumers in Poland and Portugal (48% and 52%, respectively) expect a reduction of the account by one-fifth or more (Figure 2). One in four respondents in Poland (26%) and one in five in Portugal (18%) declare that no reduction can motivate them to install such a system at home. In the case of the Netherlands, the issue is somewhat more complicated: nearly a half of Dutch consumers (45%) are not interested in the system at all, regardless of any reductions in the bills. The average expected reduction is 37% of the monthly bills in Portugal, 34% in Poland, and 30% in the Netherlands. By juxtaposing these values with the value of actual electricity bills, we arrive at an average reduction of EUR 13.3 in Poland, EUR 26.2 in the Netherlands, and EUR 24.3 in Portugal. Therefore, the expected savings are significant.

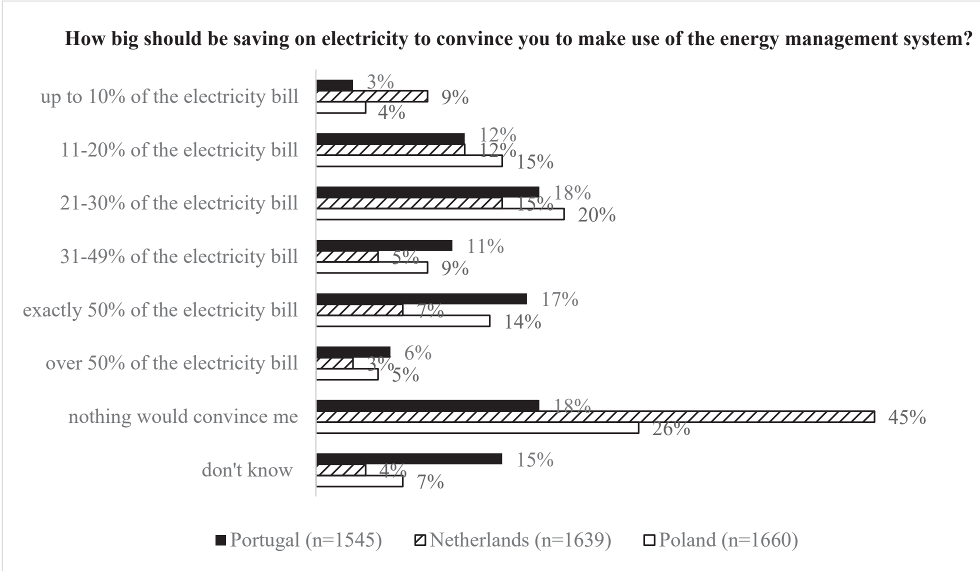

Figure 2. Expected savings on electrical energy. Base: electrical energy consumers aged 18–79 years.

7 Simulations and results for the business cases prepared in the e-balance project

The e-balance project took various systems of profits into account: from tokens to point systems, and also a proposal of gamification, as well as actual monetary payments (www.e-balance-project.eu/deliverables (D2.3; D2.6)). The simulation studies (only for Poland and the Netherlands) for “financial rewards” indicate that upon the aggregator’s request, and using the peak shaving mechanism only, a single prosumer could save an average of EUR 7–31* per year, depending on the degree of engagement and answers/responses to system signals (all data used in the price-related simulations came from the Polish market in 2016, with a total of 5,000 prosumers included in the computation). In the Netherlands, the savings ranged from EUR 5 to 26, respectively. The aggregator will be able to earn more thanks to the aggregation scale. The simulation results reached EUR 101,000* in Poland and EUR 450,000* in the Netherlands. The mathematical basis for the simulation studies (game theory and the Nash equilibrium method), the flexibility levels adopted (the so-called “user’s activity” – this is user’s elasticity for their agreement for being active in the system), and detailed results were presented and analyzed in the project [details are given in www.e-balance-project.eu/deliverables D2.6 and in Matusiak and Bartkiewicz, 2018]. In addition, an assumption was made that the photovoltaic installation did not exceed 4 kW. Prosumers with a higher capacity to produce and sell energy to the grid would be able to achieve additional financial gains.

It should be remembered that the distribution of the system would be subscription based and the system devices would be rented or leased by users, with additional annual fees charged. It seems, therefore, that the resulting financial gains may not meet the expectations of potential users.

Table 1. Annual profits for different levels of user elasticity/activity v_i (a 5,000 user pool) – Warsaw TGE

The level of user activity	Supplier profit (EUR)*	User profit (EUR)*	Aggregator profit (EUR)*
Low elasticity/activity (v_i = 0.02)	37,087.86	6.90	21,661.43
Medium elasticity/activity (v_i = 0.01)	80,571.67	8.81	36,392.38
Normal elasticity/activity (v_i = 0.005)	153,998.81	12.86	61,806.90
High elasticity/activity (v_i = 0.0025)	313,380.95	30.95	101,849.52

Source: www.e-balance-project.eu/deliverables (D2.6).
*1 EUR = 4.20 PLN. TGE, Towarowa Giełda Energii (Polish Power Exchange).

Table 2. Annual profits for different levels of user elasticity/activity v_i (a 5,000 user pool) EPEX SPOT Power NL

The level of user activity	Supplier profit (EUR)*	User profit (EUR)*	Aggregator profit (EUR)*
Low elasticity/activity (v_i = 0.001)	35,741.00	5.00	18,803.00
Medium elasticity/activity (v_i = 0.0008)	58,227.00	16.00	28,267.00
Normal elasticity/activity (v_i = 0.0006)	89,574.00	25.00	43,713.00

Source: www.e-balance-project.eu/deliverables (D2.6).
*1 EUR = 4.20 PLN.

The main results of the simulation studies for e-balance aims are summarized in Tables 1, Table 2 and Table 3. They indicate that demand response in the discussed approaches is profitable for all parties involved. However, the level of profits is highly dependent on the flexibility of the users and their willingness to adjust their load in response to proposed incentives.

The load-shifting activities seem permanent and can shape users' load profile on a daily basis, primarily with the aim to reduce energy procurement costs on the market. The second area of possible revenues for the e-balance platform stakeholders is associated with a reduction (curtailment) of users' loads at the aggregator's request. In this case, the profits for prosumers have exceeded even EUR 38.50* (on the Polish market), which is still relatively low.

Table 3. Annual profits for different levels of user elasticity/activity v_i (a 5,000 user pool) – Polish balancing market

The level of user activity	Supplier profit (EUR)*	User profit (EUR)*	Aggregator profit (EUR)*
Low elasticity/activity (v_i = 0.2)	16,494.29	5.00	8,247.14
Medium elasticity/activity (v_i = 0.1)	32,988.57	10.00	16,494.29
Normal elasticity/activity (v_i = 0.05)	65,977.38	19.76	32,988.57
High elasticity/activity (v_i = 0.025)	127,982.38	38.57	65,680.00

Source: www.e-balance-project.eu/deliverables (D2.6).
*1 EUR = 4.20 PLN.

In conclusion, the simulation shows that the profits might turn not to be very high for most stakeholders, such as prosumers, while they will be rather attractive for the aggregator and the suppliers. This may result from the fact that the photovoltaic installations taken into consideration in the simulations were too small. Installations of a larger size would provide more possibilities to produce more energy. It should be noted that for environmentally minded consumers and for much larger installations, the benefits would be proportionately larger and more attractive, also in terms of nonfinancial factors. Another very important observation is that if the incentives and financial benefits are too small, they would not suffice to trigger changes in users' behavior.

8 Other motivators

Thus, it is clear that financial benefits cannot meet the financial expectations of potential users. In order to encourage them to install the system, other motivating factors must be applied. Our study has indicated some potential motivations of that kind (Figure 2). It seems that the "environmental impact" may be important for a significant number of potential users. The idea to do something good for the environment would be an incentive for 38% of consumers in Portugal, 25% in the Netherlands, and 27% in Poland. Another group of motivators is related to "self-awareness of one's own energy consumption". The qualitative research carried out as part of the project shows that the level of self-reflexivity on common electricity consumption patterns is rather low. The possibility to predict one's own consumption is an encouraging factor for 31% of consumers in Portugal, 16% in Poland, and 13% in the Netherlands. The opportunity to analyze one's own consumption profile is a driver for 21% of the Portuguese, 17% of the Polish people, and 15% of the Dutch consumers. Another aspect of data analysis is the ability to compare one's own power consumption with others: this is attractive for 11% of respondents from Portugal, 12% from Poland, and 7% from the Netherlands. In total, one of the three aforementioned incentives related to data analysis was indicated by 26% of the Dutch, 33% of the Poles, and 43% of the Portuguese. The phenomenon whereby elements of reality are quantified and translated into data was termed “datafication” by Mayer-Schonberger and Cukier [2013]. The SG will offer the possibility to analyze and optimize energy consumption, not only by analyzing past consumption volumes but also by predicting the future usage [Kobylinski et al., 2018].

Two of the incentives presented to the respondents related to “technology as a social status indicator” (impressing others or offering the satisfaction of using technically advanced equipment). The opportunity to have/use attractive technological gadgets is a motivating factor for 21% of the respondents from Portugal, 14% from Poland, and 10% from the Netherlands, whereas the possibility of impressing family and neighbors is important for 5% of the Portuguese, 6% of the Polish, and 4% of the Dutch consumers. In total, one of these two incentives was indicated by 23% of the respondents in Portugal, 17% in Poland, and 12% in the Netherlands.

The hierarchy of prosumers’ incentives for installing the system is very similar to the hierarchy among all respondents (Figure 3). Interestingly, motivators related to access to data and the possibility of impressing others are valued more highly by prosumers.

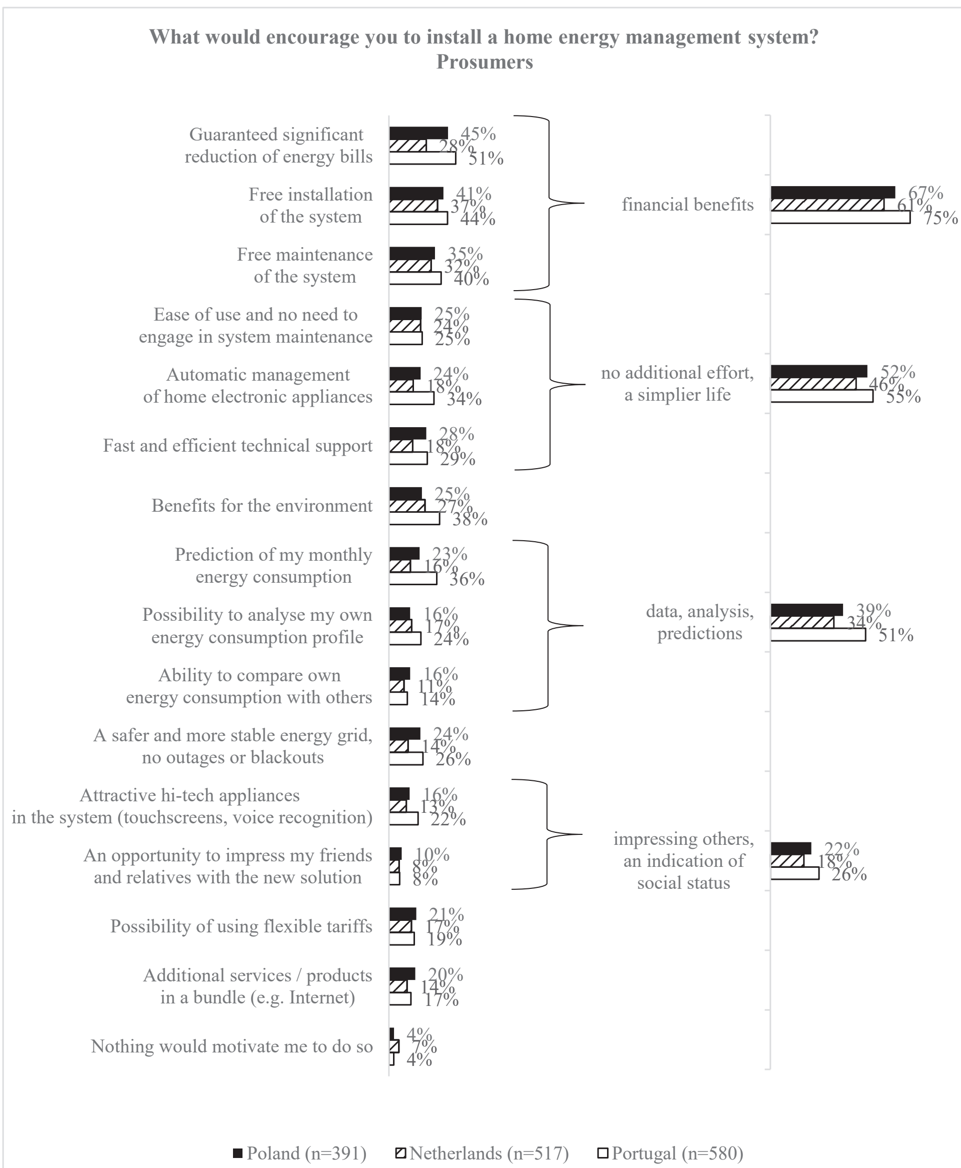

Figure 3. Motivations for installing HEMS. Base: prosumers aged 18–79 years HEMS, home energy management system.

9 Conclusions

The conducted study shows that the adoption of an HEMS by end users faces two major challenges. The first challenge is the "background technology". From the user's point of view at the moment, the use of electricity is unreflective and very easy. Introduction of an HEMS will change this situation. Electricity will no longer be a background technology used without thought. It will become a technology that is visible and requires attention and decision-making from the user from time to time. If users are to implement such a technology in their everyday lives, the technology must compensate them for the cost of additional time and attention. The most basic condition is financial profitability: users expect that by agreeing to flexibility in consumption (e.g., on active demand in the form of shifting the washing or dishwashing cycle), they will receive significantly lower electricity bills.

And here, we come to the second challenge: the challenge of financial remuneration. The simulations showed that the bill reductions will be much lower than those expected by end users. Since the first simulations show that financial easing may not match users' expectations, it is extremely important to use additional motivators. The simulations conducted under the project have shown that ease of use and minimum attention are also very important aspects. Moreover, other motivating factors may play a role, namely providing data to increase self-awareness of one's own habits and positioning the system as a status symbol.

10 Implications

Without taking social factors into account, it will be very difficult to achieve the adoption of the active demand system [Kowalski et al., 2018]. It is worth noting that the rapid development of smart metering and the SG technology gives additional opportunities for generating motivational factors. Smart metering gives unprecedented opportunities to acquire data, which becomes a very valuable resource nowadays. New concepts are created to describe this phenomenon: "datafication" is defined as the trend of quantifying and translating as many elements of the surrounding world into data as possible, which are then aggregated and algorithmized [Mayer-Schonberger and Cukier, 2013], whereas the term "dataism" is a kind of ideology in which data and their flow become the highest value [Harari, 2016].

Today, the value of data which can serve to describe consumers is growing rapidly. Meanwhile, extremely detailed knowledge on specific users may be retrieved from the data on their consumption of electricity. For example, whether householders tend to reheat dishes in the microwave oven or use the oven for this; whether they eat breakfast at home; how many electrical appliances they have at home; whether lighting and individual devices are used at unusual times. In addition, it can be determined, for example, when and who is usually present at home; what the family sleep hours are (and whether they suffer from sleep deficiencies); whether and when they turn on the alarm [Cavoukian et al., 2010], etc. It is clearly visible that a detailed profile of the household and its users is a very sensitive one. Despite this, some users would be ready to share data about their electricity consumption in exchange for additional benefits or even for a lower electricity bill [Kowalski, 2016]. The balance between user privacy and the willingness and possibilities of monetizing data must be preserved. Some researchers claim the creation of a new type of SG (techno-social SG) in which technology is supported by all information about users derived from social networks to motivate them for using the SGs [Nambi et al., 2016].

Another way in which the latest technical developments can support the adoption process of HEMS is to reduce the cost of extra attention and decision-making. The development of neural networks and AI algorithms gives the HEMS the ability to "learn" the preferences and habits of the household members and make automated decisions based on this knowledge. Of course, a new issue arises here: to what extent humans will retain their agency and who will control whom: technology controlled by the user or vice versa.

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