VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
BRNO UNIVERSITY OF TECHNOLOGY

FAKULTA ELEKTROTECHNIKY
A KOMUNIKAČNÍCH TECHNOLOGIÍ
FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

ÚSTAV JAZYKŮ
DEPARTMENT OF FOREIGN LANGUAGES

VLIV MÉDIÍ NA SPOTŘEBITELSKÉ CHOVÁNÍ V OBLASTI ENERGETIKY

THE IMPACT OF MEDIA ON CONSUMER BEHAVIOUR IN THE ENERGY SECTOR

BAKALÁŘSKÁ PRÁCE
BACHELOR'S THESIS

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BRNO 2019

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
FAKULTA ELEKTROTECHNIKY A KOMUNIKAČNÍCH TECHNOLOGIÍ

Bakalářská práce

bakalářský studijní obor **Angličtina v elektrotechnice a informatice**
Ústav jazyků

Student: Štěpán Sedláček ***ID:*** 189820
Ročník: 3 ***Akademický rok:*** 2018/19

NÁZEV TÉMATU:

Vliv médií na spotřebitelské chování v oblasti energetiky

POKYNY PRO VYPRACOVÁNÍ:

1. Definujte spotřebitele a faktory ovlivňující jejich chování.
2. Vysvětlete, jaké jsou druhy médií a porovnejte je mezi sebou.
3. Proveďte rešerši studií zabývajících se vlivem médií na spotřebitelské chování v oblasti energetiky.
4. Na základě výsledků studií porovnejte míru citlivosti spotřebitele na získané informace.

DOPORUČENÁ LITERATURA:

Dle pokynů odborného konzultanta

Termín zadání: 4.2.2019 ***Termín odevzdání:*** 28.5.2019

Vedoucí práce: Mgr. Magdalena Šedrlová
Konzultant: Ing. Michal Vrána

doc. PhDr. Milena Krhutová, Ph.D.
předseda oborové rady

ABSTRAKT

Tahle bakalářská práce se zabývá rozborem aspektů, které brání, či naopak umožňují integraci principů sociálních sítí do systému smart meteringu, jakožto i rozbor jejich potenciálu a možnosti provedení. Přínosy inteligentních sítí pro spotřebitele jsou dnes žhavým tématem. V této práci je prezentován průzkum zaměřený na tyto aspekty. Analýza výsledků průzkumu a klíčových sdělení identifikuje názory obyvatelstva na tohle téma a navrhuje možné směry kterými se mohou vydat budoucí aplikace a služby pro spotřebitele žijící v inteligentních městech.

KLÍČOVÁ SLOVA

Obnovitelné zdroje energie, fotovoltaika, udržitelný rozvoj, elektrizační soustava, distribuční soustava, přenosová soustava, topologie sítí, smart grid, smart meter, sociální sítě.

ABSTRACT

This bachelor thesis deals with the analysis of the aspects that prevent or allow the integration of the principles of social networks into the system of smart meters as well as the study of their potential and possibilities of implementation. The issue of how the future smart grid consumer will benefit from the future smart city grid services are hot topics. Here, a survey is presented that focuses on these aspects. An analysis of the survey results and key messages identifies view of the people on the topic and proposes directions that may be followed when designing applications and services of residential smart city consumers.

KEYWORDS

Renewable energy sources, photovoltaics, sustainable development, power system, distribution system, transmission system, network topology, smart grid, smart meter, social sites.

Sedláček, Š. *The impact of social networks on consumer behavior in the energy sector*. Brno: Vysoké učení technické v Brně, Fakulta elektrotechniky a komunikačních technologií, 2019. 45 s. Vedoucí bakalářské práce: Mgr. Magdalena Šedrlová

PROHLÁŠENÍ

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V Brně dne ....

(podpis autora)

ACKNOWLEDGEMENT

I would like to thank my advisor, Mgr. Magdalena Šedrlová from the Department of Foreign Languages and my expert advisor, Ing. Michal Vrána for guiding me throughout the year and for the pieces of advice, feedback, and valuable remarques.

CONTENT

1 INTRODUCTION

The electricity system is undergoing historical changes, as a new paradigm of bi-directional real-time interaction with its stakeholders is now possible. However, such interaction involves upgrading an ageing power system to a so-called smart grid that will include the modernisation of electrometers. The newly emerging generation of electrometers (Smart meters) will through 4G and 5G subsequently form the IoSM (Internet of Smart Meters). Smart meters, as well as sensors and actuators, will provide the basis for communicating with energy companies and with its consumers and provide the informational background to which will consumers have access to. This new, highly interactive and collaborative infrastructure will enable, for instance, retailers to communicate more effectively with their customers, thus enabling them to take a more active role in the system. With smart meters, it becomes possible to create social networks that could become a tool to reduce the electricity consumption of residential consumers by applying certain psychological methods.

This bachelor thesis consists of a theoretical and a practical part. In the theoretical part, I will shortly provide a basic overview of the electricity system of the Czech Republic, with the breakdown of network topologies and the recent expansion of photovoltaics power plants and its impact on the stability of the grid. Thereupon I will describe the smart meters, their potential and provide insight into the smart meters boom in the UK and Czech innovative moves in the industry.

Furthermore, I present the current theoretical trends in the field of social networks in the energy sector from a practical and psychological point of view. In the practical part, I analyse the questionnaire, in which I find out the opinions of the inhabitants of the Czech Republic on the news in the field of energy and also whether they would be interested in a more active role in this system.

2 ENERGETICS

The reason why I include this topic in my research is that affordable, safe and cheap energy is one of the underlying conditions for the very existence of society, its security and economic success. Also, it is essential to break down the influence of the increasing supply of renewable resources and its impact on the topology of the Czech distribution system. Mention the risks for the Czech transmission system and also Europe's dependence on imports of energy raw materials.[1]

That is why the European Commission presented its Strategy for Competitive, Sustainable and Secure Energy in November 2010. In the energy strategy, two aspects are highlighted concerning security.[1]

1. The threat of supply disruptions and the need for secure and ensured networks due to
    a. Vulnerability and inability of consumers.
    b. The incoherence of market mechanisms to ensure fluidity of supply

during the supply crisis.

2. Risks to the population arising from energy production and transport.
   a. Nuclear power plant - Development of safety systems, transportation, and storage of radioactive waste.
   b. In the field of oil and gas extraction and processing, the European legal framework must guarantee the highest degree of safety and a clear binding regime for oil and gas; similarly applies to new energy technologies. [1]

2.1 The power system of the Czech Republic

The power system is a centrally and uniformly managed a set of parallel operating power plants, electrical transmission and distribution equipment, and electrical appliances with a general power reserve. Its main task is to reliably supply a sufficient amount of electricity to all customers with high quality, low cost, and guaranteed safety. Its secondary task is to secure transit flows of electricity from border states, as described in paragraph 3.1.3 below. [1]

According to the Czech Transmission System Code. The Power system is an interconnected set of facilities (and equipment) for the generation, transmission, transformation and distribution of electricity, including electrical connections and direct lines, and measuring, protecting, controlling, signalling, information and telecommunication systems.[1]

The Power system has several parts:

- Power plants
- Electrical substations
- Power grid
  - Mains
  - Power lines

The power plants are structures that serve to convert different energies into electrical energy. [1]

Electrical substations are buildings located in nodes of the Power grid. They enable transformation, distribution with the same voltage in several directions, conversion of the alternating current to direct current or vice versa, or conversion of the frequency of the alternating current, or compensation of reactive currents.[1]

Power grid (or electrical networks) are sets of interconnected electrical substations and lines for power transmission and distribution. We divide them into transmission systems, for 220kV and 400kV long-distance transmissions and distribution systems for distributing energy from the transmission system to customers with voltage 110kV, 35kV, and 22kV. The distribution system also includes 22kV, 10kV, 6kV and 0,4kV industrial networks. Networks that lead electricity directly to consumers are called local and have a voltage of 0,4kV.[1]

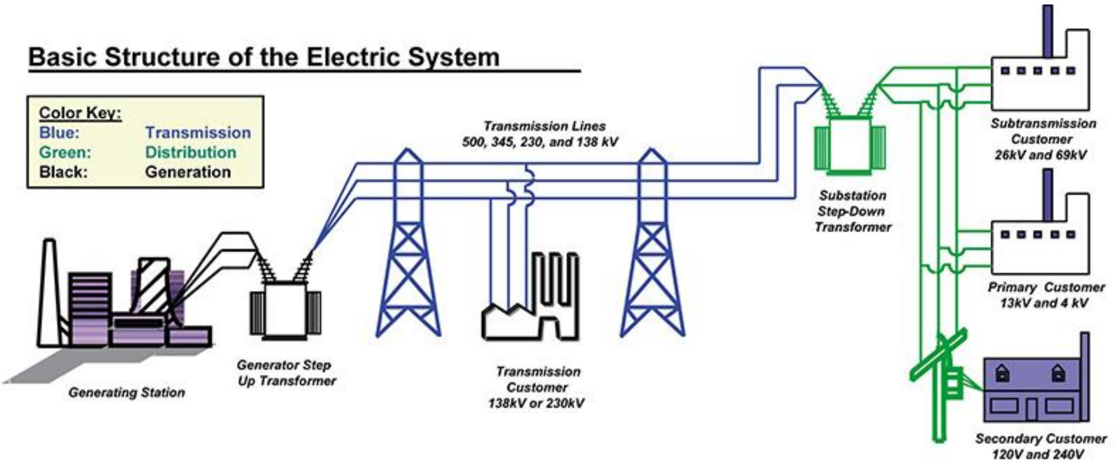

Figure 1: Basic Structure of the Electric System (source: University of Idaho)

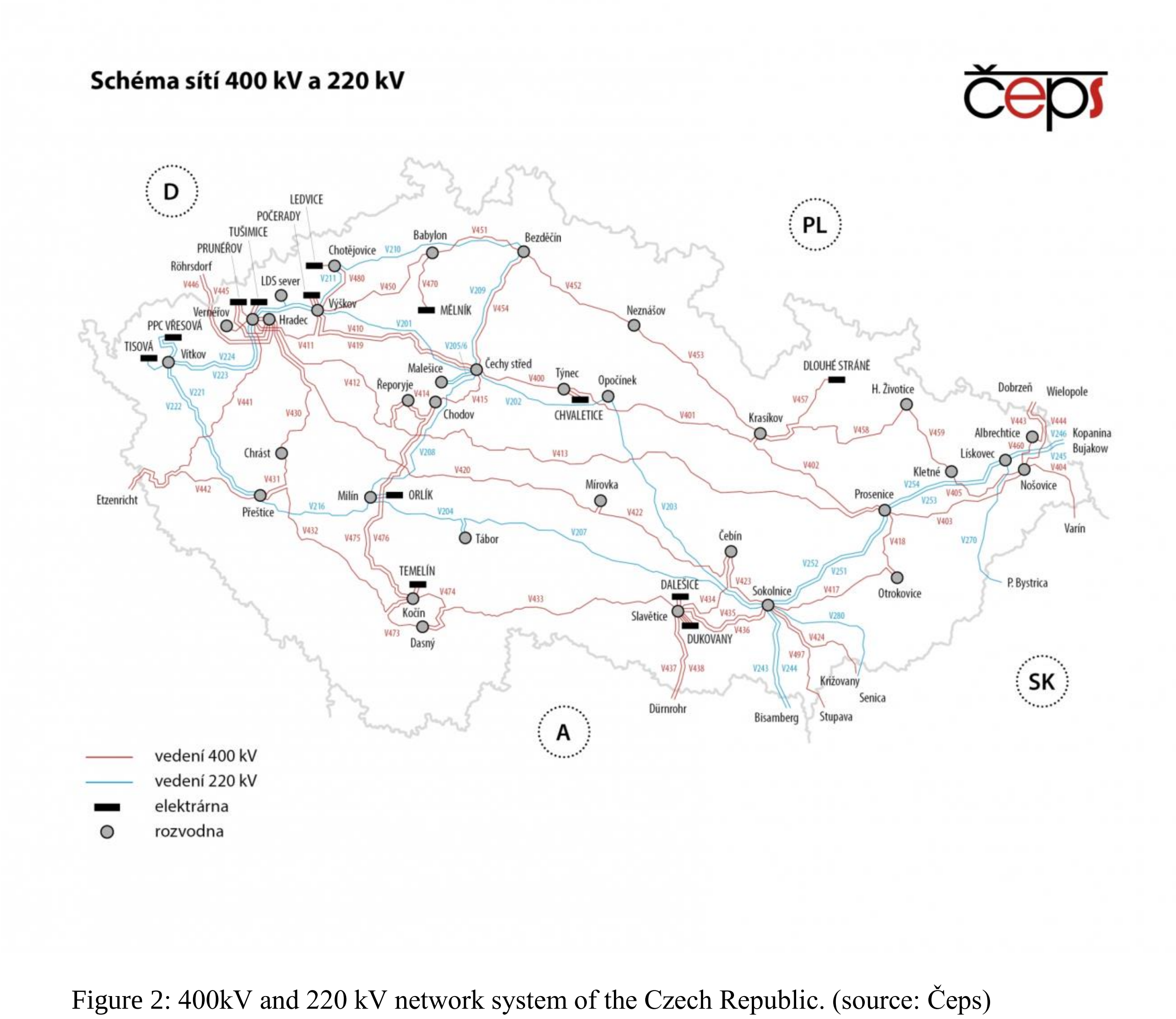

Figure 2: 400kV and 220 kV network system of the Czech Republic. (source: Čeps)

2.1.1 Production photovoltaic energy in distribution grids

Due to the increase in photovoltaic energy production, mainly because of the original Act no. 180/2005 Coll. in 2009 and 2010 that caused a sudden reduction in the price of photovoltaic panels on the market and returned on investment in photovoltaics in the Czech Republic was thus reduced from the planned 15 years to about 6-7 years. According to the Center for Renewables and Energy Saving (photovoltaika.ekowatt.cz), more than 2,000 plants with a total capacity of over 80 megawatts were installed in mid-2009. In 2006, the installed capacity, according to the MPO (Ministry of Industry and Trade of the Czech Republic) estimate, was less than 0.8 MW.[2]

Figure 3 : Photovoltaic plant (source MIT news)

According to the Center for Renewables and Energy Saving, the rapid development of photovoltaics does not only concern the Czech Republic. Thanks to the state subsidisation, similar to the one in the Czech Republic, installing of photovoltaic power plants pays off in many European countries. The largest share is in Germany and Spain. In Spain it is about twice as much solar radiation as in the Czech Republic, which means that the same photovoltaic panel will produce twice as much electricity as in the Czech Republic. However, the purchase prices in Spain are higher than in our country. That is why Czech and foreign investors are interested in the construction of photovoltaic power plants in the Czech Republic[2].

The impact of the photovoltaic boom in 2009 and 2010 has already arrived. In March 2011, the Czech Association of Regulated Electricity Companies issued a press release[3] announcing the tightening of the rules for the connection of small power plants. They said that the New contracts for the connection of other photovoltaic and wind power plants would not be concluded before the real effects of electricity generation from the already installed PV sources and reliability of the distribution system operation.

The direction of flow in some parts of the distribution system may turn due to the power plant's involvement because a photovoltaic power plant built in rural areas as a new source of energy appears in a place that was not taken into account as a location for electricity generation in the moment of designing a distribution network.

Reversed streams of electricity can cause destabilisation of the system, in particular, to increase the electrical networks strain around the power plant that has smaller diameter conductors. If the current is rotated, electricity starts to flow from a smaller diameter conductor into a larger diameter conductor creating an unpredictable environment.[3]

Preventing overflows into a network of small producers in a moment of overvoltage of a grid with outputs of 10 kW which are labelled as micro electric power plants is covered by a decree[4]. The reality is that when you run a photovoltaic power plant, you defend the grid against unwanted overflows by purchasing an autonomous control functions equipment, like a microinverter (shown in picture 4), but at the cost of losses at times when the flow to the network is undesirable, as shown in a picture.

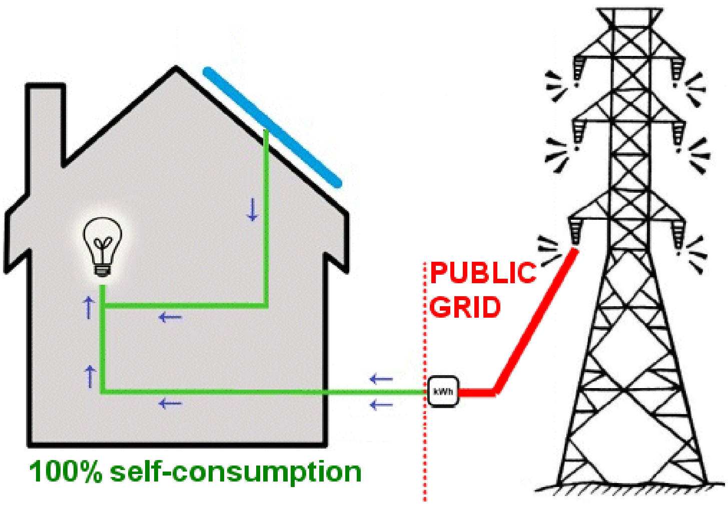

Figure 4: Demonstration of micro-inverter function (source: i4wifi.cz)

2.2 Smart Grids

At this time when much of the electricity produced is fossil fuels dependent [5], which are harmful to the environment and becoming more and more inaccessible, the electric power system is undergoing historical changes.

As a new paradigm of bidirectional real-time interaction with its stakeholders is now possible. Fuelled by an ageing infrastructure requiring modernisation, rising fuel costs, increasing effort to produce electricity in a more environmentally-friendly way and the need to reduce consumption towards a more sustainable future the electric power system is changing in a way that will give producers and consumers (prosumers) more information on and control over their energy behaviour, by allowing them to interact in a fine-grained manner [6]. Renewable energy has the wrong feature that its production grows and falls with the influence of the environment and can be regulated only to a certain point. With its increasing use, therefore is an increasing need for the best possible regulation and control of its supply to the grid.

As reported by the US Electricity Authority[7] modernizing the grid to make it “smarter” and more resilient through the use of cutting-edge technologies, equipment, and controls that communicate and work together to deliver electricity more reliably and efficiently can greatly reduce the loss of power in the grid, the frequency and duration of power outages, reduce storm impacts on the grid, and restore service faster when outages occur. Consumers can better manage their own energy consumption and costs because they have easier access to their own data.

The future dictates towards a great number of decentralised, small-scale production sites, in decentralised, small smart grids, mutually connected, yet able to run separately, based on renewable energy sources or efficient production systems. Utilities benefit from smart grid construction too, offer improved security, lower operational costs, and due to the better respond to user behaviour, thanks to the possibilities to change the tariff more often will be DSO able to reflect better the real grid status enabling more efficient peak load reduction.[7]

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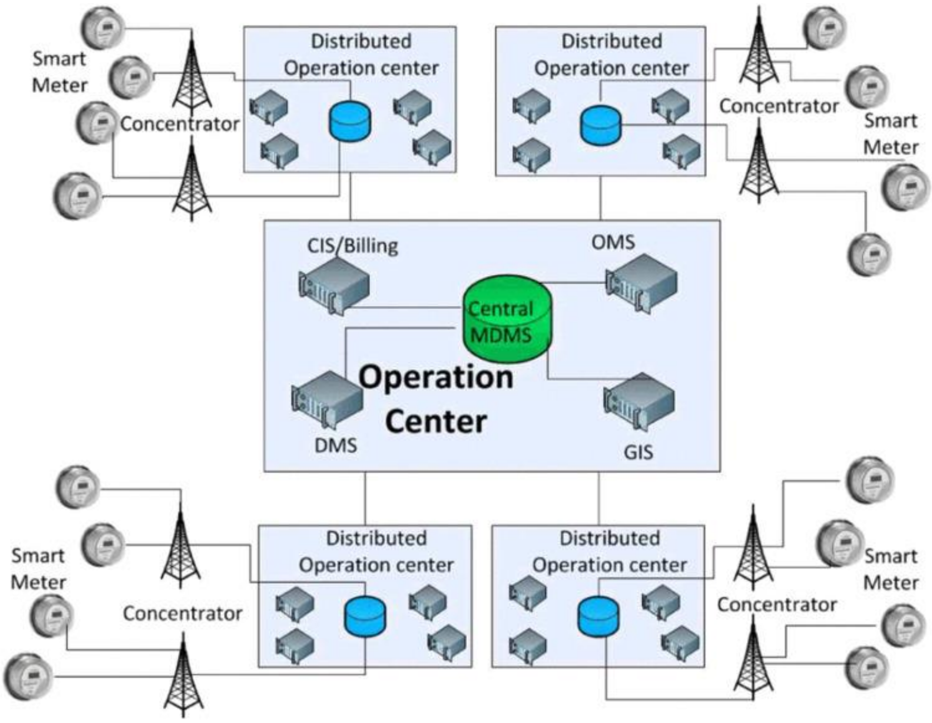


Figure 5: Demonstration of a smart grid (source: ResearchGate)

The Eurostat (European Statistical Office)[8.] states that: More than half of EU-28 Smart grid technologies are revolutionary due to two-way communication and computer processing of control systems and are required to be implemented first then we can start thinking of making smart grid social networks.

3 SMART METERS

A „Smart meter“ is a modern communicating electrical utility used for measuring Killowat/hour or gas and as the normal electricity meter used for billing purposes of the utility. Unlike the standard electricity meter, the smart meter offers a range of intelligent functions. A smart meter can read power consumption and send this information via wireless technology to the Internet, allowing various computer and mobile applications or home screens to be able to track current or past power consumption, show energy-saving tips, display current network status, or if the operator permits, display the current tariff. It also communicates with its energy supplier and sends data on monthly/annual consumption.

Figure 6: Smart meters representation (source: energie21)

The potential of the Smart meter

The potential of using smart metering, according to a I. Guiciu, R. Meersman and T. Dillon [9 lies in creating the Internet of Things where will each smart meter (installed in flat, house, SME, or large enterprises) represented as an a node on the IoSM (Internet of Smart Meters) through their electricity meters, sensors and actuators. Which allows to rational energy exchange between technical and non-technical participants by expressing their goals in a standardised language through hybrid ontologies. Assuming the transformation of the current topology of the distribution and transmission network which would allow electricity to flow in both directions and the installation of a smart meter into every household, it could change the whole concept of electricity production.

In such a smart grid would be the consumer, or communities of consumers empowered as first-class citizens with a novel role in the management of their electricity by sharing excess electricity, therefore becoming energy producers (prosumers).

Smart meter technology allows DSO to instantly and transparently send consumers information on the current tariff, allowing DSO to change energy prices according to current consumption, this would allow consumers to install IoT switches in the house that would turn on, for example, domestic heating systems, at a time when prices would be lowest.

Communities could also be involved in tackling the problem of energy consumption at peak load by shutting down appliances at the request of an electricity provider or sharing their excess energy. The incentive for such gentle behaviour could be the reduction of electricity prices by electricity providers, social network visibility, or in the form of charitable or other bonuses. An essential psychological motivation could be a very effort to maintain a reliable supply of electricity. It is precisely the reason why people sort and recycle waste, even without bonus promises.

The medium through which the consumer could contribute to energy conservation could take the form of a social network. There have been conducted studies that have shown, that collaborative competition would be a strong motivating factor for reducing energy consumption [5]

3.1.1 Smart meters in the UK

The main reason why Britain introduced smart meters rollout, according to R. Hampshire in "Realizing the Benefits of Smart Metering: Creating Consumer Engagement" [10], was the United Kingdom's continuously narrowing gap between peak demand and production capacity, which in future can become a reason of power outages. The article mentions the conversion of surplus primary fuel production and 18% of surplus export abroad in 2007 to the import of 80% of primary fuels estimated for 2020 due to the assumed increased electricity consumption. Due to globally increasing electricity consumption, Britain is increasingly dependent on the volatile rise in primary fuel prices, which will increase the cost of electricity production and hence increase tariffs.

According to a quarterly released statistics published by the UK Department for Business, Energy & Industrial Strategy published on May 31.2018 [11], which researched the roll-out of smart meters in Great Britain since 2013. There are currently over 12million smart and advanced meters operating across domestic consumers and businesses in Great Britain by both large and small energy suppliers.

Smart Metering programme in the UK began in 2011 with the foundation stage, when the Government engaged with the energy industry, consumer groups, and other stakeholders to put commercial and regulatory frameworks in place to support smart metering, trial and test systems, protect consumers and learn lessons from initial installations. The following step was The main installation stage, beginning in 2016 and should be running till the end of 2020. After this period, most of the British households and small businesses will have smart meters installed. [11]

In the UK are the energy suppliers responsible for planning and delivering the installation of smart meters as they did with the standard electricity meter in the past. Nevertheless, they are free to plan they roll-out in a way that suits their business and the needs of their customers, subject to the requirement to complete the roll-out by the end of 2020. [11]

All domestic consumers will be offered an In-Home Display (IHD) with the ability to show an overview of electricity consumption. It can show how much electricity is being used and how much it cost in almost real time. A smart meter can also transmit meter readings to energy suppliers and receive data remotely. [11]

3.1.2 Trends in the Czech Republic

Energie24

The effort to better monitor electricity consumption is apparent in the Czech Republic, even without the use of smart meters. The energy company E.ON SE, based in Essen, Germany, and the largest energy company in the Czech Republic, has released a mobile application[12] called "energie24".

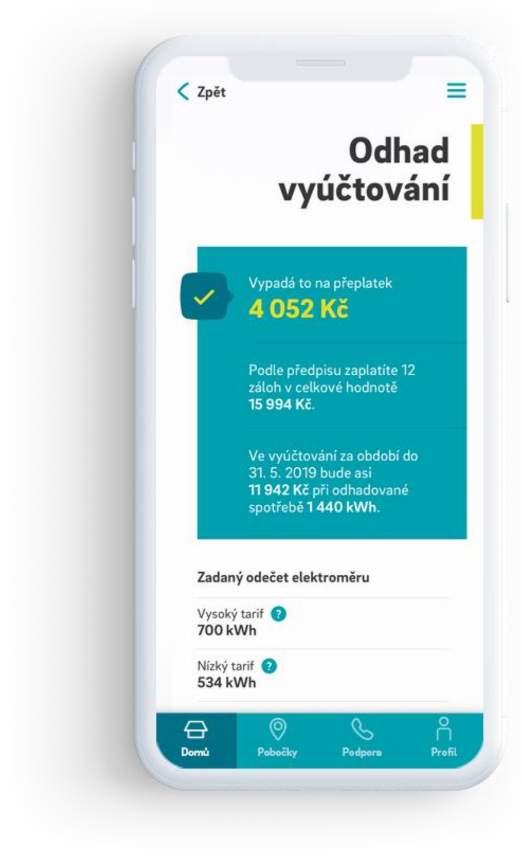


Figure 7: Application Energie24 (source: eon.cz)

With this application, the consumer can use his smartphone to take a photo of the electrometer and the app automatically converts the data into a graph and estimates his next electricity bill. The more often the consumer takes pictures of the electricity meter, the more detailed it will have data about his continuous electricity consumption. The application offers a clear overview of backups, invoices and consumption history. It can also be used to pay for electricity bills.[12]

The application is free and requires a profile that registers for a particular electrical connection. The identification information that the consumer finds on the electricity invoice is enough to register. After creating a profile and installation the app, you can start using it.[12]

Smart region Vrchlabí

The Smart Region Project Vrchlabí is the most ambitious project in the development and testing of new technologies in the energy sector in the Czech Republic yet.

In the Smart Region project, ČEZ Distribuce verifies new technologies and features that are not used in the operation of the existing distribution network and can contribute to increasing the reliability and quality of electricity supplied to customers.[13]

State-of-the-art technologies are installed in the distribution system, information technology is largely used to monitor and control power elements, a local electricity source (CHP) is connected, and the impact of electromobility on grid stability is tested.[13]

Goals:

1. LV network automation - automatic location and fault definition. Assessing the Impact of Electric Vehicle Infrastructure on the LV Network.
2. HV network automation - automatic localisation and definition of network faults with new topology (so-called loop wiring)
3. Island operation in the event of a fault in a superior network using a local power plant

The knowledge and experience of the project will be crucial for the further development and deployment of smart grids in the Czech Republic and will also contribute to standardisation in the European Union.

3.1.3 Consumer-centric framework

The intelligent network and its promises have evoked global developments research and demonstration projects, some of which focuses on how to empower its users with better monitoring tools, understand and manage their energy behaviour. Nonetheless, it is often the case, that providers of such lectures are blinded by technological advances and make conclusions that may not be best for the users or they may not understand them entirely.

The benefits of smart meter and social networking are evident both for energy companies and for media, but it is not entirely clear for residential consumers which can perceive smart meters to be an infringement to their interests and rights. There are many smart metering projects, across the world, that are facing resistance from consumers. As claims R. Yesudas, in his work about smart grid implementation situation in Australia [14] mentions, that this could have been avoided if the consumer benefits and risks had been identified earlier during the requirement elicitation phase of the project. Yesudas also claims that when implementing social networking technologies and smart meters, it is critical to analyse the technology from a residential customer perspective and to conduct social research. Because a lack of understanding of the real needs of users and the impact of new technologies and tools can lead to lack of interests or disagreements from the public that may lead to leaving innovative approaches, and technology that could change the world for the better will only become a costly mistake.

Smart grids implementation is a costly investment. The price just for initial investment is in the order of millions of dollars, and it is always taxpayer money. The scientific article by R. Yesudas describes the rollout of smart meters in Victoria, Australia, one of six Australian states with 6,290,700 inhabitants, where the initial final price for a smart grid was $ 800 million and additionally bloated up to $ 2.3 billion[15]. According to the media, the average price of the annual electricity tariff rose by 17-20%[16]. The consumers now have to pay for maintaining the new system and also pay an increased fee for electricity. R. Yesudas, in his work[14], argues that the Roll Out of Smart Meters in Victoria is an example of failure analysis of end-user effects and risks. To avoid similar mistakes, proposes a framework called The Consumer Focused Smart Grid Framework (CFSGF) which is based on identifying and analysing the stakeholders/consumers needs and interactions in the Smart Grid [14].

In comparison to other smart grid frameworks, that are trying to figure out, how to narrow the consideration on the infrastructure and how to make smart grids smarter, apart from CFSGF are not taking in to consideration the fact, that if it, from the previous experiences, creates risk for the stakeholders it will not be advantageous to retrofit the grids with the smart technology. The CFSG contributes to user-centric and secure architecture, which will ensure that the infrastructure supports the requirement of the mass as can be seen in figure 8.

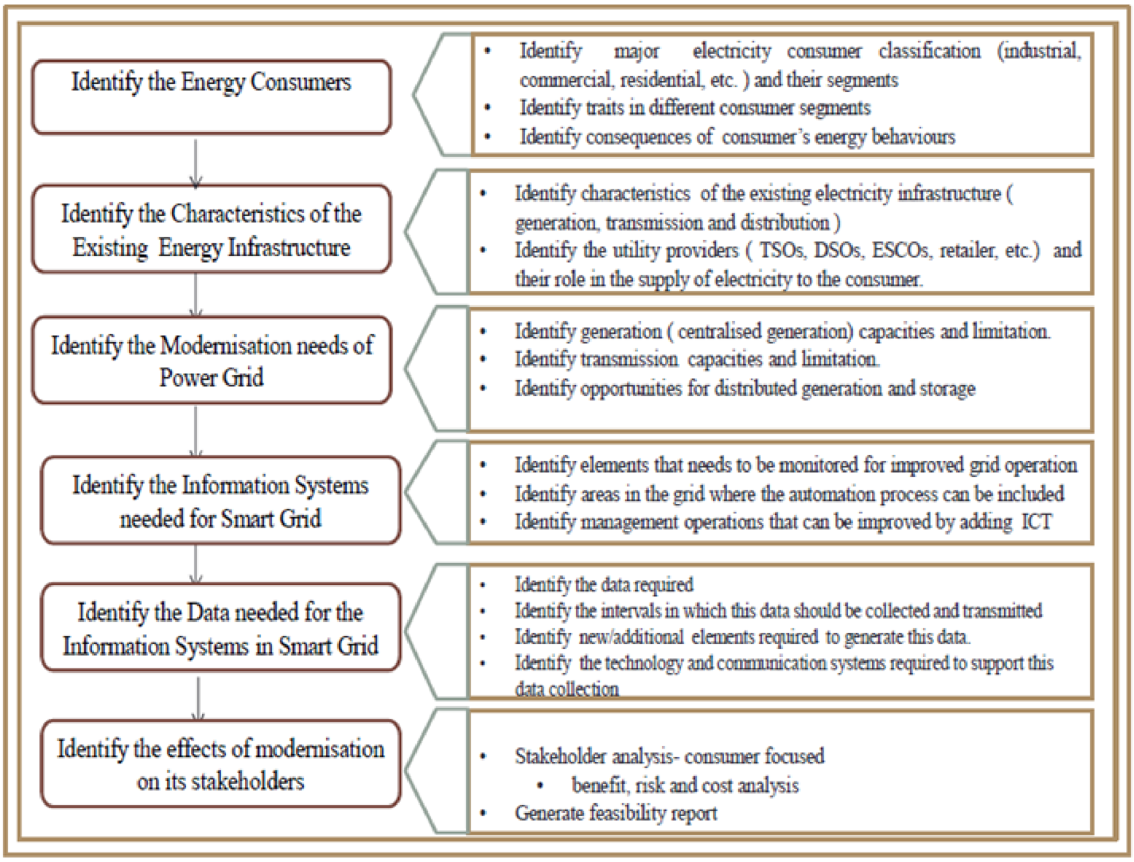


Figure 8: Framework for consumer focuser Smart Grid initiatives (IEEE, A consumer friendly framework for smart grid initiatives, 2015)

4 SOCIAL SITES

As states Y. Huang, M. Warnier, F. Brazier and D. Miorandi [17], the recent trend in studies on smart metering and smart grids, is that research is not only addressed to technological aspects of the grid, focusing mainly on hardware and software of grid infrastructures, but also to the social dimension of the grid. There are many research efforts on both topics, but the idea of research combining both of them is relatively new.

With new technologies in the energetic field and with a possible new role for home consumers as a prosumer, which can affect the price and quality of electricity, a new area of marketing and media opens. As stated in abovementioned, there are several ways how to use it. From combination smart meters with home management systems, that would track actual energy consumption, monitors your consumption and suggests when and how to save, to the social sites where could everybody share its daily consumption, compete for the smallest consumption or trade surplus energy from a private power plant.

4.1 Related work

If you have a renewable energy source as a private person, or SME (small and medium enterprise) and you have surplus electricity production, you can either limit your power plant production or, if your contract with the DSO allows, you can sell the energy to the grid for a fixed price. Some projects are dealing with the idea of the creation trade market for consumers to trade with each other in the common grid.

4.1.1 EnergyCity

Symeonidis at al.[18] designed and developed EnergyCity, a Multi-agent framework designed to simulate the power system and to explore the Consumer Social Networks (CNS).

EnergyCity simulates the power system with all its parts (Consumes, producers, suppliers, Transmission and Distribution operators) as a simulation of demand-side response and raises social awareness. Study claims that due to changing electrical environment from classical power grids, to the distributed energy resource one, there's raising need to restructure power grid and even though the R&D is buzzing, pressure for better energy management is rising, and all these changes offer substantial opportunities for all energy market stakeholders, the opportunities remain largely unexploited. The study explains this phenomenon by saying that vast majority of stakeholders are small-scale consumers who are individually insignificant and on the other hand, individually significant large stakeholders are often reluctant to implement the new technologies because they are unable to anticipate the possible benefits. There is a lack of tools for the modelling of the energy market complex enough to completely include or simulate all or at least most of the variables.

That's why Symeonidis at al.[18] introduces EnergyCity, which provides a tool for modelling all market stakeholders and essential grid components. As its creator say, through EnergyCity one may specify consumption habits and patterns, consumer types and behaviours, intermediaries and policy regulations, so that these are diffused in the simulated community, to identify behaviour, drives or policy makers. The revolutionary feature of EnergyCity is that it simulates role and the market power of small-scale electricity consumers utilising the concept of social sites.

The EnegyCity is implemented in Java with all agents developed in Java Agent Development Framework (JADE) and is in continuous development. It is a significant tool in a field of optimising consumer social sites, and its impacts as well as in simulating, designing and debugging smart grids.

4.1.2 Privacy

In the future, the smart meters will be an essential element in acquiring and transporting household consumption information to the social network layers and to an operator who will monitor the electricity grid and improve energy efficiency. With this technology, there is a potential danger of misusing that information to derive the consumer's private activities. Y. You, Z. Li and T. Oechtering [19] in 2018 explained in their research that there are security methods that blur, anonymise or aggregate data from the smart meter. However, the main problem with the methods that corrupt SM data is that they degrade the level of information displayed. An innovative privacy-based approach has the task of modifying the real demand for the electricity of the consumer that owns the energy storage system or an alternative energy source. In the study, Y. You, Z. Li and T.

Oechtering [19] compare five studies dealing with the extent of private data leakage using different theoretical measures, such as mutual awareness or conditional entropy, and it is only one of the studies [20] that has taken into the consideration energy consumption costs. They considered the trade-off problem between smart privacy leakage and the energy cost of the consumer, for which they used Kullback-Leibler divergence rate and expected cost-saving rate as the measures. They found out that with designing the privacy-enhancing and cost-efficient energy management can be reformulated as a belief-state Markov decision process (MDP) problem and optimal solution can be derived using Bellman dynamic programming. They showed that the numerical example both privacy-enhancement and cost saving can be achieved and can be traded-off while having energy management.

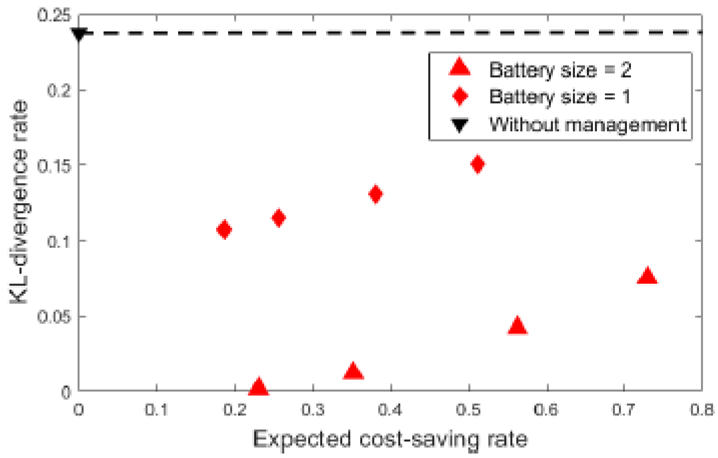


Figure 9: Trade-off between piracy leakage and cost-saving for different battery sizes (Source: IEEE, Optimal Privacy-Enhancing And Cost-Efficient Energy Management Strategies For Smart Grid Consumers, 2018)

4.2 Psychology

In the past, there already were several psychologic tests, trying to prove, whether or not could greater awareness of electricity consumption reduce the energy consumption of the household. Dr Wokje Abrahamse et al. in 2005[21] have evaluated several interventions to promote energy conservation. The result was the finding that merely providing general information on energy saving is less effective than providing this information with a mix of rewards motivating a change of behaviour. However, achieving a lasting behavioural change was either not monitored, or rarely successful.[5]

In the psychological experiment of M. S. Pallak et al. published in 1976[22] when one of the two sample groups was in public commitment, and their use of energy was monitored and published and the other group, where the participants were guaranteed anonymity. It was shown that the sample group with published consumption recorded a lower level of growth in electricity consumption than the group whose results were not published, as well as increased long-term behavioural change.

The results of the second attempt show us that the social and public aspect can be decisive in changing habits in electricity consumption, where the price can not be a main decisive aspect. To determine whether data technology and visualisation can help in this process, E. Costanza et al.[23] conducted a study using interactive visualisation of household electricity consumption in 2012. When interactive visualisation was involved, consumers became more aware of their consumption. It follows that the visualisation element is beneficial for a change in behaviour.[5][22]

4.2.1 Methods of visualisation

Since the visualisation of energy consumption is an essential element in creation, it is important to understand the basic principles of what is considered to be the right visualisation of information.

Information visualisation is defined as the presentation of abstract data in graphical form so that the user can use his visual perception to evaluate and analyse the data. Edward. R. Tufte [24] wrote four critically acclaimed books explaining the principles and concepts of visualisation, many of which are inspired by the 100th tradition of visualising maps and parcels. Tufte says that when visualising data, the graphics should always be true and pay close attention to the data. Poor graphics distort the truth and divert attention from the grasp of the evidence presented and the subsequent intelligentdecisions.

Colours

Colour is an essential tool in visualisation[5]. Colour spots on light grey or muted fields can highlight and emphasise data and also contribute to overall harmony. Using intense colour on a dull background can create a very striking object that attracts the attention of the user. This technique can be used for alarm symbols or other kinds of graphics that require immediate attention. These instructions are described by cartographer Eduard Imhof [25] and can be transferred to the use of visualisation in computer graphics.

4.2.2 Types of motivation

Alex Lasky, the owner of company Opower, presented on TED[26] about a behavioural experiment conducted in California, USA. The goal of this experiment was to find out, what is the most effective persuasive method to induce gently behaviour amongst residential consumers.

Figure 10: Types of persuasive methods (TED)

The experiment was conducted during the hot summer, and the subject was to make participants turn off their air conditioning and instead switched on fans. Graduate students put signs on every door in a neighbourhood. One-quarter of the homes received a message that explained how much money would residents save on electricity bill, the second group got an environmental message, and the third group got a message about being a good citizen by not contributing on blackouts (which were common in that area and time). First, three messages did not have any impact on electricity consumption. The last group got a message that informed residents that 77% of their surveyed neighbours turned off their air condition and turned on fans and pleaded to join them. People from the fourth group showed a remarkable decrease in their household energy consumption.[26]

The ways of motivating and encouraging gentle consumer behaviour can be diverse. Just making consumption monitoring easier to obtain will have some effect, yet allowing consumers to publish their energy consumption, therefore make energy consumption social related subject, seems like an excellent behaviour changing tool.[26]

Save the day competition

Julie Marie Røsok, in her work entitled "Combining Smart Energy Meters with Social Media", proposes a charitable collaborative competition called Save the Day.

It is a competition where the consumer can add to the group and compete with other groups for the most energy saving. [5] At the end of the contest, the group with the most significant amount of saved energy will win a certain amount of money that they donate to a charity of their choice. Groups can create energy companies. The purpose of this competition will be to increase energy awareness and hopefully motivate individual consumers to make more energy-conscious behaviour.

Rewarding correct behaviour

Ioana G. Ciuciu et al.[9] describes the emergence of a social network within IoT smart meters to support demand-response decision-making. Ioana presents a way of combating increasing power consumption by combining smart meters with a home management system with the demand-response decision support system on top of smart metering and social web technologies. Therefore the home management system could highlight when and where the consumer could reduce his energy consumption by switching high-energy demanding domestic appliances at the right time of the day and save money from electricity bills.

Ioana [9] mentions that similar programs in the demand-response system are working in the world. More specifically, some Energy companies offer financial rewards and incentives to electric consumers (homes and businesses) who are willing to reduce their consumption at times when demand exceeds supply.

Serious Games

Serious games or gamified interactions are Game-based approaches aimed at stimulating, increasing or modifying user activities have attracted growing interest in recent times. This is also the case of the energy sector where C. Rottondi and G. Verticale [27] in their work, designed a game that supports the reduction of network load and shaving of the daily peak. In the envisioned application scenario of smart electricity or water grid where the utility adopts a gamified mechanism to influence the consumption patterns of the users to shape their aggregate load indirectly.

The game works on the principle of competing teams that can consist of up to thousands of smart meters. The game publishes approximate information (for privacy reasons) of the consumption of their homes and players are trying to maintain the team-aggregated consumption below a threshold. The threshold is defined by the utility and enabling members of a team to compute their overall resource consumption and put it in comparison to the overall resource consumption of another team.

The authors of the work were genuinely concerned about privacy issues and the potential for misuse of personal information that every online activity faces. Based on the collected pieces of information about consumption in time and game selections, sensitive information about the player's habits and lifestyles can be derived. Because of the privacy concerns of the parties involved, they suggested a cryptographic framework for online gaming portal operated by a third-party entity.

4.3 Surveys

Lack of understanding of the real world of small-scale consumers can lead to critical mistakes that discourage consumers from new technologies that, although with good intent, can be missed, and the whole innovative technology could be abandoned due to the lack of interest of most users. P. Silva, S. Karnouskos [6] conducted a survey in 2012 on mostly European from Spain, Germany, France and Italy with small percentage from other parts of the world such as Egypt and Australia, to find out if the aforementioned switch from a passive consumer of electricity to a "prosumer" who will actively participate in maintaining the grid will be successful. The overview of the process is depicted in figure 11 where one can distinguish the following steps

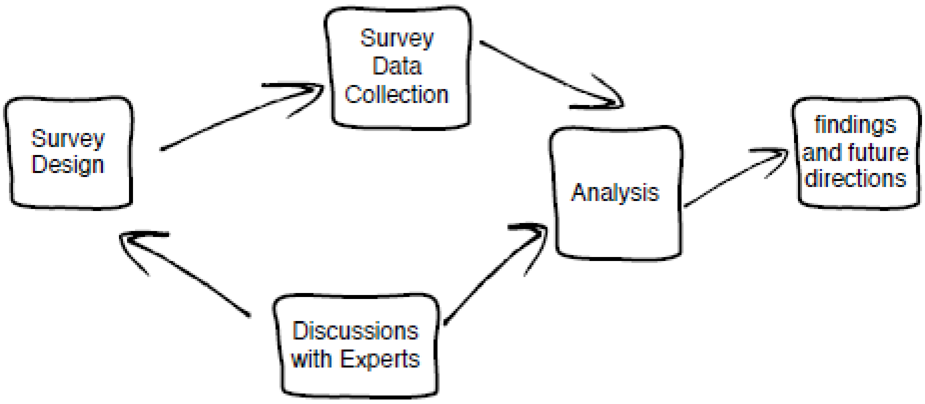


Figure 11: Overview of survey methodology (Source: IEEE, A survey towards understanding residential prosumers in smart grid neighbourhoods, 2012)

The survey was aimed at evaluation and understanding the interest, impact and willingness of prosumers and targeted at end prosumers of electricity in the residential sector, while no assumptions were made for their background. In figure 12 Is shown the part of the survey questions were pertaining the willingness of participants to modify their consumption behaviour based on external signals such as price and in figure 13 is shown the percentage of participants willing to pay more for green energy.

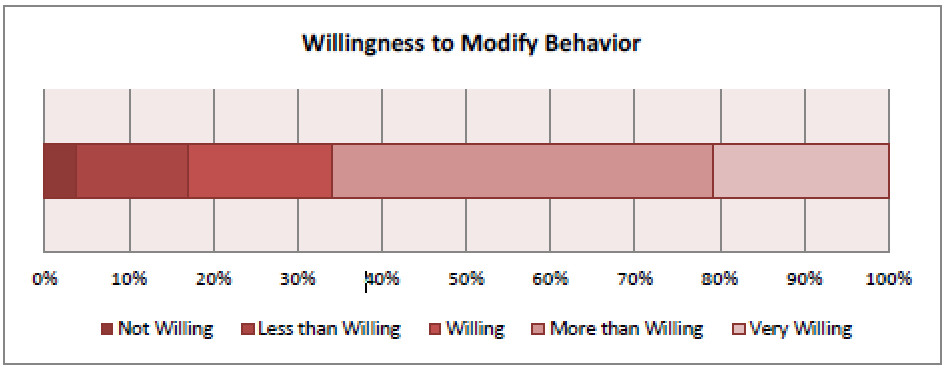


Figure 12: The willingness of participants to modify their consumption behaviour based on external signals such as price. (Source: IEEE, A survey towards understanding residential prosumers in smart grid neighbourhoods, 2012)

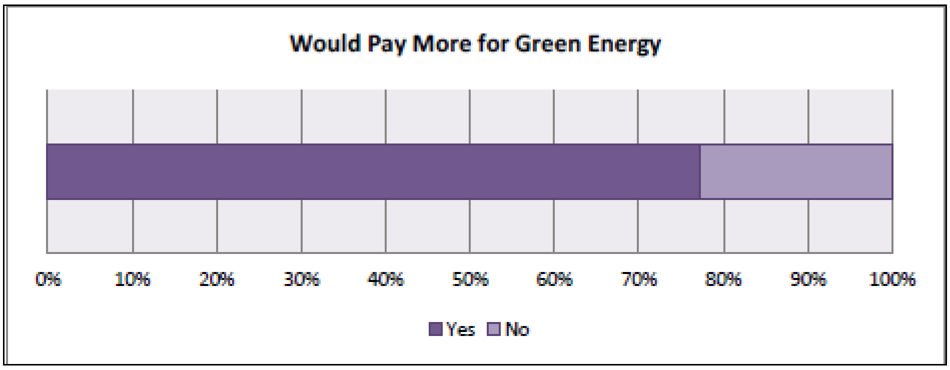


Figure 13: The willingness of participants to pay more for green energy. (Source: IEEE, A survey towards understanding residential prosumers in smart grid neighbourhoods, 2012)

As shown in figure 14 (bellow) in terms of community engagement, there is overwhelming support of the idea of sharing unused resources, especially in combination with financial bonuses. Additionally, about 2/3 of the prosumers are positive about participating in shared-interest groups via social sites or value-added services.

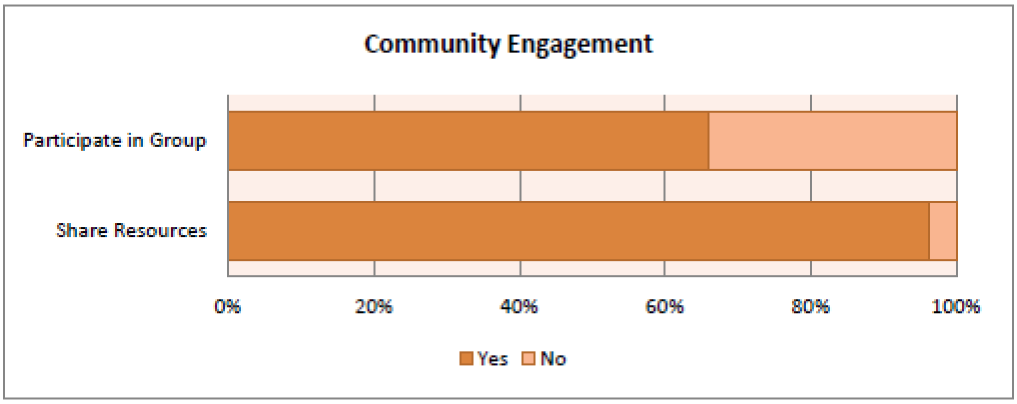


Figure 14: The percentage of participants willing to engage in their community to form groups and share resources. (Source: IEEE, A survey towards understanding residential prosumers in smart grid neighbourhoods, 2012)

With regard of participant's willingness to trade-off patterns in the field of exploiting their private information, by their retailer concerning reducing smart grid load forecasting errors etc. in exchange for financial incentives or bonuses, as depicted in figure 15 reveals that the majority of participants are willing to provide information about their energy-usage expectations to third parties. Unfortunately, only half of the respondents agreed with a provision of information about their behaviour pattern, for example work hours and vacations.

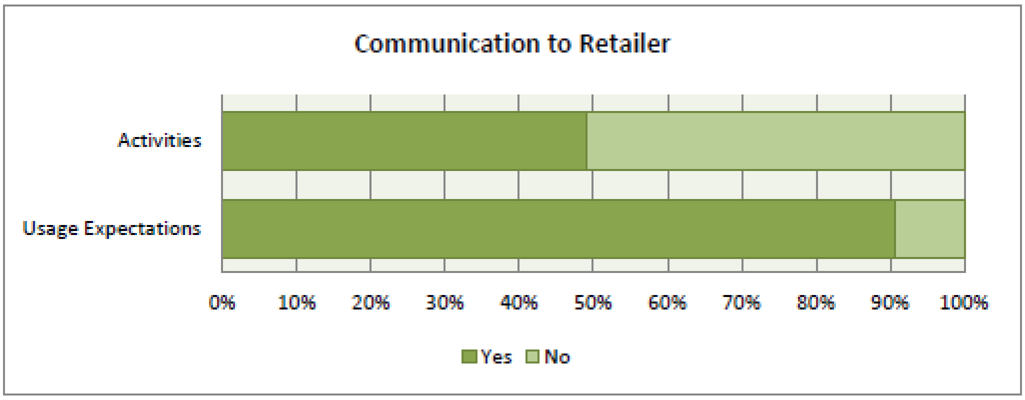


Figure 15: The percentage of participants that would communicate their activities and their usage expectations to their retailers(Source: IEEE, A survey towards understanding residential prosumers in smart grid neighbourhoods, 2012)

P. Silva, S. Karnouskos [6] suggest the creation of such a tool that would let participants model and understand their energy usage patterns so they could implement their usage expectations to retailers without revealing delicate privacy-infringing aspects.

The results of the survey show, that end-users desire for a detailed overview of the energy consumption by day, and by year and introduction to real-time or time-of-use (TOU), energy pricing seems suitable. The need for information about the generation mix, weather information and consumption forecasting was also prevalent. Over 70% of survey participants wanted to compare their energy behaviour with others in the scope of a smart neighbourhood, smart city or even at the regional and national level to couple them to ongoing efforts towards better energy management and sustainability efforts. The survey also shows that the users preferred monitoring way of this information would be via smartphones or Laptops/PCs (Fig: 16).

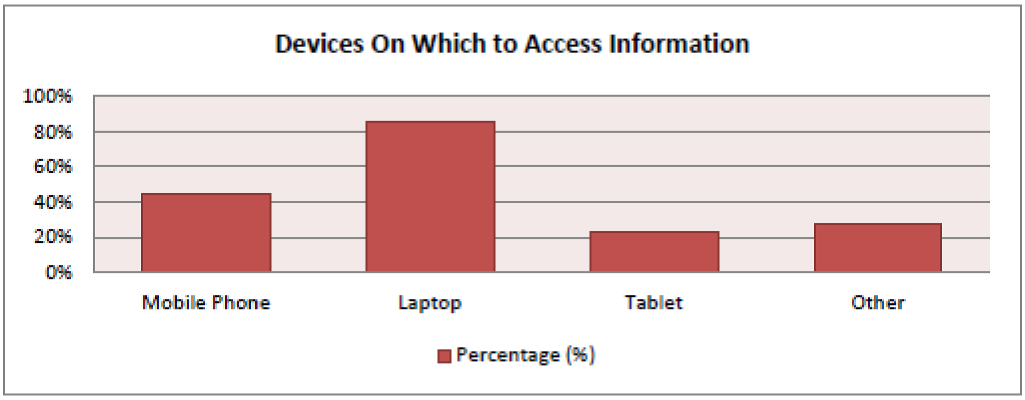


Figure 16: Participant preferred devices (Source: IEEE, A survey towards understanding residential prosumers in smart grid neighbourhoods, 2012)

In terms of social-sites or Value-added Services which are, according to the s expected pivotal according to the survey creators, expected to play a pivotal role in DSOs or retailer offerings, because they will serve as crucial system differentiators between competing stakeholders. As an example of social sites based services in survey presented are: end-users consumption comparison of similar households in the region, provision of retailers/DSOs suggestions on how to improve users behaviour, so-called bill shock service (Notify consumers when they are on the way to the account more significant than usual) and vacation services (Consumer's alert when there's unexpected energy usage in the house during the set period)

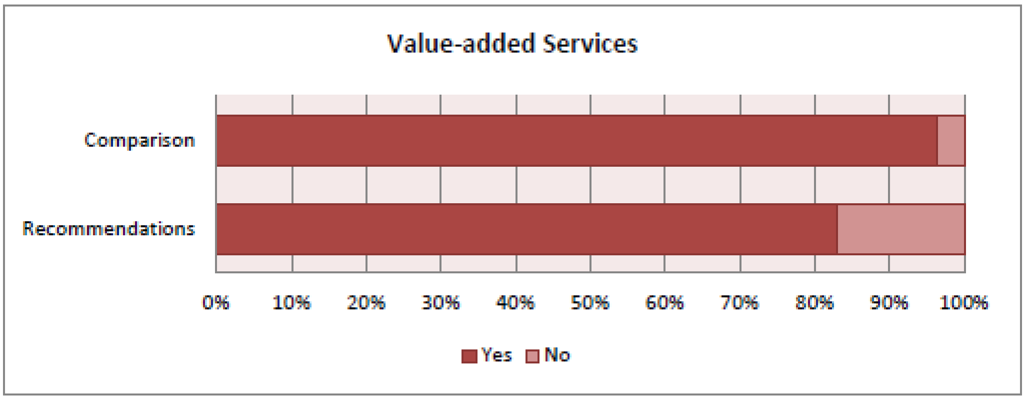


Figure 17: The percentage of participants that would like value-added services. (Source: IEEE, A survey towards understanding residential prosumers in smart grid neighbourhoods, 2012)

As can be seen in Figure 17, there is a tremendous level of interest in value-added services. The study implies that innovative online services could be created and use this data to create value for the customer and deliver service in the same way, how Facebook and Google works.

5 PRACTICAL WORK

In April 2019, I have conducted a survey that participated in 127 people, mostly from the southern part of the Czech Republic. The main goal of the conducted survey was to analyse, whether and to what extent would be accepted the implementation of a social aspect to the smart city technology. Some of the questions focus on whether would be participants interested in better tools to monitor understand and manage their electricity consumption. The issues of how the future smart city residential prosumer will benefit from the future smart grid services and what trade-offs s/he will be willing to make are hot topics.

5.1 Methodology

I divided the questionnaire into several parts. The first part focuses on collecting the demographic data of the interviewees and in the following three parts, I find information on the topics.

In the first part, I tried to find out participants attitude towards their electricity consumption, ecological consciousness and likeliness of contribution on new eco-friendly approaches.

Second part of questionnaire focuses on household electricity consumption control and their effects on participants electricity consumption, willingness to contribute to peak load reduction (acceptance of variable rates). The questionnaire also deals with effects of behavioural psychology (whether the consciousness of the electricity-saving neighbours would motivate the questionnaire participants to take the same habits) and whether they would be interested in economic measure packet or electricity saving tips.

The third part focuses on the properties of emerging electricity focused social and the likelihood of utilising them by questionnaire participants. I also ask whether would be participants of questionnaire interested in participation on possible charitable and non-charitable electricity saving competitions.

The last question of the first and second part of the questionnaire will end the questionnaire if the answer is negative. Due to this measure, the third part of the questionnaire contains 100 participants and fourth only 33.

5.2 First part

The participants I have questioned are living mostly in rented flat or house in private ownership; only 24 percent respondents stated, that they live in flat in private ownership. Only 7 percent of questioned own air conditioner or other above standard high energy demanding appliances or electronics such as electric heating, pool or sauna. 63 percent of questioned stated their electricity usage as low.

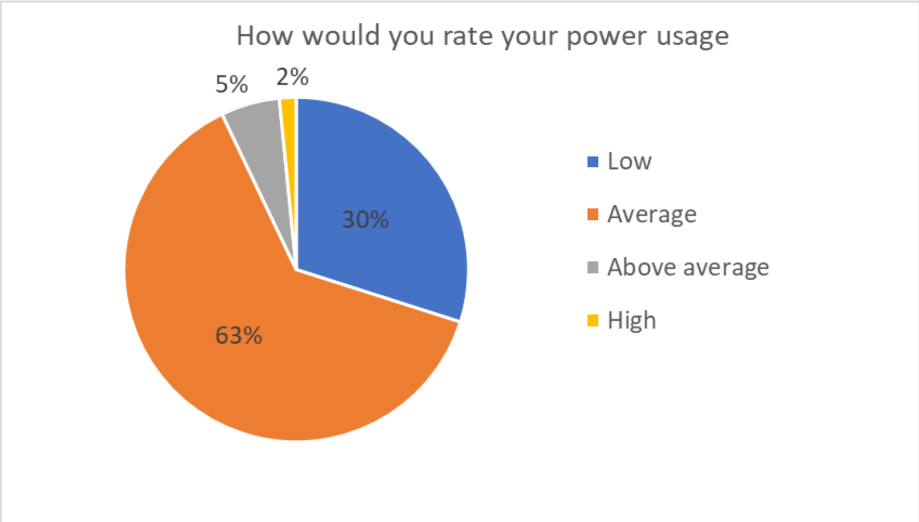


Chart 1: How would you rate your power usage?

Most of the questioned participants stated financial factor as their most powerful means in motivation to save electricity, even though the 83 percent of questioned stated that they are aware that saving electricity helps the environment as much as waste sorting.

Survey shows that women (almost 50 percent of questioned women) rather than men voted for environmental protection to be their most powerful motivation to save electricity. With comparison to the occupation of questioned it seems interesting that 80 percent of currently employed participants stated, that they would find financial factor the biggest motivation.

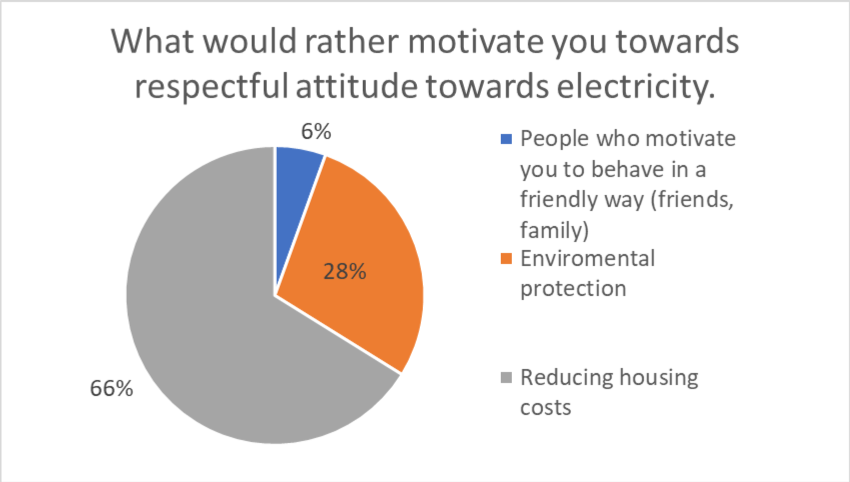


Chart 2: What would rather motivate you towards a respectful attitude towards electricity.

The remaining 20 percent of the votes consisted of most students. More specifically, 47 percent of the students voted yes. The phenomenon persists in the next question, where I ask whether they would pay more for green energy (electricity that would come from environmentally friendly resources) and 47 percent of the students voted yes

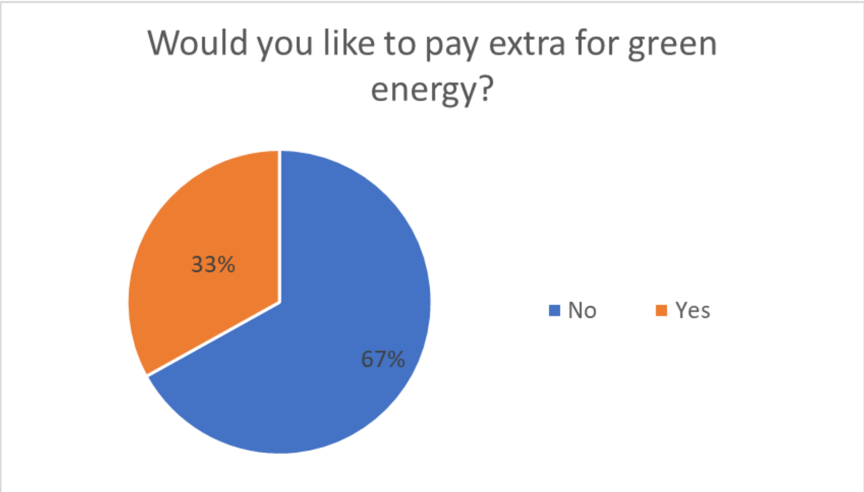


Chart 3: Would you like to pay extra for green energy?

Saving electricity by switching off appliances or electronics which consumer do not use at the time and which therefore does not contribute to the well being of a consumer is an excellent opportunity for utilities to focus on to reduce overall electricity demand.

On the question of whether the participants were able to save electricity without taking account of their comfort, 26 percent responded that they are sure about it and 42 percent were quite sure about it. This information tells us that with some incentive or encouragement, the utilities would be able to encourage gentle behaviour towards household electricity consumption.

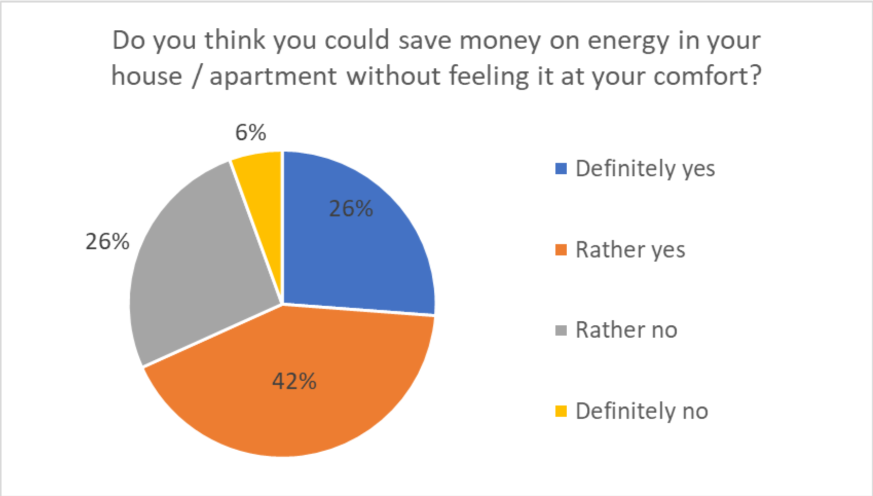


Chart 4: Do you think you could save money on energy in your house / apartment without feeling it at your comfort?

The answer to the question of how could small household consumers participate in relief of electricity demand is not easy to answer. With the supply of useful information through social sites about actual levels of electricity demand, it is possible to influence consumer behaviour. In this regard, there is another way, and that is a promotion of installation small scale renewable source of energy in the form of solar panels or household cogeneration system which would cause part of a demand to move out of the grid.

I have asked participants whether they would agree with installation some of these systems in their home even if they would get no economic savings but could contribute to more conservative treatment of electricity and less environmental damage.

As can be seen in the chart, the majority of participants would definitely or rather agree with the installation of such devices. It shows a potential opportunity to suppress growing peak demand by subsidising renewable household solutions.

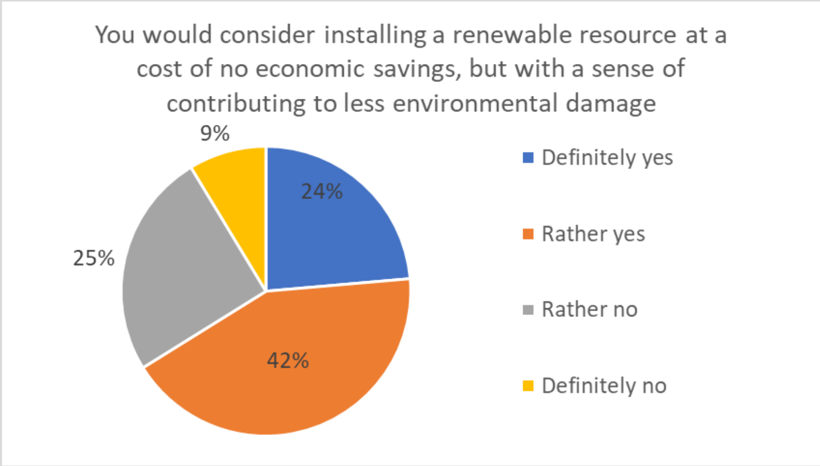


Chart 5: You would consider installing a renewable resource at a cost of no economic savings, but with a sense of contributing to less environmental damage?

When the answer to the last question of this part is negative, the questionnaire will end itself at that spot. For this reason, only 100 respondents voted in the third part of the questionnaire.

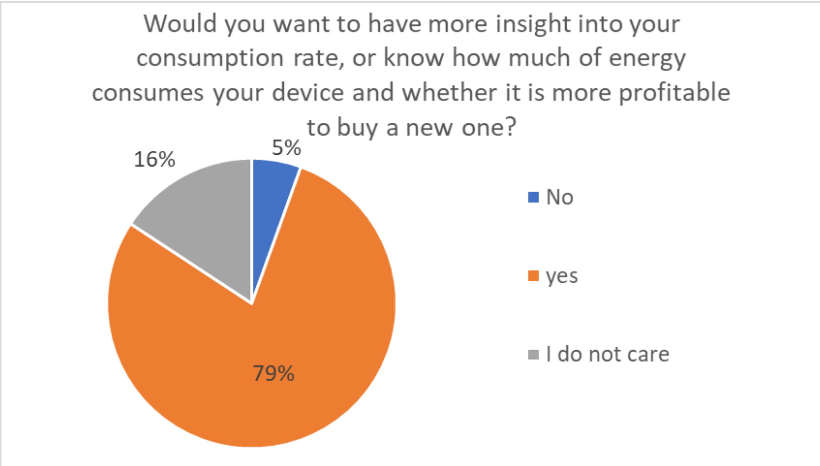


Chart 6: Would you want to have more insight into your consumption rate, or know how much of energy consumes your device and whether it is more profitable to buy a new one?

5.3 Second part

In the second part, I wanted to find out, for those who wanted more monitoring of electricity consumption, what they expect from such a service tool. I questioned participants about whether they would appreciate variable rates of electricity, which would reflect the actual value of electricity on the market. I also questioned participants about the reacting on the scenario of neighbour saving more energy presented in abovementioned research of Alex Laskey.

In terms of means of controlling household's consumption the mobile application was chosen by 41 percent of questioned, followed by In-Home Display with 32 percent and as the least favourite was chosen web application accessible from pc or mobile phone. It is interesting to mention that the participants with high education voted massively for mobile application.

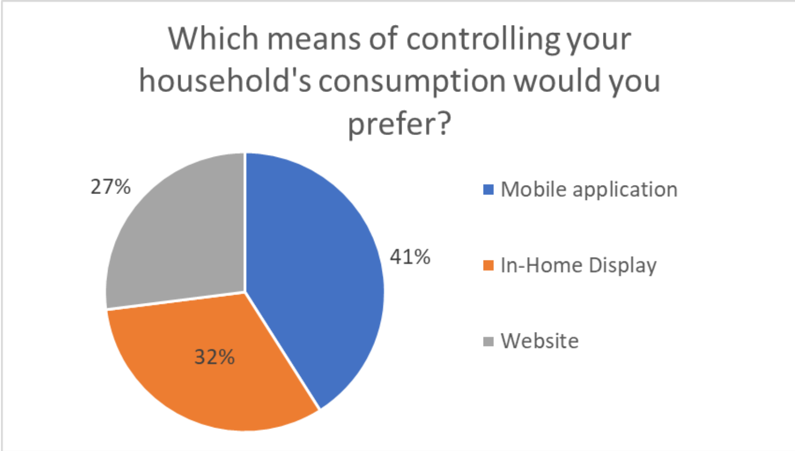
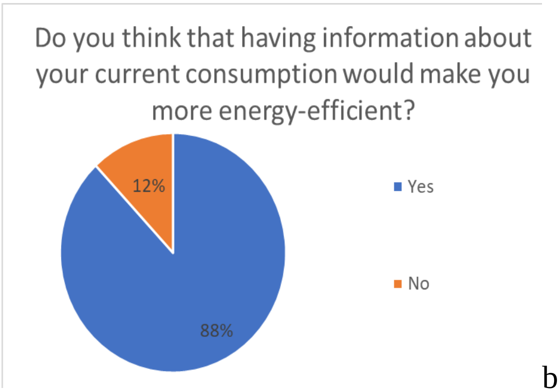


Chart 7: Which means of controlling your household's consumption would you prefer?

The question of whether the participants would be more thoughtful towards using electricity if they were able to monitor current energy consumption responded 88 percent positively. It is interesting to mention that all questioned women answered yes to this question. Most of the highly educated participants also agreed. Result of this question indicates that enabling the real-time consumption tracking of electricity would be appreciated by citizens and therefore, smart meter roll-out acceptable progress in grid development.

a.)



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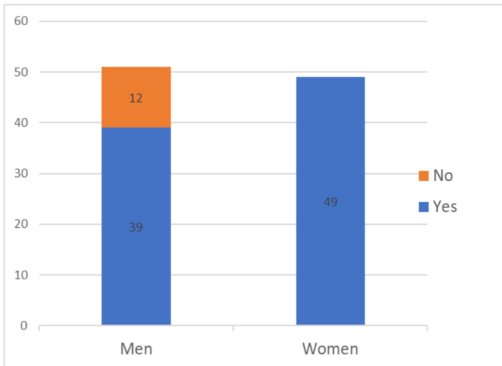


Chart 8: a.) Do you think that having information about your current consumption would make you more energy-efficient? b.) comparison of men and women

The subsequent question is also unequivocal. On the question of whether the participants would want variable rates responded positively 91 percent of participants. Compared to the occupation, only 4,5 percent of the working class would not appreciate a change of fixed rates to the variable ones. The same number of participants who wanted variable rates also agreed to that when would it happen, they will shift the suspensory consumption to part of the day when electricity demand would be the lowest.

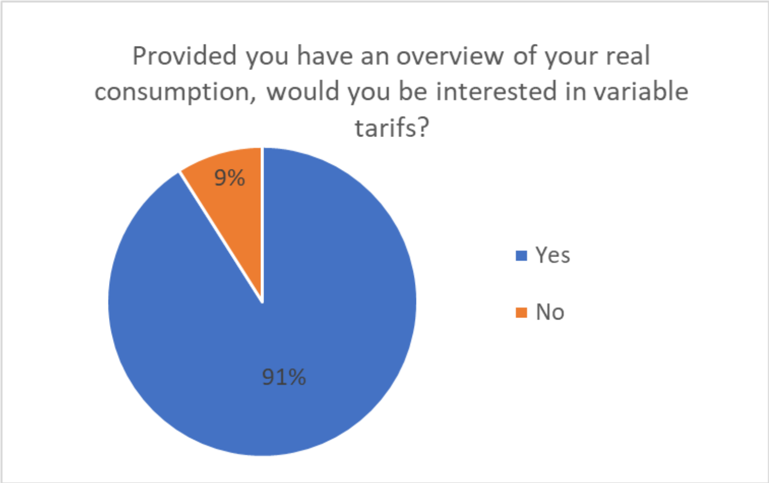


Chart 9: Provided you have an overview of your real consumption, would you be interested in variable tarifs?

In the following four questions, I try to find out if the interviewee's behaviour could be positively influenced if he knew that people in his vicinity would save energy whether he would like the picture of him saving more energy than their neighbours and whether they would want to inspire or motivate other people by presenting their consumption assuming that his consumption data will be summarized in the "efficiency ratio"

In the first question, whether the information about current consumption would make participants more gentle about electricity answered yes 88 participants. On the following question, I asked if participants would like to know if their neighbours are saving more electricity. Positive voices fell to 68 percent. The highest share of negative answers comes from the group of university graduates. Unlike in a first question where roughly 96 percent of students agreed to, followed by secondary school educated and all respondents with primary education answered the question negatively.

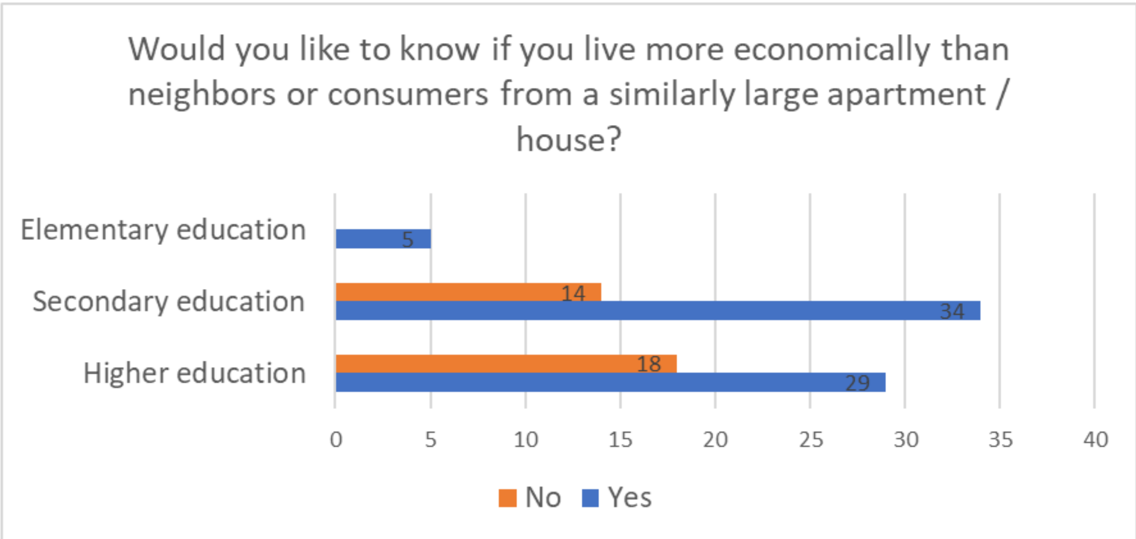


Chart 10: Would you like to know if you live more economically than neighbors or consumers from a similarly large apartment / house?

The participants were asked what they would do if they knew that their neighbours were saving more electricity than they were, would the situation motivate participants to be more electricity-efficient? 55 percent of participated answered negatively. As can be seen on the charts below, most women and students responded positively to the question, on the contrary majority of negative votes comes from employed participators and men.

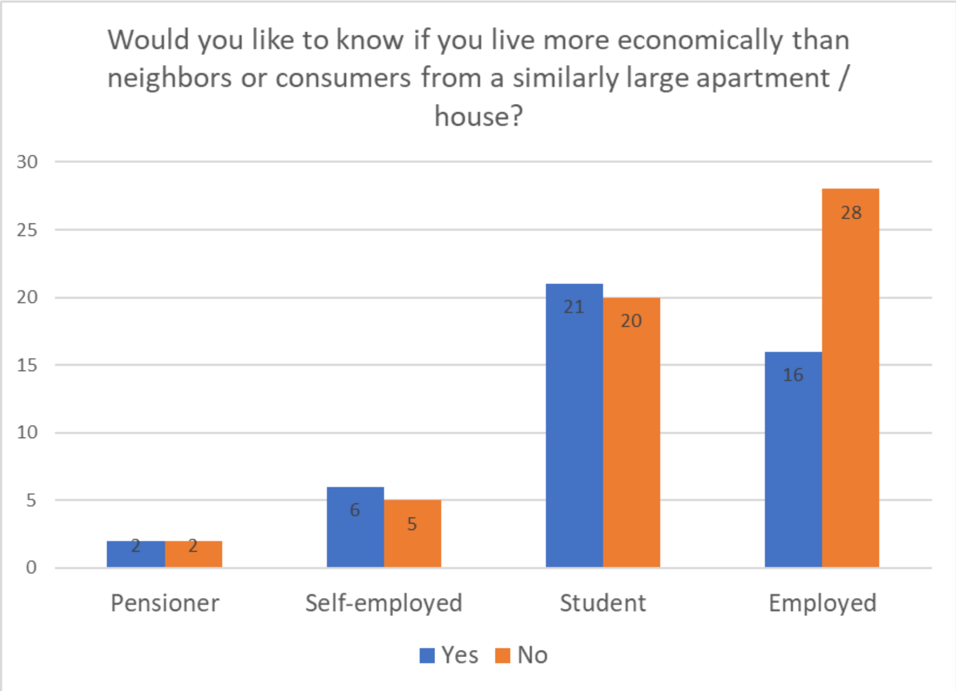


Chart 11: Would you like to know if you live more economically than neighbors or consumers from a similarly large apartment / house? (Comparison by occupation)

Chart 12: Would you like to know if you live more economically than neighbors or consumers from a similarly large apartment / house? (Comparison by gender)

The 82 percent of participants agreed that they would be interested in a personalised offer of austerity measures designed with the use of their consumption data. Participants in this question showed interest in education in the electricity savings field.

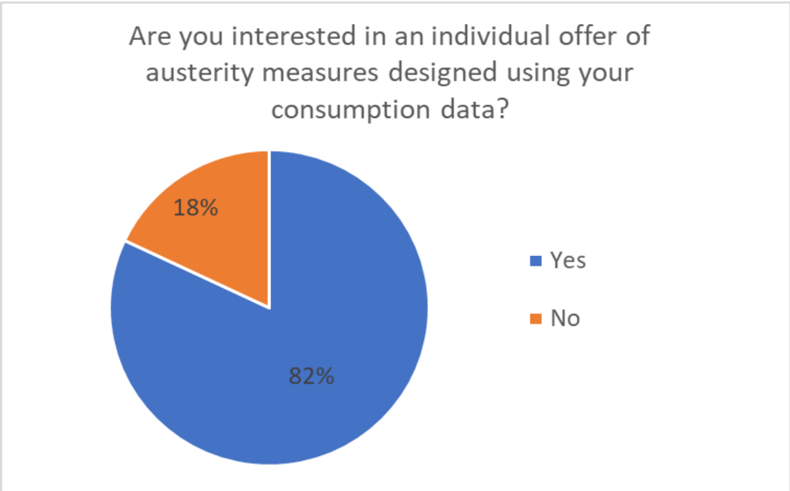


Chart 13: Are you interested in an individual offer of austerity measures designed using your consumption data?

The participants responded negatively to the question whether they would be interested in such social site (shown on the chart) even though the almost half of participants (48) desired to share their consumption data and thereby became an inspiration to others. The greatest number of positive votes was held by graduated students, although they had mostly negative answers too.

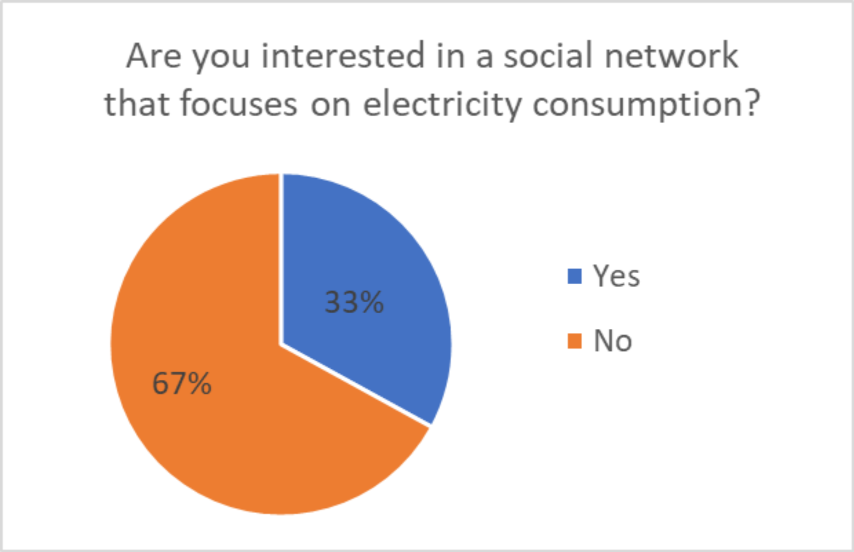


Chart 14: Are you interested in a social network that focuses on electricity consumption?

When the line of questions approaches the main part of the questionnaire, there is observable a growing trend of negative responses to topics involving personal privacy and resistance to the main ideas of social networks in the energy sector.

When the answer to the last question of this part is negative the questionnaire will end. For this reason, only 33 respondents voted in the third part of the questionnaire.

5.4 Third part

The last part of the questionnaire focuses on the features of possible social networks described in the studies mentioned above.

The first question was if would participants prefer energy consumption oriented social site in the form of a programme layer on top of the usual social site such as Facebook, or Instagram, or whether they would prefer new social sites focused preferably to the energy consumption. Most of the participants were inclined to create a brand new application.

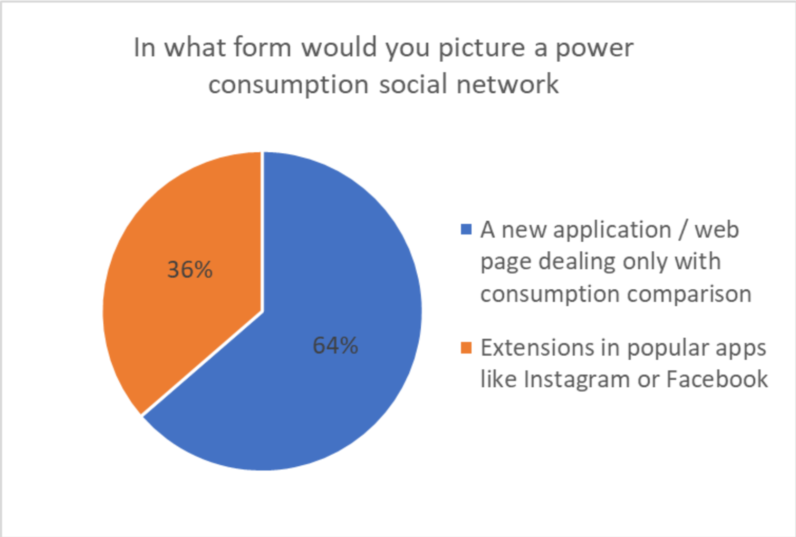
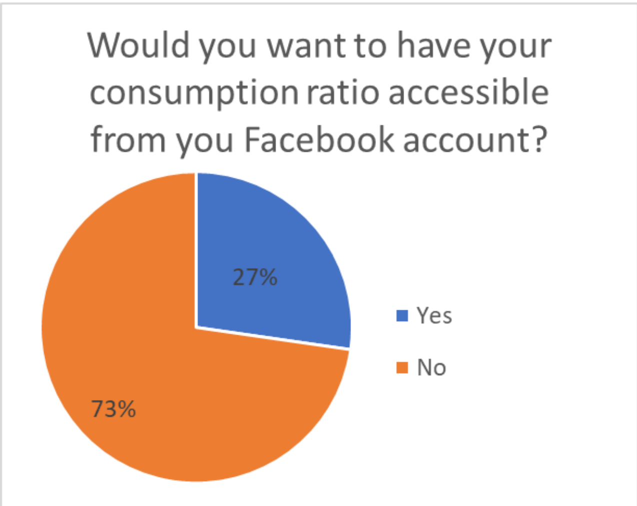


Chart 15: In what form would you picture a power consumption social network

The next question was if the participants would want to share their consumption ratio on Facebook wall. As can be seen on the chart, 72 percent of participants answered negatively. Although about 53 percent of women would not have a problem sharing their consumption over the internet.

a.) 

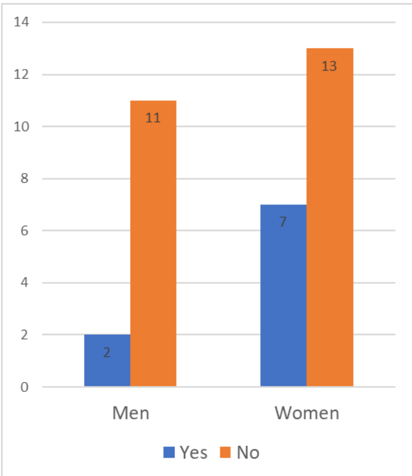
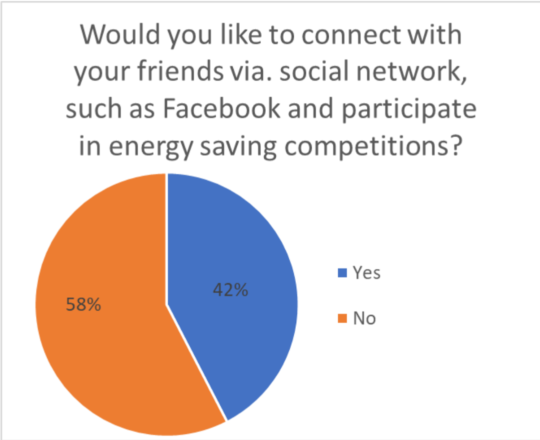
b.) 

Chart 16: a.) Would you want to have your consumption ratio accessible from your Facebook account? b.) Comparison by gender.

The next question builds on the previous question by asking if the participants liked to participate in the energy-saving events through the Facebook platform. 58 per cent of participants does not like this idea. More than twice, as many positive votes came from women. Through the progress of the questions, we can notice the increasing disinterest of participants in sharing their electricity consumption through social networks. 24 percent of participants disagreed with publishing their personal consumption on

Facebook, but would like to participate in energy-saving events. All such voting participants were of higher education, which indicates that people with higher education are more concerned about sharing their personal information over social networks.

a.) 

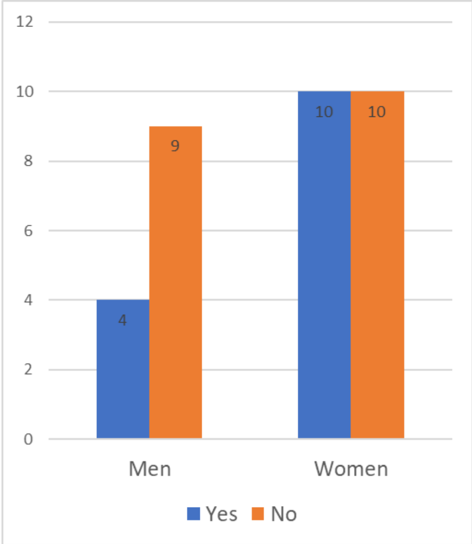
b.) 

Chart 17: a.) Would you like to connect with your friends via social networks, such as Facebook and participate in energy saving competitions? b.) Comparison by gender.

As was mentioned on page 16, some research projects are dealing with the idea of the creation trade market for consumers to trade with each other in the common grid. So the last question was whether the participants would want to sell or purchase electricity through such a network. Even though the yes or no ratio stays the same as in the previous question, 12 percent of respondents from each question answered differently. Respondents who expressed interest in participating in energy-saving competitions but were not interested in trade with energy were women

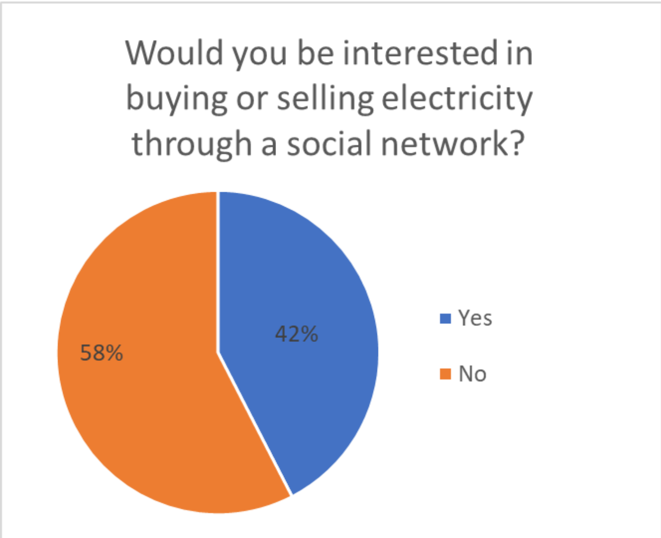


Chart 18: Would you be interested in buying or selling electricity through a social network?

6 CONCLUSION

We live in a world where we can not imagine life without electricity. This world is changing rapidly in terms of energy. Effects of global warming are more and more visible, which motivates a positive attitude towards sustainable energies.

It is, therefore, possible to monitor an increase in the share of renewable energy. These renewable energy sources are uncontrollable and weather dependent, so our electricity system will sooner or later have to adapt to the growth of small renewable power plants spread throughout the country.

With this impact, grid stability will worsen, and the need for better control and measurement of the network will grow. The best way to deal with this problem is to rebuild the current power grid to a more efficient, better positioned and manageable "smart grid". Such smart grid will support smart metering technologies, with features like measurement of the instantaneous consumption of every single household or even part of a household involved in the network, which enables consumers to oversee their consumption. With features like that will everyone have the opportunity to contribute to the stability of a grid.

According to the studies presented in this thesis, the application of behavioural science could be a great way how to support more energy gently approach between the household electricity consumers. Social sites appear to be the best medium for this application. For this reason, I created a social network questionnaire. The goal of the survey was to gauge how willing Czech people would be to change their habits within energy saving. What would be the best motivation to do so. Whether and to what extent consumers would like to contribute to energy savings through social sites and what kinds of information they would like to access.

The major insights analysed in the first part of questionnaire shows, that questioned participants do care about the environment (the majority do sort waste and do think that saving electricity is as much important) and would want to behave more environmentally friendly, yet they do not want to invest any extra money to this process. The majority of 66 percent of the voters stated that the most motivating means to save electricity would be to save money and only 28 percent would do it primarily for environmental reasons. When the money factor would be out of the equation, 65 percent of the questioned would undergo efforts to become more environmentally friendly. 68 percent said that they could save electricity by turning off electrical appliances and lights in the moments they did not need them. This information tells us that with some incentive the utilities would be able to encourage gentle behaviour towards household electricity consumption.

The social factor as the strongest incentive that drives most of the studies on electricity social networks reviewed in this work was not confirmed in this section.

The second part of the questionnaire shows that the majority (79 percent) of participants want a better level of understanding of their electricity behaviour. They have no concrete preferences for the nature of devices they want to access that information on — only the university graduates voted massively for the option of the mobile version of the application.

The major insights analysed in the second part of the questionnaire shows that 88 percent of participants claim that if they had the information on current electricity consumption, they would save more electricity. With electricity consumption monitoring, electricity will become more tangible than paying once or twice a year. An even larger number of respondents (91 percent) claimed that they would want variable electricity rates to be able to pay less for electricity consumption in times of low power load because they would be rewarded for shifting the suspensory consumption to the part of the day when electricity demand would be the lowest. This consensus of the majority suggests that citizens are interested in contributing to energy savings and reducing the environmental impact of its harsh production. This observation shows participants interest in smart meter roll-out and the introduction of variable rates.

The opinion of the interviewees about the basic features of social networking was not so positive. The ability to know the consumption coefficient of a friend/neighbour was mostly welcomed (68 percent), but answers to whether this information, under the condition that participants have higher energy consumption, would motivate participant towards gently electricity behaviour were mostly negative. Even though the participants mostly liked the idea of saving more energy than their neighbours/friends, a slim majority of the questioned participants did not want to share their consumption ratio online, even though they could inspire others towards more gentle behaviour.

The biggest advocates of social networking in the energy sector were surprisingly women with university education; men with secondary education expressed the least interest. Due to a large number of negative responses (77 percent) to the elimination question of whether respondents would be interested in a social network, only 33 respondents get to the last part of the questionnaire. This suggests that although there is currently no technical barrier to implementing a similar system, the current population is not inclined to share such data. Rejecting attitudes came from all circles from employed people to students. This is probably because social networks are a novelty which part of the population has missed. It is also possible that the concept of energy sharing is still too difficult to grasp today.

For the reasons mentioned above, it does not make sense at this time to build a social network with an energy sharing system. The current population does not seem to be ready. However, we can see great interest in the application of power monitoring with features such as conversion of current electricity consumption to crowns per hour, tips on saving energy or even monitoring network load.

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