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Limiting Privacy by Using Smart Meters – Information Security Perspectives

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Purpose:

The purpose of this paper is to present the key features of smart energy meters, their strengths and weaknesses. In addition, the paper aims at establishing how they interfere with user privacy and determine the users' level of awareness.

Design/Methods/Approach:

For the purpose of this paper, existing literature was reviewed and analysed, and a questionnaire was distributed in a digital form. 229 respondents participated in the survey.

Findings:

It has been found that smart energy meters collect very accurate information about users' electricity consumption at short intervals. The information can then be used to identify devices, identify the presence or absence of people, their habits and activities. According to the survey results, the awareness among people using smart energy meters is low.

Research Limitations/Implications:

The limitations stem from the survey sample, as only people who are users of online social networks, e-mail and internet messaging applications (Viber, WhatsApp) were included in the survey.

Practical Implications:

The paper presents key findings in the field of smart energy meters and their potential for compromising individuals' safety and privacy. The paper discusses different ways in which energy consumption information can be exploited and used to harm users, as well as methods for establishing a secure and reliable network.

Originality/Value:

Due to the increasing share of smart energy meters installed in Slovenia, there is an increasing risk of privacy intrusions and threats to the safety of individuals. The research findings will help increasing users' awareness about smart energy meters and prevent potential abuse of their data.

UDC: 004.056

Keywords: smart meters, information security, privacy, energy consumption

Omejevanje zasebnosti s pametnimi merilniki – informacijskovarnostni vidik

Namen prispevka:

Namen prispevka je predstaviti ključne lastnosti pametnih merilnikov energije, njihove prednosti in slabosti ter ugotoviti, kako posegajo v uporabnikovo zasebnost in kakšno zavedanje o tem imajo ljudje.

Metode:

Za namen članka je bila pregledana in analizirana obstoječa literatura ter posredovan vprašalnik v digitalni obliki. V raziskavi je sodelovalo 229 anketirancev.

Ugotovitve:

Ugotovljeno je bilo, da pametni merilniki energije zbirajo zelo natančne informacije o uporabnikovi porabi električne energije na kratkih časovnih intervalih. Z informacijami se lahko nato identificirajo naprave, ugotavlja prisotnost ali odsotnost oseb, njihove navade ter dejavnosti. Glede na rezultate ankete je med osebami nizka ozaveščenost o pametnih merilnikih energije.

Omejitve/uporabnost raziskave:

Omejitve izhajajo iz raziskovalnega vzorca, saj so bili v anketo vključeni le uporabniki spletnih družabnih omrežij, elektronske pošte in internetnih aplikacij za sporočanje (Viber, WhatsApp).

Praktična uporabnost:

V prispevku so predstavljene ključne ugotovitve na področju pametnih merilnikov energije in njihov potencial za ogrožanje varnosti ter zasebnosti oseb. Prikazani so načini, kako lahko informacije o porabi energije izkoristijo in uporabijo za škodovanje uporabnikom, ter načini za vzpostavitev varnega in zanesljivega omrežja.

Izvirnost/pomembnost prispevka:

Zaradi vse večjega deleža nameščenih pametnih merilnikov energije v Sloveniji obstaja vedno večja verjetnost za poseg v zasebnost in ogrozitev varnosti oseb. Ugotovitve raziskave bodo pripomogle k večjemu ozaveščanju uporabnikov o pametnih merilnikih energije ter možnih načinih zlorabe njihovih podatkov.

UDK: 004.056

Ključne besede: pametni merilniki, informacijska varnost, zasebnost, poraba energije

1 INTRODUCTION

Technological development contributes to the introduction innovations and novelties in every sphere of our day-to-day lives. Numerous devices have been transformed from the analogue to the digital format. Wireless technologies used for sending and receiving information, as well as internet services are widely used today. Thus, our personal data are becoming less private and ever more public.

Such a transition to the latest technologies is also observed in the field of energy (Véliz & Grunewald, 2018). In the past, analogue meters were mostly used to measure household energy consumption. However, the emergence of smart homes and smart networks also contributed to the modernisation of systems and devices (Souri, Dhraief, Tlili, Drira, & Belghith, 2014). Due to the increasing demand for electricity, the development of the energy sector has been focusing on optimisation, which means that power plants usually generate as much energy as necessary to meet consumers' demand. In doing so, they are lowering their impact on the environment and cutting the costs for consumers. Smart energy meters are one of the most prominent innovations in this respect, since they are designed to achieve efficiency, reliability and safety (McLean, 2016).

Smart energy meters represent a step towards the modernisation of electricity grids. They are devices designed to supply the information regarding energy consumption to both consumers and providers or energy services in a fast, efficient and reliable manner (Horne, Darras, Bean, Srivastava, & Frickel, 2015). While analogue meters only provide energy consumption data at the end of each month, smart meters are able to transmit such data every hour, minute or second. Thus, they provide accurate information on how many watts or kilowatts of electricity an individual consumes at a specific time and place. In this context, large quantities of sensitive data are being collected, which represent a significant challenge for managing such data and safeguarding user privacy (Asghar, Dán, Miorandi, & Chlamtac, 2017; McKenna, Richardson, & Thomson, 2012).

2 USE AND IMPLEMENTATION

Due to technological developments and the increasing environmental awareness, the use of smart meters across the globe has been dramatically increasing. EU Member States have already introduced such smart meters. By 2020, smart meters are estimated to replace 80% of all meters or metering points. In the EU, approximately 182 million smart meters will be installed in the period between 2016 to 2020, amounting to an investment of USD 37.8 billion (Sprinz, 2018).

The main reasons for the implementation of smart meters in EU Member States arise from the commitments made when adopting an EU Directive (Directive 2009/72/EC) and the desire to boost energy efficiency and grid modernisation. This will contribute towards a significant growth in the quantity of user-related data. Before introducing smart meters and grids, Member States must adopt appropriate legislation (privacy and data security) and roll-out plans, as well as conduct cost-benefit analyses. The trend of smart meter implementation in the EU has been rising steadily, however, the rate of their introduction varies greatly among Member States (European Smart Grids Task Force, 2016; USmartConsumer, 2016).

Certain countries, such as Finland, Spain, Sweden, Estonia and Malta, have already completed their smart meter implementation, adopted suitable legislation and support policies, and provided for an adequate regulation of information collected from energy consumers. Thus, they have removed (almost) all barriers and are providing various services to consumers. Other countries, such as Austria, France, Ireland, Norway, Poland and Slovenia, have embarked on a clear path towards a complete roll out of smart meters and have already started or plan to start introducing smart meters and offering related services. In Cyprus and Poland, smart meter implementation is not prescribed by law, however, they are being installed because state bodies and energy companies see them as an advantage or because of consumer demand. Countries, such as Germany, Greece, Hungary and Romania, have already adopted the necessary legal bases, albeit only some distribution system operators (DSOs) in these countries decided to implement smart meters. Last but not least, countries, such as Bulgaria, Croatia, Czech Republic, Latvia, Lithuania and Slovakia, have shown an interest in smart metering, however, corresponding initiatives are still in relatively early stages of development (European Smart Grids Task Force, 2016; USmartConsumer, 2016).

In the USA, the number of smart meters started growing rapidly after 2007. In 2016, 72 million smart meters were installed, which represented 60% of all households in the USA. By the end of 2020, the total number of smart meters is estimated to reach around 90 million (Zheng, Gao, & Lin, 2013).

3 FUNCTIONS AND BENEFITS

Every individual feature offered by smart meters is considered as an advantage when compared to conventional energy meters, as they allow for several potential applications. The benefits of smart meters are multifaceted, as they not only bring advantages at the level of individual users, but also in terms of power transmission and distribution, marketing, grid load forecast, billing, etc. (Asghar et al., 2017; Kabalci, 2016).

The functions of modern smart energy meters include (Sun et al., 2016; Zheng et al., 2013):

- bi-directional communication between energy suppliers and consumers;
- data collection and storage;
- automatic and two-way metering and service charging;
- detecting and diagnosing systemic errors;
- load management.

All of the aforementioned functions produce improvements at various levels, which is why they can be divided into the following three sets of benefits.

Benefits at the level of consumers (Sun et al., 2016; Zheng et al., 2013):

- access to and insight into electricity consumption data, which allows consumers to review the available data and thus manage their electricity consumption more efficiently;
- more accurate and timely information regarding electricity consumption and billing;
- faster power restoration in the event of power failure;
- possibility to delay/defer high electricity-consuming devices to specific time slots during which the price of electricity is more affordable.

Benefits at the level of energy management and distribution (McKenna et al., 2012; Sun et al., 2016; Zheng et al., 2013):

- better energy managements during peak demand;
- higher efficiency with respect to energy consumption and the use of energy resources;
- larger quantity and better quality of data necessary for grid load forecasting and decision-making;
- error and energy theft detection;
- reduction of costs related to data acquisition.

Benefits at the level of environmental protection (Sun et al., 2016; Zheng et al., 2013):

- higher investments into renewables;
- reduced impact on the environment or lower CO_2 emissions.

Smart energy meters represent a significant step forward in comparison with electromechanical meters. Due to their aforementioned benefits, they promote progress in the field of further development of electricity grids. It is estimated that smart meters will soon be installed in every building. By acquiring data directly from consumers, which takes place every single day, usually at an 1–60 minute interval, they enable the creation of specific consumer profiles, thus providing for a more accurate forecast and better management of grid demand (Sun et al., 2016). This leads to more efficient electricity grids and reduced energy consumption.

4 CONSUMER PRIVACY

The previous chapter focused on the advantages and benefits of smart energy meters. While they contribute to reduced energy consumption and thus lower the adverse impacts on the environment, the security and privacy of grid users must not be neglected. In fact, security is one of the most important goods, which one becomes fully aware of only after it is gone.

The advantages of technological innovations may be observed in all spheres of life, however, such innovations also decrease the potentials for preserving one's privacy. The ever greater presence of smart energy meters brings about certain threats, which may jeopardise individuals' privacy and security (Hou, Qu, & Shi, 2019).

Smart meters usually record and collect data at an interval between 15 and 60 minutes. They also enable metering at the interval of one second. The efficiency and reliability of such grids depend on the metering interval. At the same time, the metering interval corresponds to the quantity and accuracy of data regarding individual consumers and their households. By way of comparison, conventional electromechanical meters submit a single total sum of energy consumption for the whole month, while smart meters perform between 24 and 100 (or more) measurements in a single day, which corresponds to approximately 750–3,000 measurements per month. When data regarding the power usage of various devices in individual households is submitted at such frequent intervals, it may be used to reveal occupants' habits and behaviours (Harvey, 2014). Devices and appliances that are consuming energy at certain points in time can also be identified. In fact, different devices and appliances are drawing power in different or rather unique ways – for instance, a refrigerator or water heater draws power in a different way than a television set or a radio. As a result, it is possible to develop a unique energy consumption pattern of activities performed by household occupants (McLean, 2016).

Smart energy meters collect extremely accurate information on the consumers' electricity consumption at very short time intervals. Therefore, it is possible to obtain data regarding the quantity of consumed energy in Watts and the time at which a certain quantity of energy had been used. This allows for the monitoring of consumers' activities in their own homes, the monitoring of their habits and the identification of appliances and devices in the household. A simple overview of the metering performed by a smart meter allows one to clearly identify the activity of household occupants; energy consumption is generally steady during the day but peaks when the user is active within the home

Smart meters could thus be used to monitor individuals' activities not only at home, but also at the workplace. The intrusion into one's privacy at the workplace may occur in various ways: by checking e-mails, controlling internet activity and phone calls, video surveillance, etc. (Lobnikar & Golmajer, 2016). Smart energy meters could serve as a stealth method of establishing, for instance, whether individuals are actually at their place of work, etc. Naturally, the accuracy and level of detail of such data depends on the interval of smart energy metering.

In their study, Greveler, Glösekötterz, Justusy, and Loehr (2012) found that taking measurements at an interval of two seconds is sufficient to identify which television programme an individual is watching, provided there are no major interferences of other home appliances. By measuring and testing the power consumption of a television set and monitoring the sequence of pictures it shows, researchers were able to use the RGB colour notation to accurately identify which channel or film an individual was watching.

Data on energy consumption may be used for different purposes (Farokhi & Sandberg, 2018; McKenna et al., 2012):

- Illegal purposes:
    - persons wanting to break into a household to perform a robbery would have precise knowledge of the owners' absence; and
    - stalkers could easily follow and monitor their targets at home and would be able to tell if they were home alone.
- Advertising purposes:
    - on the basis of collected data, targeted/behavioural advertisements could be published in a certain time-frame, i.e. while the person concerned was at home. On the basis of energy consumption data, consumers could be bombarded with advertisements of devices and appliances boasting lower energy consumption, etc.; and
    - insurance undertakings could monitor and adapt their premiums based on whether consumers posed a risk (due to leaving devices and appliances switched on when leaving their home, etc.).
- For the purposes of State authorities:
    - police and other state bodies could use such data to investigate illegal activities and acts (production of marihuana or other stimulants, etc.); and

  - police and other state bodies could use such data to check individual's alibi (verify whether they were actually at home at the time they claimed to be).
- For the purposes of individuals' statutory benefits:
  - child custody (checking if a father/mother often leaves their child at home alone); and
  - in landlord-tenant relationships (checking whether a rented accommodation is used by more people than prescribed by the tenancy agreement).
- For family purposes:
  - monitoring the activities of other family members (checking whether a child is asleep or playing computer games); and
  - monitoring partner's activities (checking whether the partner lied or whether they were actually at home at the time they claimed to be, etc.).

Slovenia's Information Commissioner, Mojca Prelesnik, noted that smart meters are contentious in terms of personal data protection, since there are no legal bases for such a detailed metering they provide (Prelesnik, 2019). Smart meters allow rapid and accurate collection of data, however, such data may be abused for various purposes (device or appliance identification, personal habits, individuals' absence, etc.). All of the aforementioned activities represent a substantial intrusion into privacy. In terms of information security, it is therefore crucial that such data be adequately protected and regulated. It is also vital that the main elements of smart energy meters be examined in order to identify potential threats or risks for information leaks and find appropriate solutions.

4.1 Threats to Privacy

The use of smart energy meters may jeopardise data protection and consumer privacy in various ways. Threats are observed at all four areas of the metering infrastructure. The first area relates to consumers, i.e. contract users of energy services and own a smart meter, often together with a display enabling them to monitor energy consumption. The second area encompasses communication technologies linking smart energy meters and metering data management systems. The most common communication technologies include Power Line Communication (PLC), ZigBee and mobile networks. The third area of metering infrastructure refers to the system for managing meter data, which collects, manages and stores data generated by smart energy meters. The fourth area is linked to the use of information. Energy consumption data are used for billing, increasing the efficiency and reliability of energy distribution and providing value-added services (recommendations for lowering energy costs, diagnostics, etc.) (Asghar et al., 2017; Jin, Jia, & Spanos, 2017).

Each of these four areas is characterised with its own set of vulnerabilities, which pose a threat to information security.

- Consumers

Consumers, who are part of the smart grid, have a smart energy meter installed in their building. Smart meters are usually installed at an easily accessible location (to enable potential maintenance) and are often unprotected or exposed. Therefore, they represent a risk for the materialisation of potential threats, since third parties could obtain a physical or remote access to the smart meter and exploit the vulnerabilities or shortcomings of the meter's software. Smart meters also contain cryptographic keys. Therefore, if an individual gained access to the meter, they could extract metering data and cryptographic keys, thus jeopardising consumers' privacy (Asghar et al., 2017).

Individuals could exploit the shortcomings of smart meters to steal electricity. Furthermore, they could reduce the quantity of consumed electricity by changing and manipulating available data. As a result, they could offer this "service" to others, thus causing the inefficiency and unreliability of the energy distribution (Asghar et al., 2017). It is therefore important to prevent any unauthorised access to smart meters. It is crucial to protect smart energy meters, so that they may only be accessed by authorised persons (different passwords for individual smart meters) (Asghar et al., 2017; Desai & Upadhyay, 2014).

- Communication technologies

The main risk related to communication technologies arises from information leaks. Data encryption is often used to prevent the leaking of information and ensuring confidentiality. Communication channels between the smart meter and the corresponding database must be adequately protected in order to ensure data confidentiality and consumer privacy. This typically leads to the use of Public Key Infrastructure (PKI), which establishes and maintains network security by using encryption keys, thus providing for sender authentication and the detection of unexpectedly modified data (Asghar et al., 2017; Tonyali, Munoz, Akkaya, & Ozgur, 2018).

- Meter data management

Data, which is stored and collected, must only be accessible to duly authorised persons. Data integrity must also be guaranteed, particularly in order to ensure the accuracy of measurements and billing. The use of PKI for sending and storing data could guarantee data security. It is vital to be able to verify and validate the accuracy of data regarding individual measurements (Asghar et al., 2017).

- Use of information

The consent of an individual consumer should be obtained every time their information is being used. However, even if consumers agree that service providers may use their information for specific purposes, it is extremely difficult to check whether such data were actually used only for that express purpose. In such cases, data may be modified or restricted, so that they can only be used for the specific purpose for which consumers' consent has been obtained (Asghar et al., 2017; European Smart Grids Task Force, 2016).

Various techniques geared towards preserving consumers' privacy are usually applied with respect to elements, such as billing, improving efficiency and reliability of energy distribution and value-added services. For instance, the charging and billing of consumed electricity require extremely accurate data, which may reveal a great deal about consumers. One way of protecting privacy is to make sure that the smart meter submits data regarding the total quantity of consumed energy at the end of each month, without disclosing the data on individual measurements (Asghar et al., 2017; McKenna et al., 2012).

In terms of improving grid efficiency, it is important that energy service providers are familiar with the most current situation of the entire grid (energy demand and energy supply). This is why they need a continuous supply of data. In order to safeguard consumers' privacy, energy companies could collect data regarding the entire neighbourhood, thus protecting the privacy of individual consumers. This would mean that the greater the number of consumers, the greater the degree of security; however, this could affect grid efficiency. Another possible solution would be to programme the smart meter in a way that it would provide a specific consumer profile for the purposes of billing and an anonymous consumer profile for ensuring grid efficiency (Asghar et al., 2017; Rial, Danezis, & Kohlweiss, 2018).

Value-added services are aimed at optimising energy consumption on one hand and identifying errors in individual appliances and devices on the other. In this respect, an intrusion into one's privacy does not represent a major risk, since such services do not require a continuous supply of data, but only a certain segment of collected data (Asghar et al., 2017).

4.2 Preservation of Privacy

Due to large quantities of sensitive data, which may be used to be benefit of cyber-attackers and third parties, it is vital for smart meters to provide information security. In order to guarantee information security and consumers' privacy, smart meters must feature certain characteristics, such as confidentiality, integrity, availability, authenticity, non-denial and verifiability. All of these features contribute to the security and efficiency of distribution networks and smart meters. Thus, individual consumers' measurements can be protected from unauthorised persons (Desai & Upadhyay, 2014; Souri et al., 2014). It is important to ensure:

- Confidentiality: ensures that information cannot be accessed by unauthorised persons. It prevents access to generated data regarding individual consumers, smart meters, networks, etc. Confidentiality must be guaranteed in the scope of data transmission (between smart meters and the database), within the database itself, as well as in the scope of data usage. Encryption is often used to provide data confidentiality. Thus, unauthorised persons cannot extract the content of such data by eavesdropping or bugging (Asghar et al., 2017; Desai & Upadhyay, 2014; Souri et al., 2014).
- Integrity: ensures that measurements taken by individual smart meters remain accurate, correct and reliable during data transmission, storage and use. It prevents any modification of data. In fact, every potential data modification should be detected (Asghar et al., 2017; Hou et al., 2019).
- Availability: is crucial for the correct, constant and continuous functioning of electricity distribution networks. It enables a fast and timely detection of errors in the network and guarantees a successful delivery of energy (Desai & Upadhyay, 2014).

- Authenticity: enables the validation of data sources or, in other words, the identification of a source (Asghar et al., 2017; Hou et al., 2019).
- Non-denial or nor-repudiation: guarantees that a data source (i.e. a smart meter) cannot deny the generation of such data. At the same time, non-denial or non-repudiation ensures the integrity and authenticity of data (Asghar et al., 2017; Lee & Brewer, 2009).
- Verifiability: enables the possibility to verify, whether a request has received a correct response or, in other words, whether measurements taken by the smart meter are accurate and correct (Asghar et al., 2017).

The aforementioned features must be guaranteed in order to establish a secure and reliable grid. It is vital that energy service providers are aware of all types of threats and methods for their prevention. Consumers have a right to privacy. Therefore, they expect all data related to their energy consumption and energy activity to be adequately stored and protected (Weaver, 2017). Lobnikar, Prislan, and Markelj (2012) state that security culture ought to be an integral part of every organisation. Security must be maintained constantly and consumers must be informed in a clear and comprehensible manner of their rights and the use of their data.

If providers fail to guarantee a suitable level of protection to their consumers, this will have a negative impact on grid efficiency and reliability. Furthermore, individual consumers will not agree with the installation of smart meters, if these are untrustworthy and unreliable. Consumers must be familiar with smart meters and their functions, since their knowledge of both positive and negative features, as well as of the importance of consumption data, and personal data in general, will contribute to their safety and security. If a consumer, for instance, realised that an energy service provider is unable to explain the purpose of data collection or finds that their data are being used for purposes other than those they consented to, they would understand that this represents a risk and would most likely demand the installation of a conventional meter (Horne et al., 2015). In fact, in most countries, consumers have to right to reject the installation of a smart meter, as this is not obligatory (USmartConsumer, 2016).

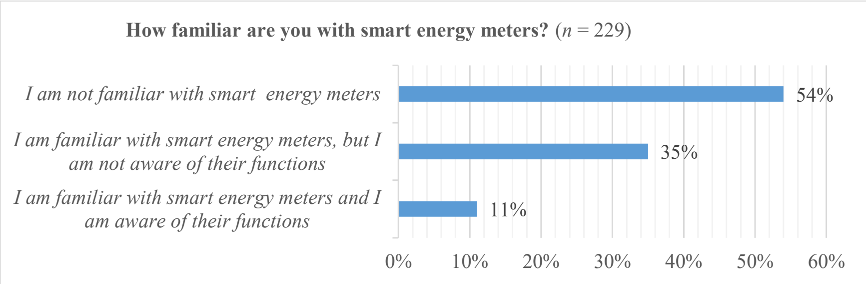
5 METHODS

To obtain additional data and to estimate users' awareness of smart energy meters, a survey questionnaire was used. The survey questionnaire was used to acquire information regarding the degree of knowledge that respondents had of smart energy meters, particularly their level of awareness about potential threats posed by smart energy meters. Furthermore, respondents were asked whether data that may be generated by smart energy meters are of any relevance to them. The survey questionnaire was composed by using the *1ka* online tool. Data were collected by publishing the questionnaire on online social media – the sample consisted of Facebook, Viber and e-mail users. The questionnaire comprised a total of 15 questions, which were divided into two sets. The questions required either *yes/no* answers or answers provided on a 5-point Likers scale, where 1 stood for *I completely disagree* and 5 corresponded to *I fully agree*. The first set of questions was aimed at establishing respondents' familiarity with smart meters, their perception of smart meters, as well as smart meters' positive and negative characteristics. The second part of the questionnaire comprised demographic questions referring to respondents' gender, age and qualifications. 229 respondents participated in the survey. 200 respondents completed the questionnaire in its entirety, while 29 respondents did not complete the questionnaire. 124 (62%) of respondents were female and 76 (38%) respondents were male. The highest share of respondents was aged between 21 and 40 (56%), as well as between 41 and 60 (33%), while the lowest share of respondents was over 61 (8%) and under 20 years of age (4%). The majority of respondents completed general secondary education (44%), followed by tertiary-level education or higher (41%), vocational or technical secondary education (14%) and primary-level education or lower (2%).

6 RESULTS

The objective of the questionnaire was to establish whether respondents were familiar with smart energy meters, whether they recognised potential threats and positive features, as well as whether they believed that energy consumption data were at all relevant.

Figure 1: Familiarity with smart meters



Respondents were asked whether they were familiar with smart energy meters. The question was answered by 229 respondents. 123 (54%) respondents were not familiar with smart meters or had never heard of the term "smart meter". The number of respondents who were familiar with smart meters, but are not aware of their functions, amounted to 80 (35%), while 26 (11%) respondents were familiar with smart meters and their functions.

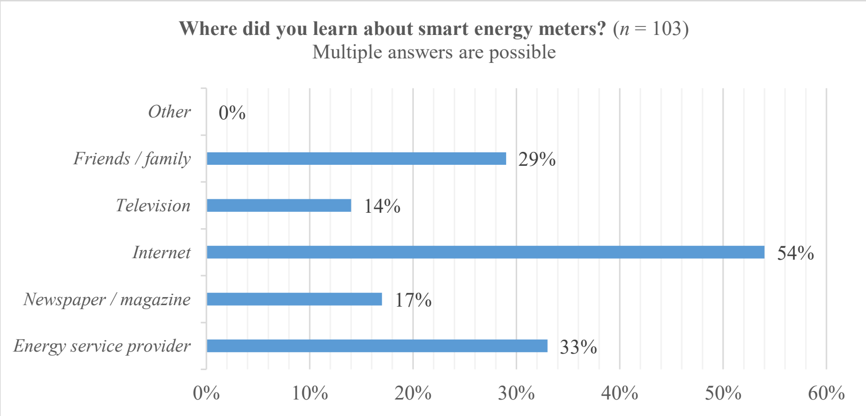


Figure 2: Where did respondents learn about smart meters

Respondents were asked where they learned about smart meters. This question was answered by 103 respondents. They were able to choose among several answers. 54% of respondents stated that they learned about smart meters on the internet, 33% learned about smart meters from their energy service providers, 29% learned about smart meters from their friends and family, while 17% learned about them from newspapers or magazines and 14% heard about them on television.

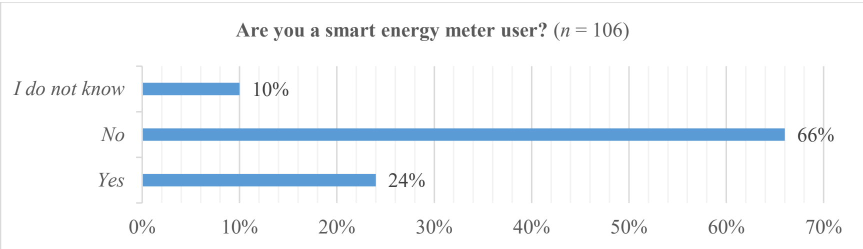
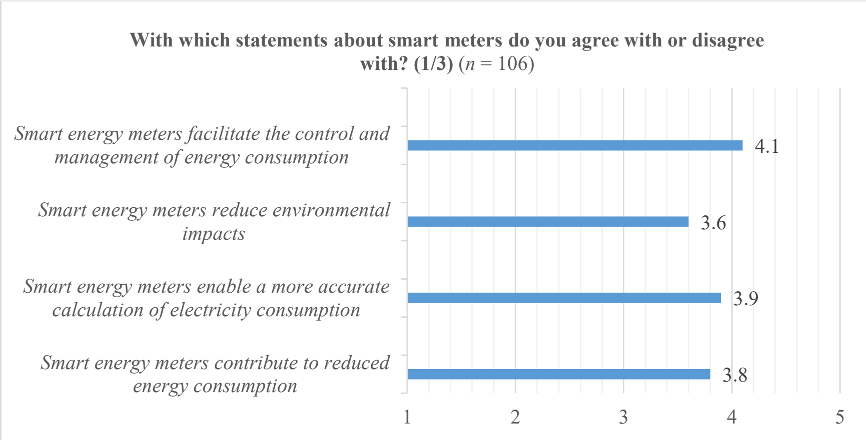


Figure 3: Smart meter usage

Respondents were asked whether they had used a smart energy meter. This question was answered by 106 respondents. 70 (66%) respondents stated that they had not used a smart energy meter. 25 (24%) respondents were users of smart meters, while 11 (10%) respondents did not know whether they had used a smart meter or not.

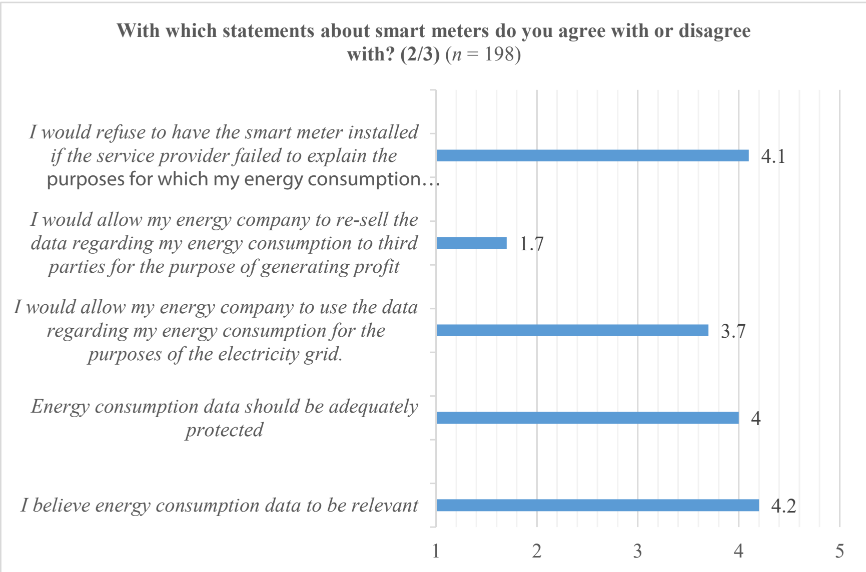
Figure 4: Positive statements about smart energy meters



Legend: 1 – I completely disagree; 2 – Disagree; 3 – Neither agree nor disagree; 4 – Agree; 5 – I fully agree

The following question contained several statements regarding smart meters, which were assessed by respondents by selecting answers from 1 (*I completely disagree*) to 5 (*I fully agree*). 106 respondents provided their positive answer regarding individual statements. The statement *Smart energy meters facilitate the control and management of energy consumption* received an average grade of 4.1. Respondents gave a 3.9 mark to the statement *Smart energy meters enable a more accurate calculation of electricity consumption*. The statement *Smart energy meters contribute to reduced energy consumption* was marked with an average of 3.8, while the statement *Smart energy meters reduce environmental impacts* received an average of 3.6.

Figure 5: Statements regarding the relevance of data on energy consumption



Legend: 1 – I completely disagree; 2 – Disagree; 3 – Neither agree nor disagree; 4 – Agree; 5 – I fully agree

Respondents were asked about the relevance of energy consumption data. The statement *I believe energy consumption data to be relevant* received an average grade of 4.2, while the statement *Energy consumption data should be adequately protected* received and average of 4. Respondents mostly agreed with the statement *I would allow my energy company to use the data regarding my energy consumption for the purposes of the electricity grid* (3.7), while respondents predominantly disagreed with the statement *I would allow my energy company to re-sell the data regarding my energy consumption to third parties for the purpose of generating profit* (1.7). The statement *I would refuse to have the smart meter installed if the service provider failed to explain the purposes for which my energy consumption data would be used* received an average response of 4.1.

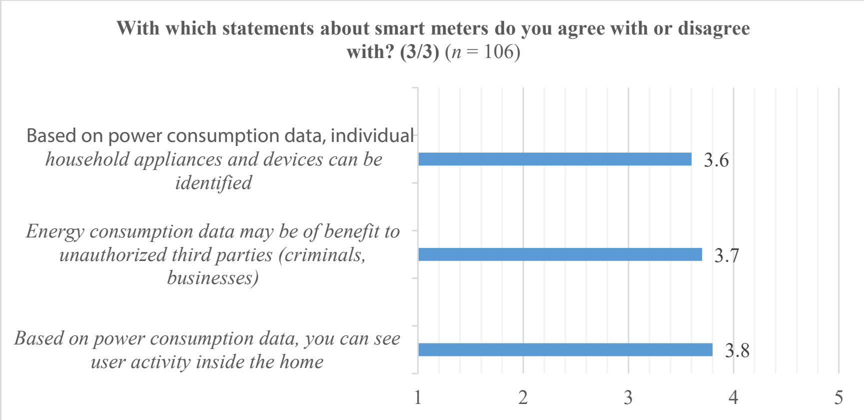


Figure 6: Statements regarding potential threats posed by smart energy meters

Legend: 1 – I completely disagree; 2 – Disagree; 3 – Neither agree nor disagree; 4 – Agree; 5 – I fully agree

106 respondents answered questions regarding threats posed by smart meters. The statement referring to the fact that smart meters may disclose consumers' activities received an average response of 3.8. Respondents also mostly agreed with the statement that energy consumption data may be used to the benefit of third parties (3.7) and with the statement claiming that electricity-related data may be used to identify individual household appliances and devices (3.6).

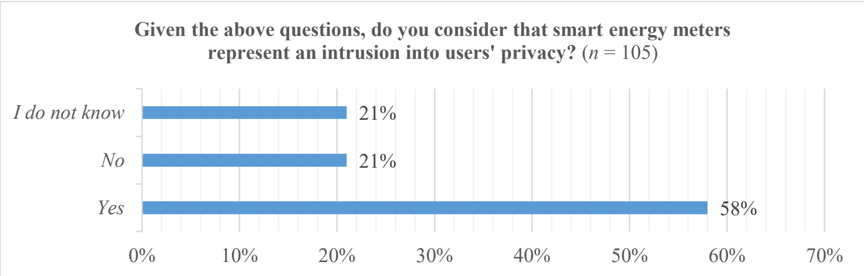
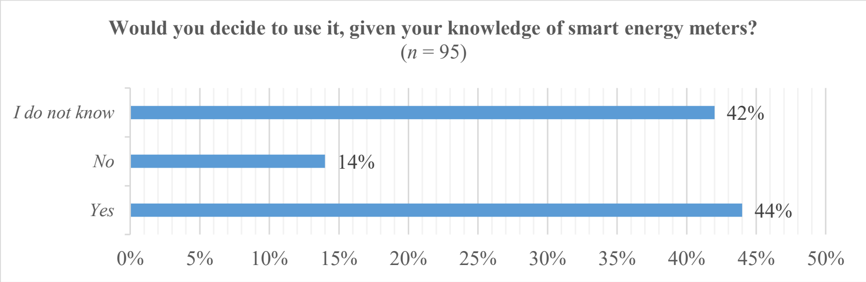


Figure 7: Privacy and smart energy meters

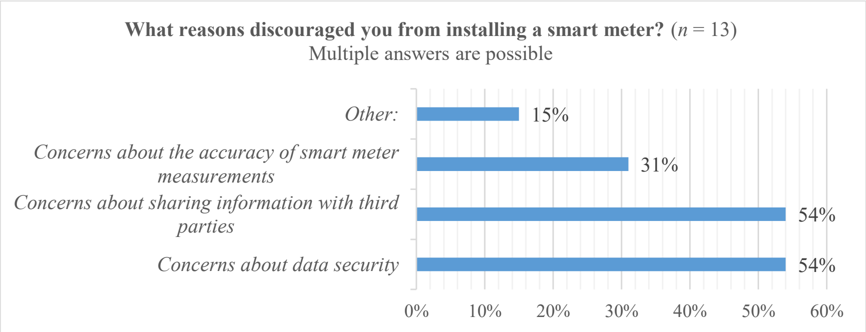
Respondents were then asked whether they believed that smart meters represented an intrusion into their privacy. A total of 105 respondents answered the question. They were able to choose between the following answers: Yes, No, and I do not know. 61 (58%) respondents considered smart meters to be an intrusion into their privacy, 22 (21%) respondents answered that they did not have an opinion about that, and 22 (21%) respondents believed that smart meters did not represent an intrusion into their privacy.

Figure 8: Decision to use a smart energy meter



The next question referred to the familiarity with smart meters and respondents' decision to use them. 95 respondents answered the question. They were able to choose between *Yes*, *No*, and *I do not know*. 42 (44%) respondents stated they would decide to install a smart meter, 40 (42%) respondents did not know whether they would do so, and 13 (14%) respondents claimed they would not decide to install a smart meter.

Figure 9: Reasons for refusing to install a smart energy meter



The majority (54%) of respondents who claimed that they would not install a smart meter, stated that the reason for rejecting the smart meter installation arises from their concerns regarding data security, as well as from their concerns with respect to the sharing of data with third parties. 31% of respondents reported they had concerns about the accuracy of metering, while 15% states that they would not install a smart meter because they simply had no need for it.

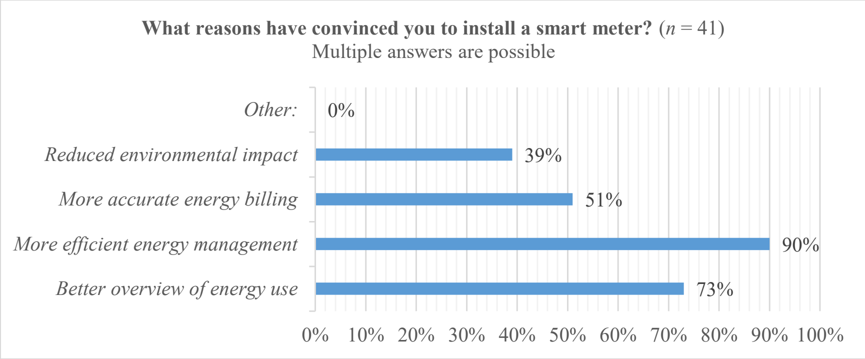


Figure 10: Reasons for installing a smart meter

The vast majority (90%) of all 41 respondents, who would decide to have a smart meter installed, stated that they would do so for the purpose of a more efficient management of energy consumption, 73% of respondents stated that they would thus obtain a better overview over their energy consumption, 51% of respondents would use a smart meter because it provides a more accurate billing of electricity, while 39% wanted to install smart meters in order to reduce environmental impacts.

7 DISCUSSION

In the future, smart energy meters will be an integral part of every household. They bring about certain advantages, however, they also pose threats, which may harm unaware consumers. Research results show that the vast majority of respondents appreciate receiving information about energy consumption and are aware of the need for protection. The survey also shows that, in certain cases, respondents would be willing to give consent to their energy service providers to use their data for the purpose of enhancing grid efficiency. In contrast, a relatively high resistance can be observed in cases where energy companies would provide consumers' energy consumption data to third parties. Respondents would also react negatively if energy service providers would fail to explain the purpose of using their data. Indeed, if companies abuse consumers' data or if consumers become wary of smart energy meters, this would cause a strong reluctance towards smart meters and thus produce a negative impact on the further development of smart grids.

Out of 106 respondents in our survey, only 25 (24%) of them actually used a smart energy meter, and 11 (10%) respondents did not know whether they had it installed or not. According to Slovenia's Energy Agency (Agencija za energijo, 2019), the share of installed smart energy meters in Slovenia in 2018 amounted to 66%. At the same time, research results show that more than half (54%) of 229 respondents were not familiar with smart meters. Out of 106 respondents, who answered the question regarding the use of smart meters, 70 (66%) respondents believe that they did not use it. Given the widespread use of smart energy meters in Slovenia and elsewhere in the EU, these results are rather surprising. One would assume that the number of people, who are familiar with smart meters, would be at least equal to the share of installed smart meters (Agencija za energijo, 2019). Nevertheless, results show that the level of awareness about smart energy meters in Slovenia is quite low, despite the fact that Slovenia boasts a 66% share of installed smart meters.

In the survey, 44% of 95 respondents stated that they would have a smart energy meter installed, particularly in order to ensure to a more efficient management and a better overview of energy consumption. 42% of respondents were not convinced whether they would want to have a smart meter installed or not, and 14% of respondents would not install a smart meter. Respondents, who would not want to use a smart meter, listed two main reasons for their decision, i.e. concerns related to data security and concerns regarding the sharing of such data with third parties. Therefore, we may conclude that respondents, who were not convinced whether to install a smart meter installed or not, lack trust or confidence in smart energy meters.

Despite the low level of awareness about smart energy meters, 106 out of 229 respondents (46%) were familiar with the functions of smart energy meters. They mostly recognised their positive and negative features and were aware of potential intrusions into privacy. They also recognised situations, which could lead to the abuse of their data or jeopardise their privacy and security. This clearly shows that the vast majority of respondents appreciate the relevance of energy consumption data and are aware of the need to protect such data.

8 CONCLUSION

Technological progress brings about numerous opportunities for advancing all spheres of life and, in particular, improving people's lives and reducing our impact on the environment. However, technological progress also means that devices, applications and other services enabling interaction and allowing us to perform everyday tasks require a great deal of sensitive data.

The main objective of this paper was to present smart energy meters, discuss their strengths and weaknesses, and establish whether individuals were familiar with smart energy meters. This is undoubtedly an important issue, since it is vital that individuals value their data, particularly their privacy and security.

The survey, which saw the participation of 229 respondents, shows that individuals, who might become users of smart meters in the future, are very cautious when it comes to sharing their data. This is important, since energy service providers will be required to adequately process and protect consumers' data. Otherwise, consumers will reject the use of smart energy meters. Unsecured data pose a great risk, which may compromise consumers' security and privacy. Consumers may become targets of burglars, large corporations and other parties wishing to abuse their vulnerabilities.

Data regarding energy consumption may reveal the life of individuals in their own homes, their habits, activities, etc. It is therefore crucial for smart energy meters, their communication channels and the corresponding database to be adequately secured and protected. It is also important to be familiar with threats to individual fields and resulting vulnerabilities, and, most importantly, have the knowledge necessary to prevent such threats. This is the only way to ensure the necessary protection of smart energy meters and the resulting security of their users, as well as to guarantee their trust and confidence in smart meters.

Smart energy meters represent a crucial element in reducing and optimising energy consumption and promoting the use of renewable energy sources. This is why smart meters will soon become an integral part of every household and every building. Frequent metering of consumers' energy consumption will enable a more efficient energy management. However, this requires a great deal of consumer data which must be adequately protected.

The survey revealed that only a limited number of respondents were familiar with smart energy meters, and even fewer respondents had knowledge of their functions. Since smart energy meters have numerous positive features, it would be favourable if people's awareness had been much higher. At the same time, consumers ought to be made aware of the importance of data and related threats. Due to the relatively low number of research studies in the field of consumers' awareness of risks posed by smart meters and the potential abuse of their data, further research ought to be carried out in the future.

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