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Source / Izvornik: **Energy Reports, 2022, 8, 5631 - 5639**

Journal article, Published version
Rad u časopisu, Objavljena verzija rada (izdavačev PDF)

https://doi.org/10.1016/j.egyr.2022.04.019

Energy Reports 8 (2022) 5631–5639

Contents lists available at ScienceDirect

Energy Reports

journal homepage: www.elsevier.com/locate/egyr

Cost-effectiveness of installing modules for remote reading of natural gas consumption based on a pilot project

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ARTICLE INFO

Article history:
Received 13 January 2022
Received in revised form 18 March 2022
Accepted 7 April 2022
Available online 26 April 2022

Keywords:
Smart metering
Module for remote reading
Sigfox network
Financial analysis
Sensitivity analysis
Internet of Things

ABSTRACT

The gas sector in the EU is very developed and advanced, but there are still some steps and measures to improve this sector. One of the measures for the improvement, but also for the collection of data on energy consumption for an easy transition to a low carbon economy, are the projects of installing smart meters. This paper analyzes a pilot project of installing modules for remote reading of natural gas consumption on existing membrane gas meters. In the pilot project observed, modules for remote reading were installed on more than 10,000 existing meters, and their use, activation, and as well as the benefits that are achieved by using them are described in detail. These modules use the increasingly popular Sigfox network, which has proven to be an excellent tool for data transmission with low energy consumption, which can greatly simplify the digitization of many energy sectors. The installation of modules for remote reading on existing meters represents a novelty improvement of classic membrane meters towards modern and increasingly sought-after smart meters, which has proven to be time effective because, unlike some smart meter installation projects, this approach requires a very short installation time.

The results of the financial and sensitivity analysis have shown that with the currently valid legal regulation the financial savings achieved by energy supplier due to exemption from paying penalties are more than sufficient to cover the investment and operating costs of the entire investment. In case the legislation changes or is different, this paper proposes the concept of transferring partial financial value of energy savings from end consumers to energy supplier in order to cover the investment and operating costs of implementation.

1. Introduction

Natural gas, although being a fossil fuel, continues to play an essential role in the energy supply of the European Union (EU). According to Eurostat, natural gas met roughly 25% of energy needs in gross inland consumption in 2019 and was largely utilized as an energy source in the households and industry, as well as a raw material in the petrochemical industry (Eurostat, 2022). Given the EU's green strategy, it is evident that natural gas does not have a long-term future as a source of energy, but in the medium term (until 2050), natural gas will play a critical part in the transition to a totally sustainable economy (Li et al., 2020; Koltsaklis et al., 2020; Qadir et al., 2021). Even though the EU's gas sector is highly developed and advanced, there are still some steps and measures that can be taken to improve the sector and ensure security of gas supply (Sutrisno and Alkemade, 2020). Projects to install smart meters and connect the energy sector via the Internet of Things (IoT) are undoubtedly one of the measures for improving the gas sector, as well as for collecting data on energy consumption for an easy transition to a low-carbon economy (Shaikh et al., 2017; Tabaa et al., 2020). Smart metering will allow the creation of high-quality energy consumption databases, which will be critical in the design and implementation of renewable energy sources in the energy system (Mathiesen et al., 2015; Lu et al., 2019; Smajla et al., 2021).

1.1. Gas smart metering

Gas smart meters are widely recognized in the EU as one of the most effective ways to optimize the entire system, particularly in terms of reducing energy consumption. By 2019, the majority of EU member states had completed at least one cost–benefit analysis (CBA) on gas smart meter installation. The CBA analysis proved positive in the following EU members: Austria, France, Ireland, Italy, Latvia, Luxembourg, Netherlands, Romania, Slovakia and Slovenia (Castelnuovo and Fumagalli, 2013; European Commission, 2019). The majority of these members with a positive

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https://doi.org/10.1016/j.egyr.2022.04.019

CBA analysis, along with some members where the official CBA analysis has not even been conducted (Denmark, Hungary) have already implemented a strategy of mass installation of gas smart meters (European Commission, 2019; Van Aubel and Poll, 2019). Members who have had a negative CBA analysis will be required to conduct one again in a few years, and if the new CBA analysis yields favorable results, they will be required to implement a plan for the installation of smart meters over time. The reasons for the installation, i.e., the benefits of installing gas smart meters have so far been researched by many different groups of authors. The reduction of energy consumption and, as a result, the reduction of harmful emissions is unquestionably the most important benefit. The most of energy savings and, consequently, emissions reductions are the result of end consumers being able to better monitor their own consumption, which leads to a change in consumer habits, i.e., reducing consumption in order to achieve financial savings (Buchanan et al., 2016; Sovacool et al., 2017).

Although less important but not negligible, there are also the benefits of reducing labor costs (Sheikhi et al., 2015), prevention of technical and non-technical (administrative, including fraud) losses (European Commission, 2019), simpler energy categorization of buildings (Melillo et al., 2020), improved consumption forecasting (Gouveia et al., 2017), smoothing network fluctuations and increasing security of supply (Su et al., 2019). Despite all the benefits, most research and conducted CBA analysis have identified the cost and time of installing smart meters as the most significant disadvantage, resulting in projects not being completed or even started. Castelnuovo and Fumagalli (2013), who observed the Italian program for the implementation of gas smart meters, were among the first to address this issue. They came to the conclusion that installing smart meters for gas is more expensive than installing smart meters for electricity. They also concluded that implementation is slow due to the various directions in which gas smart meters are developing, all in order to reduce investment and operating costs.

According to Van Aubel and Poll (2019), the calculated financial benefits of implementing gas smart meters in the Netherlands were unrealistic because significantly higher energy savings than average were used in the calculation. This means that ultimately the entire implementation project was financially negative. Sovacool et al. (2017) pointed out that the implementation time for gas smart meters in the UK was extended several times, and the costs proved to be higher than expected, confirming the time and financial challenges of installing gas smart meters. Financial intensity is very objectively presented in the report from European Commission (2019) where the implementation of gas smart meters in the 28 member states of the European Union was observed. According to that document, 5 of the 15 states that conducted CBA analyses had a negative CBA analysis, resulting in the non-start of gas smart meter implementation. The main reason for the negative CBA analyses were the high total costs of installing smart meters.

Based on a pilot project conducted in the east of the Republic of Croatia, this paper analyzes the financial and time aspects of the installation of gas smart meters. This pilot project differs from the research conducted so far due to the fact that the gas meter is not completely changed, but the module for remote reading via the Sigfox network is installed to the existing classical membrane gas meter. The proposed technical solution, which is further described in this paper, represents a novel approach to smart metering implementation. It provides a cost-effective solution for smart metering projects, as well as a significant reduction in installation time, which is clearly a problem in the literature reviewed.

1.2. Internet of Things and Sigfox network

The Internet of Things (IoT) has been identified as a way of fully integrating everyday systems in order to realize smart grids and smart cities in the future (Raval et al., 2021). Using the Internet, billions of devices such as cameras, sensors, household appliances, cars, actuators, valves, and other devices will be connected to communicate with one another (Popli et al., 2019). The overall purpose of connecting devices is to improve the quality of life through better optimization of energy consumption, reduction of environmental pollution (Lavric et al., 2019), better daily organization of work, improvement of industrial processes (Hirman et al., 2020), increase of energy efficiency (Martín-Garín et al., 2020), etc. The connection of such a significant number of devices has expressed the need for new communication solutions that will enable the transmission of small amounts of data over long distances with low power consumption (Mekki et al., 2019). The use of a Sigfox network represent such communication solution. The Sigfox network is a Low Power Wide Area Network (LPWAN) that meets the requirements for device communication via the IoT (Penã Queralta et al., 2019; Fourtet and Ponsard, 2020). This network has been set up in more than 70 countries over the world by operating on different sub-GHz ISM bands depending on the region (Peruzzi and Pozzebon, 2020). This network is capable of transmitting data over a distance up to 50 km in rural areas and up to 10 km in cities, as there are many obstacles. One of the major drawbacks of this network is the amount of data that can be transmitted, which is quite low, only 100 bits per second (Ali et al., 2017). Nevertheless, this network has become one of the most popular LPWAN in application due to its wide coverage, very low power consumption, and long signal range. Authors Singh et al. (2020) and Hossein Motlagh et al. (2020) have shown that the Internet of Things and thus the Sigfox network has a very wide application in the energy and overall technology sectors. They describe potential applications of IoT in energy generation, smart grid implementation, smart cities, use of IoT in smart buildings, industry, transportation, communication technologies, medicine, food production, etc. (Ruckebusch et al., 2018).

From all this, it can be concluded that in the future, IoT will greatly contribute to goals that will improve the quality of life. The first step towards the introduction of IoT in the energy sector is the installation of devices with the possibility of remote communication. For remote reading of natural gas consumption, the observed literature provides a solution in the form of replacing the entire meter, while the module for remote reading without replacing the existing meter is not mentioned in the literature. This type of module is described in more detail in the following sections.

1.3. Objective of the paper

In view of the development of smart technologies and the increasing number of smart energy systems, this paper examines the installation of a module for remote reading of natural gas consumption as a novelty in the implementation of gas smart meters. The objective of this paper is the financial and sensitivity analysis of the installation of a representative number of modules for remote reading of natural gas consumption which enable the realization of smart gas meters. Also, this paper observes and proposes the concept of utilization of energy savings resulting from the implementation of smart gas meters in order to cover the investment and operating costs for the implementation.

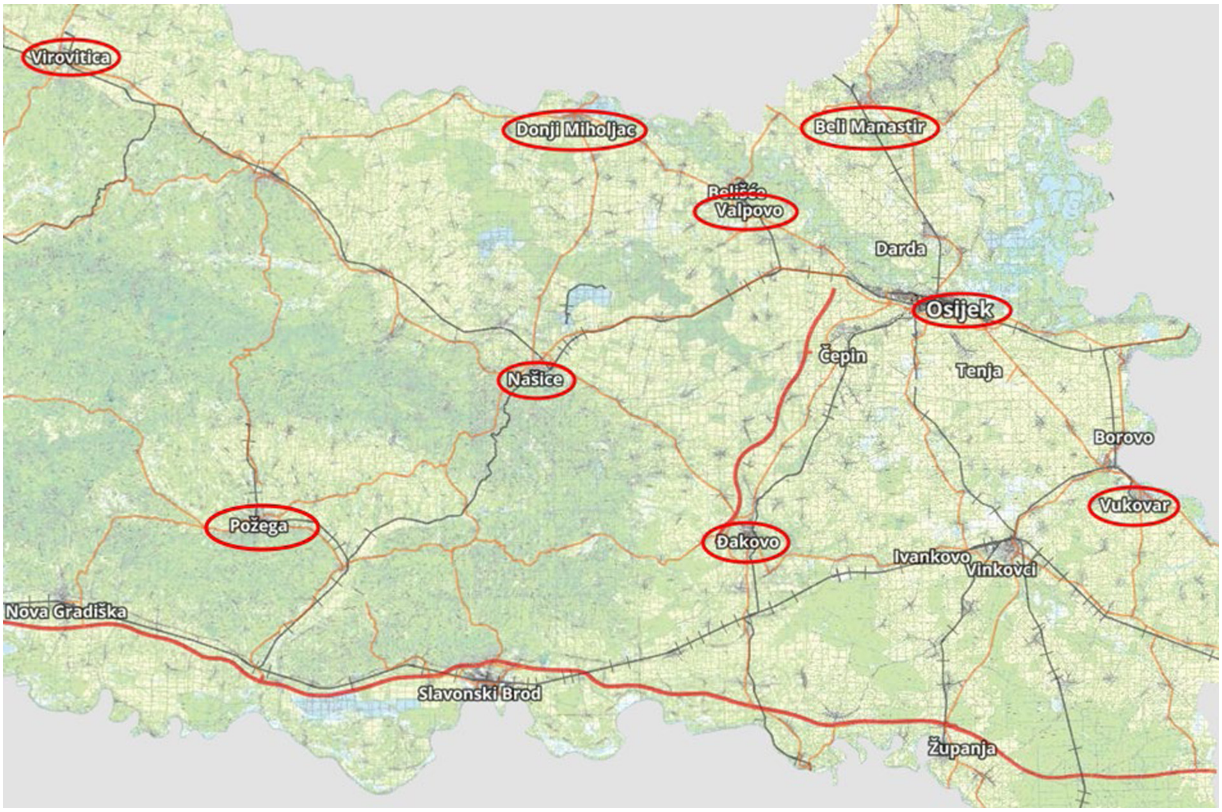

Fig. 1. Geographical location of nine cities in which areas the project was implemented (marked red) (Državna geodetska uprava, 2021). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2. Implementation of smart metering pilot project

This paper observes a pilot project for the installation of a module for remote reading of natural gas consumption on the conventional gas meters. The pilot project was initiated and implemented by an energy supplier in the east of the Republic of Croatia. The aim of the project from an energy supplier's point of view was to review the efficiency of gas smart meters in reducing reading costs, reducing technical and non-technical losses and improving consumption forecasting. The results of the pilot project will show to the energy supplier whether it is feasible to implement smart meters for all end consumers in its distribution area. The project was implemented in the area and the vicinity of nine smaller cities (Fig. 1). In the period of 18 months from May 2020 to October 2021, about 10,200 modules for remote reading of consumption were installed. Most of the modules were installed in household consumers, while slightly fewer modules were installed in small commercial consumers. Mentioned modules were not installed in large commercial consumers because they are required by law to have smart meters.

2.1. Module for remote reading of natural gas consumption

Modules for remote reading of natural gas consumption were installed on existing membrane gas meters in already mentioned city areas. The module counts the magnetic pulses generated by the natural gas meters and periodically reports the consumption. Also, the module monitors attempts to interfere with meter readings and therefore sends appropriate alarm messages and has the ability to record ambient temperature and excessive gas consumption. Alarm messages will inform energy supplier thus enabling transparent billing, better loss control and elimination of fraud on readings (bytelab, 2021). All the above possibilities of this module mean that by installing the module on the gas meter, the classic membrane gas meter actually becomes a gas smart meter. Unlike installation of most gas smart meters, the installation of this module is very simple and takes only a few minutes, and the module can be installed on most of the existing meters with the help of three types of adaptors (Fig. 2). The adaptor is a simple piece of quality plastic that allows a "click" connection of the module to the gas meter. The adaptor is first connected to the module with a "click" connection and then the module and the adaptor are "click" connected to the existing gas meter. To save battery power, the module comes in a deactivated state and must be activated after installation. This module has a very low power consumption, i.e., battery life whose lifespan is around 15 years. Activation is performed by alternately moving the magnet towards the module, which is activated after a few seconds, which is confirmed by the light signal of the light emitting diode. After activation, the module connects to the Sigfox network and waits for a configuration package that defines output data such as: internal time, number of reports per day, time to send reports, overspending algorithm, etc. (bytelab, 2021). In the observed pilot project, daily reporting in the early morning hours was selected. This installation significantly increased the resolution of consumption data (daily consumption data) compared to the previous resolution when the data were collected on a monthly or even quarterly basis. The average cost of installing a module in this pilot project was around 70 EUR per metering point. This is far more cost effective than the weighted average cost of installing smart meters given in the report from the European Commission which is 171 EUR per metering point (European Commission, 2019).

All data collected by the energy supplier is also available to end users for their metering point via the online platform. Consumption data is updated on an online platform on a daily

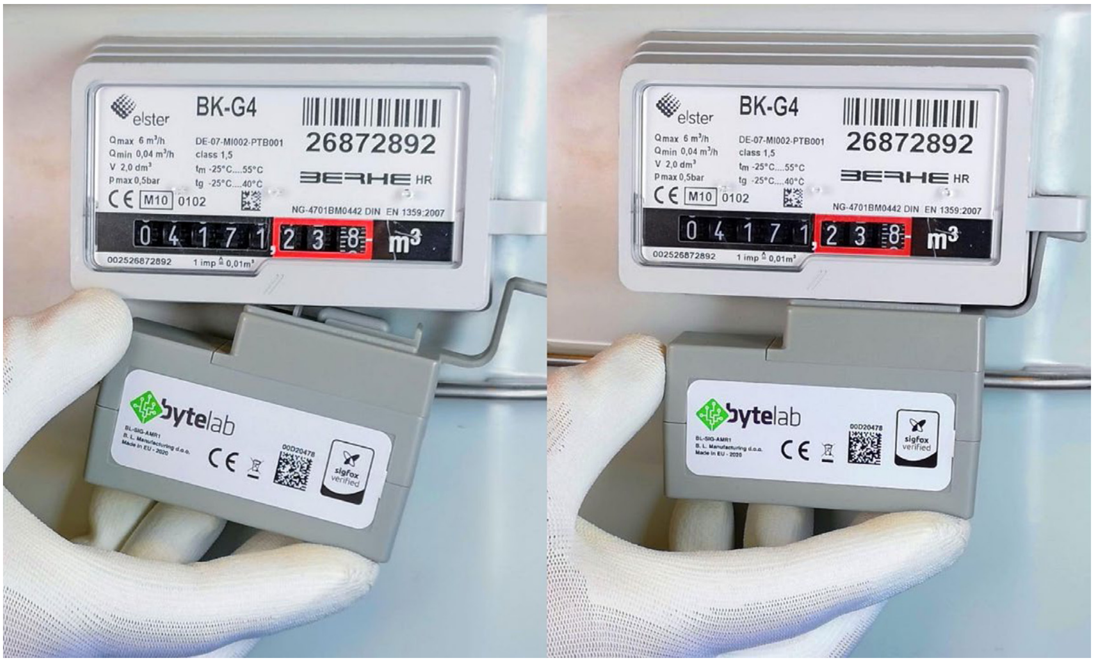

Fig. 2. Installation of module for remote reading of natural gas consumption (Šimić, 2020).

basis and each end user can access historical data of their own consumption for the last 180 days. As mentioned earlier, access to up-to-date data on own natural gas consumption can significantly affect consumer consumption habits, mostly in terms of reducing consumption due to financial savings (Mogles et al., 2017).

3. Financial analysis

The financial analysis of mass installation of modules for remote reading of natural gas consumption in households, i.e., the implementation of gas smart meters is based mostly on the pilot project described in the previous section. As mentioned earlier, in this project it was not necessary to change the entire meter, but the existing classic membrane gas meter is upgraded with the described module. Such an approach has enabled a significant reduction in costs and a significantly shorter installation time achieving the same goal, which is the implementation of gas smart meters.

For the purposes of the analysis following parameters were calculated:

- cost of installing modules for remote reading (CAPEX),
- operating cost (OPEX),
- total financial benefit (TFB),
- reduction in meter reading and operation costs (RMROC),
- value of energy savings for three scenarios (min., avg., max.) (VMinES, VAvgES VMaxES),
- financial savings achieved by the energy supplier (FSAES).

These parameters were calculated for a period equal to the lifetime of the battery in the remote reading module, i.e., equal to the lifetime of the smart meter.

The cost of installing a remote reading module, the time required to install one module and the operating cost per metering point were taken from the author's correspondence about the pilot project. The total financial benefits were calculated using the weighted average of financial benefits per metering point from the study on the deployment of gas smart meters in the EU (European Commission, 2019). The weighted average given in that study was calculated based on the available CBA analyses on the introduction of gas smart meters in the EU.

The reduction in meter readings and operating costs per metering point were calculated using the average cost reduction value calculated from the data published in the Study on the cost–benefit analysis of smart metering systems in the EU Member States (Af Mercados Emi and ICCS-NTUA, 2015). This study published data on reduction in meter readings and operating costs for 12 different regions in the EU.

Percentages of energy savings achieved by installing smart meters were also taken from the study on the deployment of gas smart meters in the EU (European Commission, 2019) which gave minimum and maximum energy savings depending on the type of smart meters installed. The minimum and maximum percentages were used to create two energy saving scenarios, while for the third scenario the average value between the minimum and maximum was taken. Because no data for the Republic of Croatia is available, certain input parameters (weighted average of financial benefits per metering point, reduction in meter reading and operation costs per metering point, minimum and maximum energy savings) were obtained using an average of EU-level projects and research, which is a small drawback and limitation of this financial analysis. Actual data on energy and financial savings for the observed pilot project will be available after several heating seasons that need to be observed due to different consumption characteristics each year as a result of the increasingly frequent unexpected weather changes each winter.

Energy saving percentages for all three scenarios were multiplied by the average household natural gas consumption (Eurostat, 2022; HSUP, 2021) to calculate energy savings. The energy savings were multiplied by the price of natural gas for households in the Republic of Croatia (HERA, 2021) to calculate the value of the energy savings for different scenarios.

Financial savings achieved by the energy suppliers were calculated by multiplying legally recognized energy savings that are achieved by installing smart meters and penalties in case of failure to achieve the legally set energy savings goals. According to the EU and national legislation, energy suppliers in the Republic of Croatia are obliged to achieve certain energy savings depending on the amount of energy delivered to end users. In case that energy supplier fails to achieve the necessary energy savings assigned to it, it must pay penalties in the amount of 160 EUR

Table 1
Values of input parameters for calculation of financial aspects.

Smart meter lifetime (bytelab, 2021)	15 years
Cost of installing a remote reading module per metering point (author's correspondence about the pilot project)	70.00 EUR
Operating expenses per metering point (author's correspondence about the pilot project)	7.00 EUR per year
Weighted average of financial benefits per metering point (European Commission, 2019)	16.50 EUR per year
Reduction in meter reading and operation costs per metering point (Af Mercados Emi and ICCS-NTUA, 2015)	3.27 EUR per year
Minimum energy savings (European Commission, 2019)	1.83%
Average energy savings (calculated)	5.73%
Maximum energy savings (European Commission, 2019)	9.63%
Average natural gas consumption per household (Eurostat, 2022; HSUP, 2021)	8.87 MWh per year
Price of natural gas for households in the Republic of Croatia (HERA, 2021)	46.57 EUR per MWh
Legally approved energy savings for the installation of smart meters (MINGOR, 2021)	3.00%
Value of legally approved energy savings (MINGOR, 2021)	160.00 EUR/MWh
Reference discount rate (author's experience in gas industry)	7%

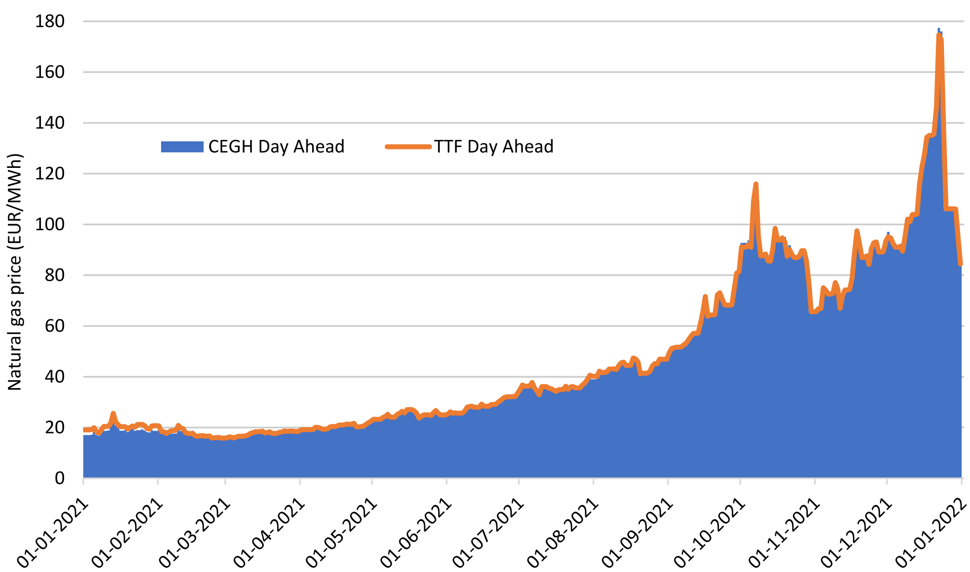

Fig. 3. CEGH and TTF Day Ahead prices thought 2021 (MONTEL, 2022).

per MWh. This amount is defined by the Law on Energy Efficiency based on the average investment by the national Environmental Protection and Energy Efficiency Fund for one kWh of energy savings (Hrvatski sabor, 2021). The measure of installing smart meters in households is credited to the energy supplier with energy savings in the amount of 3% per meter for the period of 5 years (MINGOR, 2021).

The value of energy savings and reduction of meter readings and operation costs cannot be added to the total financial benefit, as these parameters have already been taken into account in the study (European Commission, 2019) from which the weighted average was taken. They have been calculated and will be presented separately to highlight the scale of savings and cost reductions of these parameters. Since the financial aspects were calculated for a period of 15 years, a discount rate of 7% was taken into account. The values of all input parameters are shown in Table 1 below.

3.1. Sensitivity analysis

For the purposes of financial analysis, the regulated price of natural gas (category of households in the period up to 31st December 2021) from the largest household energy supplier was taken. Considering the movement of prices on the wholesale gas market in 2021, which ranged from 15.84 EUR per MWh to 174.70 EUR per MWh on the day-ahead TTF market or from 16.00 EUR per MWh to as much as 177.40 EUR per MWh on CEGH market (Fig. 3), it is necessary to take this increase into account and assume an increase in the price for household consumers in the next regulatory period. According to the current methodology of price regulation for final consumers, the expected increase in prices for final consumers will be around 72% after April 1st, 2022, if gas prices remain at the same levels until the end of that regulatory period.

Also, it should be taken into account that natural gas prices on the Croatian natural gas market are partially deregulated and that the second phase of price deregulation is currently underway, lasting until September 30th, 2024, followed by full deregulation of prices and direct connection with the market prices at current European hubs. The comparison of gas prices for the household category with other EU countries should also be taken into account when analyzing the impact of prices. Namely, prices in Croatia are 37.41% below the European average calculated for September 2021 (Fig. 4) and after the deregulation process, it is realistic to expect a significant increase in prices that will follow in the next regulatory period due to changes in the wholesale market. Therefore, the following sensitivity analysis included price increases of 25%, 50%, 75%, and 100%, which in the long run will mean a decrease and increase in prices given the expected new prices, which will be around 72% higher in the next regulatory period. Sensitivity analysis was made for all calculated parameters and, in addition to different prices, includes 3 different discount rates (5%, 7%, and 10%).

4. Results

The analysis, i.e., the results are presented on the example of the installation of 100,000 modules for remote reading due to

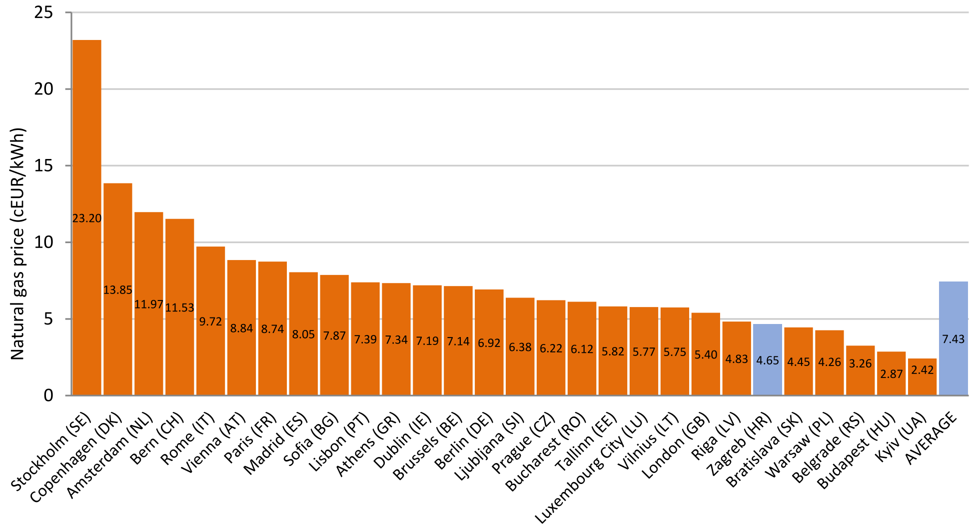

Fig. 4. Natural gas prices for households in Europe in September 2021 (HEPI, 2021).

Table 2
Annual costs and benefits of installing 100,000 remote reading modules without discounting.

Cost of installing modules for remote reading — onetime expense	7,000,000 EUR
Operating costs	700,000 EUR
Total financial benefits per year	1,650,000 EUR
Reduction in meter reading and operation costs per year	326,500 EUR
Minimum value of energy savings per year	755,580 EUR
Average value of energy savings per year	2,365,834 EUR
Maximum value of energy savings per year	3,976,088 EUR
Financial savings achieved by the energy supplier	4,255,943 EUR

a more representative magnitude. Given the very short time required to install the module per metering point, 100,000 modules can be installed in several months if a few dozen workers are employed. Since all modules can be installed in several months, the cost of installing the module is not discounted. The financial aspects, i.e., annual financial costs and benefits of installing 100,000 remote reading modules without discounting are shown in Table 2.

Given the lifetime of smart meters, all annual financial aspects beside cost of installing modules which is onetime expense were discounted over a period of 15 years. The sums of discounted values for input parameters from Table 1 are shown in Fig. 5 below.

The results of financial the analysis showed that with the total financial benefits given in the Study on the cost–benefit analysis of smart metering systems in the EU Member States, the return on investment and all operating costs is possible in 12 to 13 years. Of course, it should be taken into account that the total financial benefits include certain savings that will be realized by end consumers, i.e., not all savings will be realized by the energy supplier. The savings that will be realized through a reduction in meter reading and operation costs are entirely related to the energy supplier, and the results have shown that they can cover approximately 22% of the initial investment and operating costs.

The value of energy savings largely depends on the scenario chosen. The energy savings in the minimum scenario refer to smart meters that do not send feedback to the end user, while in the maximum scenario the end user receives feedback immediately. Given that in the observed pilot project, the end user receives feedback with a delay of 24 h, energy savings in the average scenario can be considered relevant in the worst-case scenario. Realistically, the savings could even be greater given the short time of feedback, but this needs to be further examined in future research. In this average scenario, the value of energy savings allows a return on investment and all operating costs in under 8 years.

Two energy savings scenarios (average and maximum) resulted in higher summarized financial benefits from energy savings than summarized total financial benefits, which is unusual considering that the bill reductions from energy savings were also taken into account when calculating total financial benefits. The reason for this is the use of outdated data on natural gas prices and energy savings in the Study on the cost–benefit analysis of smart metering systems in the EU Member States from which the weighted average of financial benefits per metering point was taken. Therefore, summarized benefits from energy savings can be considered as a more relevant and accurate scenario than summarized total financial benefits.

The summarized financial savings achieved by the energy supplier grow for only 5 years because that is a legally determined time period during which the energy supplier is granted energy savings for the installation of smart meters. It is important to point out that this period is enough for the energy supplier to use this measure to achieve savings that are greater than the total CAPEX and OPEX over 15 years. The reason for this is the high value of legally approved energy savings amounting to 160 EUR per MWh, which is several times higher than the market price of natural gas for households. This means that the energy supplier will use this legally enacted measure to justify the cost of investing in smart meters and the actual energy savings will be fully passed on to end customers, i.e., end customers will realize financial savings in consumption. In the event of a change in the legally enacted measures in a negative sense for the energy supplier, i.e., if he cannot cover the costs of implementing smart meters with this measure, the installation cost can be partially covered through changes in the supply tariff. Such a change would mean that the tariff for final consumers would be increased by shifting the partial financial value of energy savings to the

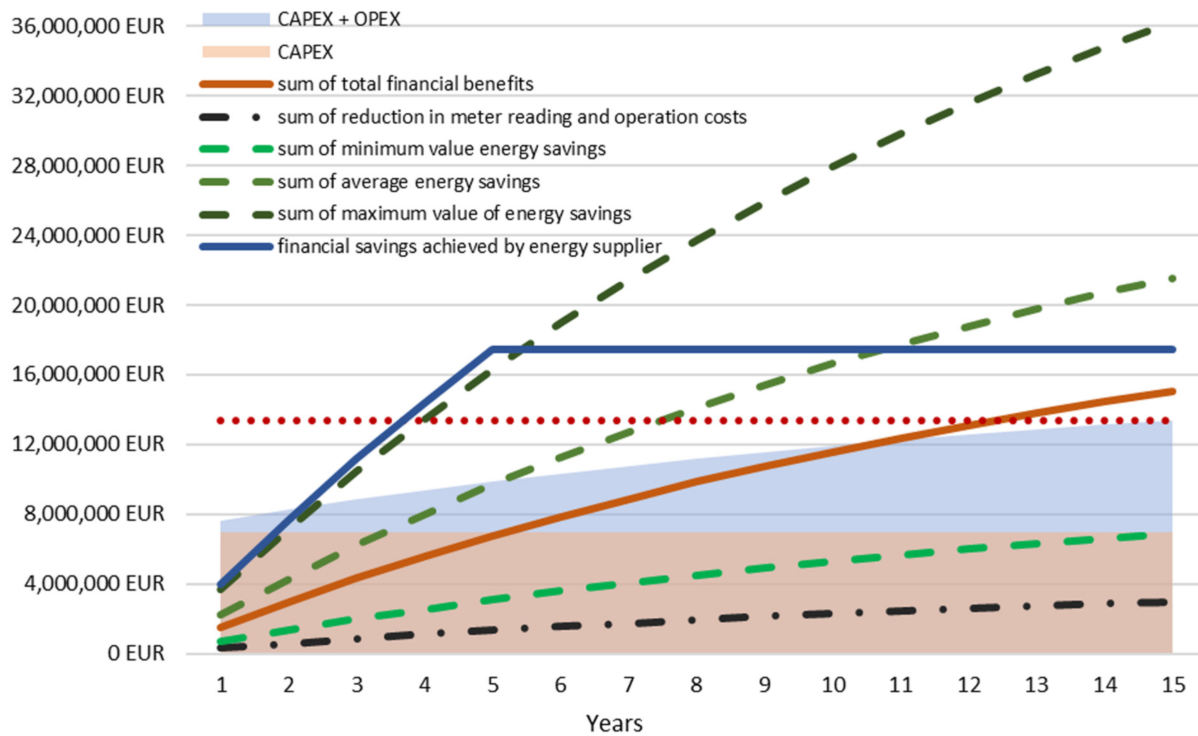

Fig. 5. Summarized annual costs and benefits of installing 100,000 remote reading modules with discount rate of 7%.

energy supplier to cover the costs of implementing smart meters. Also, the same methodology for transferring partial financial savings from end consumers can be proposed in EU members where the financial value of legally approved energy savings is not sufficient to cover the cost of implementing smart meters.

4.1. Results of sensitivity analysis

As mentioned earlier, due to significant changes in natural gas prices in major European markets but also due to future price deregulation, a sensitivity analysis was conducted. The analysis was conducted for 5 different natural gas prices (current price and 25%, 50%, 75%, 100% higher price) and 3 different discount rates (5%, 7%, and 10%) due to possible changes in business risk. Fig. 6 shows that the price of natural gas has a significant impact on the value of energy savings but has no impact on other costs and benefits because all other costs and benefits, aside from the total financial benefits. Although dependent on the market price of gas, the total financial benefits in this analysis do not change depending on the price of gas because they are obtained as the total amount per metering point from the mentioned Study. This means that it is impossible to determine the extent to which the price of natural gas affects them and can be considered less relevant as explained in the section earlier. Also, from the analysis it is evident that in all scenarios the financial savings achieved by the energy supplier will be sufficient to cover the total investment and operating costs with the current valid legal regulation.

5. Conclusion

This paper researches the installation of a module for remote reading of natural gas consumption. By installing the module on the already existing classic membrane gas meter, all the features of a gas smart meter are achieved. To send information, the module uses the increasingly popular Sigfox network, which has proven to be a very good tool in achieving IoT in many sectors. The paper observes the pilot project carried out by an energy supplier in the east of the Republic of Croatia with the installation of more than 10,000 modules for remote reading of natural gas consumption.

The results of the financial analysis have shown that the financial savings achieved by the energy supplier using the legal measure on energy savings are sufficient to cover the investment and operating costs of the entire investment. This means that the actual energy savings will be fully passed on to the end customers, i.e., the end customers will realize financial savings on their consumption. If the energy supplier cannot cover the cost of implementing smart meters with this measure, or if this measure is non-existent in some EU member states, the installation costs can be covered through changes in the supply tariff. Such a change would mean increasing the tariff for end-users by shifting the partial financial value of energy savings to the energy supplier to cover the cost of implementing smart meters. This type of change in natural gas tariffs must be proposed and approved by the national energy regulator, which is under the jurisdiction of the national parliament.

The sensitivity analysis has shown that the price of natural gas strongly affects the value of achievable energy savings, while other calculated costs and benefits are not affected. In addition, the analysis has shown that in all scenarios financial savings achieved by the energy supplier will cover the total investment and operating costs under the currently valid legal regulation.

The novelty of this paper is in presenting the installation of a module for remote reading of natural gas consumption that enables a classic gas membrane meter to achieve the characteristics of a smart meter, i.e., to become a smart meter. This has proven to be a very good solution both financially and timewise, given that in most cases the implementation of gas smart meters is very financially and time-intensive. The module can be installed in a few minutes and the cost of installation per metering point is about 2.4 times less than the EU average. The development of the module described in this paper represents a new direction in the development of gas smart meters that has proven to be more financially and time-efficient.

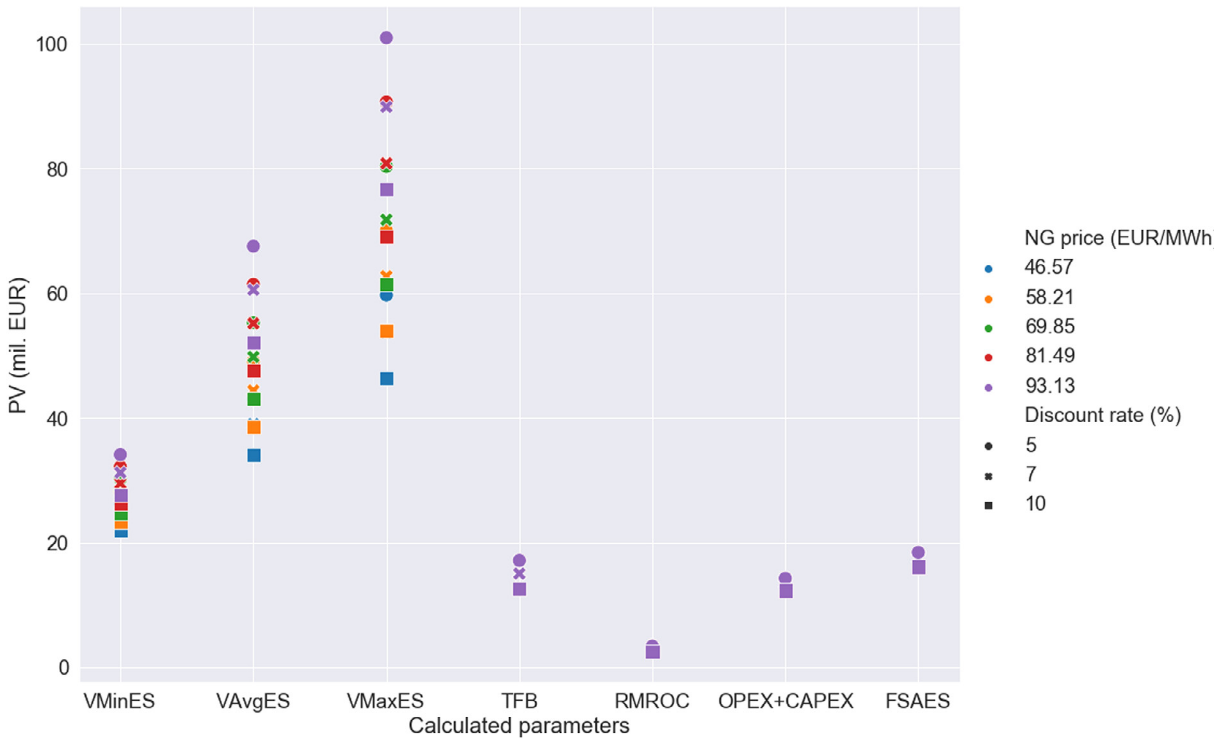

Fig. 6. Results of conducted sensitivity analysis (5 price scenarios and 3 discount rate scenarios).

Further research will focus on the calculation of achievable emission savings and the usability of the collected consumption data for an easier transition

CRediT authorship contribution statement

Ivan Smajla: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Daria Karasalihović Sedlar:** Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing, Supervision. **Lucija Jukić:** Formal analysis, Methodology, Writing – original draft, Visualization. **Nikola Vištica:** Writing – review & editing, Methodology, Investigation, Data curation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ivan Smajla reports administrative support was provided by HEP Plin d.o.o.

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