An analysis of the main Characteristics and Implementation Requirements of the Advanced Metering Infrastructure Systems in Romania

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In this paper, we analyze the main characteristics and implementation requirements of the advanced metering infrastructure (AMI) systems in Romania, taking into account that the smart metering implementation enables the consumer to devise a custom-tailored strategy for his own energy consumption. First, we have studied a series of important aspects regarding the intelligent metering systems, then we highlight legal aspects regarding the implementation of AMI systems in Europe and in Romania. Afterwards, we have analyzed the types of energy consumers, their demands regarding the technological solutions for the assessment of their own consumption, registered by the smart meters and finally aspects regarding the emerging trends of the consumers' behavior. By implementing advanced metering infrastructure systems, through judicious investments and activities related to the consumers' behavior, one can obtain an improved energy efficiency at both national and international levels.
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1 Introduction

The Romanian Authority for Energy Regulation(ANRE) regulates the implementation of the advanced metering infrastructure (AMI) systems for the energy sector in Romania, through the ANRE Order no. 145/2014 [1] and the ANRE Order no. 6/2016 [2].

Through these documents, ANRE approves the proposals of the energy distribution operators for implementing the advanced metering infrastructure (AMI) systems in the case of the operators who meet the criteria for approval of pilot projects listed in the Annex 3 of [2].

The Romanian Authority for Energy Regulation (ANRE) has also approved the implementation rate of those systems by the concessionaries operators and aims the implementation of the advanced metering infrastructure (AMI) systems for approximately 80% of the customers until 2020.

In order to obtain the approval of implementing an advanced metering infrastructure (AMI) system, the energy operators should take into account that such a project must meet some minimum mandatory conditions, namely: technically – the project must be feasible; financially – the project must be reasonable and its effect must lead to considerable savings, according to the value of the investment.

According to [2], in order to disseminate information regarding the implementation and features of the AMI systems, alongside the official information provided by ANRE, the distribution operators are compelled to display on their web pages, information regarding the AMI systems implementation projects that they are undertaking.

In the following there are analyzed the main characteristics and implementation requirements of the advanced metering infrastructure (AMI) systems in Romania, studying first a series of important aspects regarding the intelligent metering systems. Afterwards, a few of the most important legal aspects regarding the implementation of AMI systems in Europe and in Romania are highlighted. Then, it is presented an analysis regarding the types of energy consumers, their demands concerning the technological solutions for the assessment of

their own consumption registered by the smart meters and finally aspects regarding the emerging trends of the consumers' behavior.

2 General aspects regarding the advanced metering infrastructure (AMI) systems for energy

The advanced metering infrastructure (AMI) systems for energy consist of electronic systems, designed to measure the energy consumption while also achieving a bidirectional secured transmission of information to the end customers. These systems have the ability to provide much more information than the conventional meters, using electronic means of communication for the transmission of the information [2].

The advanced metering infrastructure (AMI) systems include a number of subsystems, namely: subsystems for measuring (include meter, which secures access to the equipment, transformers); subsystems for the transmission of information (communications network); subsystems for data reception and managing (**Fig. 1)**.

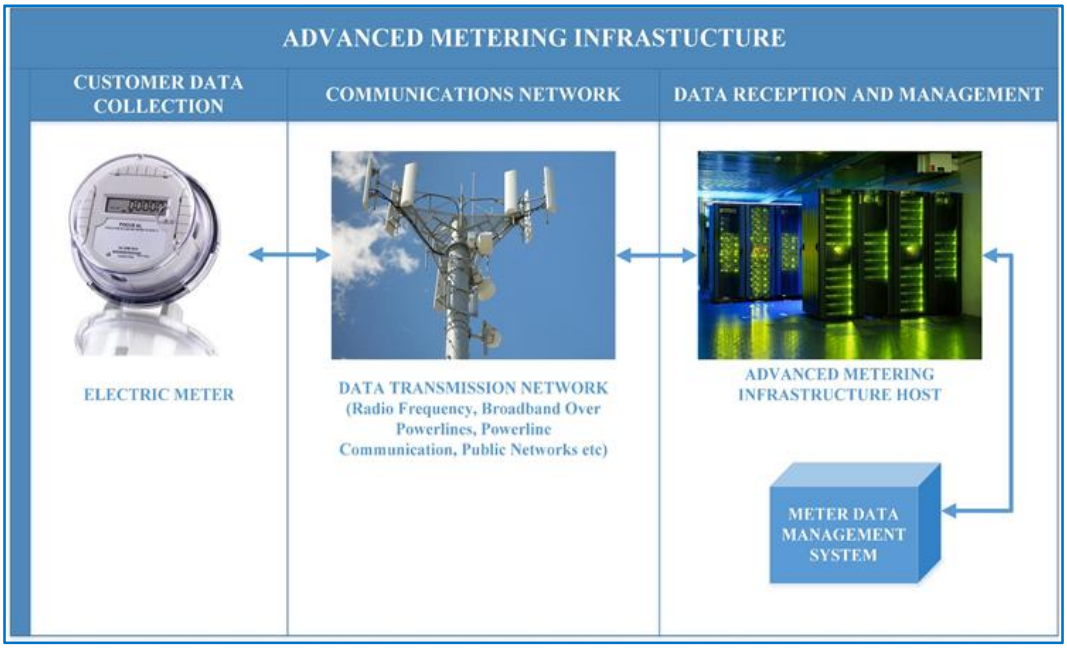

Fig. 1 Advanced metering infrastructure (AMI) systems

(The figure has been developed using the software Visio 2016 by inserting elements of "Online Pictures" type, marked with a reusable license of the "Creative Commons Licenses" type)

The advanced metering infrastructure (AMI) systems for energy must offer a series of mandatory and optional features defined in the Annex 1 of [2]. By implementing the AMI systems, a more efficient administration of tariff plans is achieved, by monitoring consumption in real time and by using the instant data transmission.

The installation project of the AMI systems, in terms of energy consumption, thermal energy and natural gas, was launched in the European Union that provides grants to implement AMI [3]. In Romania, ANRE launched in 2013 the project for advanced metering infrastructure. According to the [3] report, the plan for implementing the AMI system within the energy market in Romania targets a period of 20 years (2013 -2032), within which until 2020 approximately 80% of customers will be covered and until 2022 the AMI installation will be performed for all the consumers.

The implementation of these systems is an important step in the liberalization of the energy market (and the gas), planned for 2022, thus offering to the consumers the opportunity to choose and change their energy supplier at any moment. In addition,

the AMI systems contribute to the energy efficiency at national and European level.

After considerable investments, a smart grid will be achieved, as a result of implementing these systems. The smart grid represents a symbiosis between the components of a conventional power network and elements related to the communications and information technology, complementing the functionality of the electric grid. According to the ANRE reports, the implementation of the AMI systems aims primarily the energy market as this is the largest of the three targeted markets (energy, gas, heat).

This market addresses a number of 9.000.000 consumers, as follows: 8.38 million households, 600.000 micro, small and medium enterprises, 20.000 large consumers (local governments, public authorities, companies). The report [3] estimates that for the energy market, the investments in AMI will bring the fastest and substantial benefits, including the investments' amortization. For the natural gas market, the report expects that the benefits will be reduced, while in the case of the thermal energy the benefits brought by the transition to the AMI systems are insufficient compared to the investments needed for implementing those systems. In this case, the efficiency should be achieved at the thermal power stations level and at the transport infrastructure one, in order to reduce losses.

Taking into account the implementation pace of the AMI systems by the concessionaries operators, proposed by ANRE, the report [3] estimated that the investment has a return of 43.8% and a net positive present value of 1.17 billion lei. In the case of the gas market, the net present value is negative ($-72{,}000{,}000$ lei), but the investments in AMI implementation may be delayed by operators, because for this market The European Commission did not impose certain targets. In order to reduce the spending, the same company might deliver both the energy and natural gas to the end customers.

Currently, the cost of a smart meter device is about 140 Euro, therefore the necessary investment for acquiring the energy meters for the 9,000,000 customers amounts to about 1,260,000,000 Euro. On the other hand, in order to implement the AMI system, one requires infrastructure investments in the construction and installation of equipment that processes the data received from the consumers. In order to recover the investment, in the first step the customers' bills will increase, but one expects that these will decrease over time, as the consumption reduces, due to the intelligent metering systems. In this way, the recovery of the initial investment is ensured [3].

The core component of the AMI, the meter, must ensure on the one hand the submission of periodic consumption registrations and the evolution indexes to the end customer and third parties, and on the other hand should provide storage space for the data during specified periods of time. Based on these systems, one will record and transmit data regarding the consumption on a daily basis. The meter must transmit data remotely to the distribution operator, must offer the possibility to update remotely the software and the different types of billing tariffs, according to the existing regulations. One of the major advantages that the implementation of such a system brings to the end user consists in the fact that he can change his billing plan according to his own needs [3].

An important issue that the energy distributors will have to manage along with the implementation of AMI systems is the fact that they should ensure that the data transfer is performed wirelessly (through Wi-Fi or mobile data), or by using the energy grid (which would result in smaller costs than using the wireless transmission) [3].

Installation of AMI systems brings to the consumers a series of benefits including: real-time identification of faults that facilitates the rapid intervention when having to solve them; the fast detection of areas where the energy parameters do not

correspond to the quality standards, or there have occurred interruptions in the power supply; the ability to read data remotely, in real time; the billing accuracy. Basically, the smart meters provide accuracy, precision and efficiency in the reading process, in the recording of the consumption data and its secure transmission, in eliminating payment based on consumption estimation, in ensuring the continuous monitoring and effective intervention when incidents occur, while providing transparency on real time consumption to the customers [4].

In the following we analyze a series of legislative issues regarding the implementation of AMI in Europe and in Romania.

3 Legislative issues regarding the implementation of AMI in Europe and in Romania

At the worldwide level, there are more countries that have set up and adopted regulatory frameworks and have imposed deadlines regarding the putting into operation of the smart metering systems and, in some cases, of the smart grids [3].

In Europe, Italia has become the first country that has implemented automatic smart reading meters for more than 30,000,000 of its citizens. The national regulatory authorities have set clear objectives for the implementation of smart metering systems (especially for gas consumption, as electricity consumers are already benefiting from these systems), and imposed annual penalties on suppliers who fail to achieve the defined targets [3].

The Nordic countries have implemented these technologies as well. Sweden, for example, has mandated the installation of more than 5,000,000 smart meters by the end of the year 2009. In Denmark, although there are no legal provisions regarding the installation of smart meters, there have been conducted a series of large-scale implementations. Profile companies in Denmark offer to their customers an advanced market model and a structure that includes multi-utilities. Finland covered 80% of its households with electricity smart meters at the end of 2014 and the installation process carries on.

Norway aims to complete the installation of smart metering systems by the end of 2017. The Norwegian authorities have developed a methodology that compels the utility companies to implement smart metering systems that meet certain requirements (for example, the reading must be performed at 15 minutes intervals, options to connect and disconnect remotely, encrypted communication and integrated equipment for water and gas consumption).

Spain, France and the United Kingdom are the most active markets for electricity and natural gas. Spain has mandated the installation of a smart metering system that became operational by the end of year 2014 and its implementation must be completed by the end of the year 2018.

In France, the national energy regulator has imposed a mandatory implementation of smart metering for all the electricity consumers by the end of the year 2016 (with a coverage of at least 95%) and the manager of the gas distribution network is preparing to introduce gas smart meters to all the customers.

In the United Kingdom, the British government announced its plan to install 53 million electric and gas smart meters in households and companies by the end of the year 2019.

However, national authorities in some countries have not imposed strict targets for the implementation of smart metering systems. In Germany, for instance, electric and gas smart metering systems must be installed in new buildings, while the owners of existing buildings can optionally choose to implement this technology.

In most of the countries, the decisions to implement smart metering systems are based on a cost-benefit analysis for the investors and for the society as a whole. In most of the cases, the benefits are significant for the society, but the investments are not always profitable for the investors [3].

In the United Kingdom, a study conducted

by the Energy Saving Trust revealed that within each household one could achieve savings of 10% per year on energy bills by implementing smart meters. These results were tested using pilot projects, run by Scottish and Southern Energy, funded by the Department of Energy and Climate Change and the national regulatory authority.

As a result, the government has concluded that the implementation of smart metering systems is the most effective way to help customers reduce energy consumption in the context of this country's objective to reduce CO_2 emissions by the year 2020. In addition to this, the installation of smart meters showed a reduction of 2.8% in energy consumption [3].

In Ireland, the Energy Regulatory Commission (CER) published the results of a pilot project for implementing smart meters, developed with the support of more than 10,000 customers. These results reflect a decrease of 2.5% in electricity consumption for households, with a peak demand reduction of 8.8%.

Out of the total customers, a percentage of 82% has made changes in their energy consumption behavior and it was observed that the information displayed on the smart meters that were installed in these homes had a significant role in reducing the energy consumption.

The results showed that the implementation of smart meters brings also benefits to consumers with limited incomes or for those households that typically receive state subsidies, enabling them to reduce their electricity bills and modify their consumption behavior [3].

In Italy, after having obtained a great success by implementing smart meters for electricity, the regulator authority has conducted a cost-benefit analysis before announcing in 2008 the mandatory installation of 21,000,000 smart gas meters out of which 19,000,000 must be installed before 2016.

On the other hand, in Sweden, the installation of smart meters was not explicitly mandatory but there was an implicit requirement, as from July 2009 the legislation stipulates reading hourly all the electricity meters, which led to the widespread implementation of smart meters.

The decision to read the meters hourly was taken following a positive cost-benefit analysis conducted in 2010 that showed significant gains in terms of energy efficiency for households whose consumption exceeds 8,000 kWh [3].

The Dutch government announced the mandatory installation of electricity smart metering systems for all the 7,000,000 households in the country until the year 2013, based on a cost-benefit analysis that showed positive results. However, the implementation of smart metering was interrupted and postponed in 2009 because of concerns related to privacy among consumers.

In this context, the government sought solutions in order to obtain the benefits of an improved energy efficiency (proven through analysis and studies) while ensuring and protecting the consumers' privacy. This was achieved by setting different deadlines for the implementation of smart metering for electricity and gas, and by making optionally the transition for customers.

In Germany, the smart metering policy is also mainly driven by the customers' demand and the state hesitated to impose strict targets due to the public's strong reluctance on personal data protection. From the investors point of view, one of the major advantages of installing such systems is the reduce of technical and commercial losses in electricity supply.

This was one of the key reasons for implementing these systems in Italy and Poland, where studies have indicated a potential reduction of commercial losses by 60% (in some cases even up to 90%).

In Romania, the AMI implementation is regulated by the ANRE Order no. 145/2014, regarding the deployment of smart metering in the energy field [1], which was subsequently amended and supplemented by the ANRE Order no. 6/2016 [2].

These documents define the intelligent

metering systems, specify their mandatory and optional features, stipulate the conditions that must be fulfilled by the projects regarding the deployment of smart metering and the implementation pace of these systems.

The Order [1] also stipulated clear guidelines for the concessionaries operators regarding the implementation in 2015 of pilot projects and evaluation of specific aspects within the distribution networks, in order to establish the final implementation terms of intelligent metering systems.

For the year 2016, the Order [2] stipulates the obligation of the concessionaries operators to monitor the implementation of pilot projects regarding the smart metering systems, developed in the year 2015 and assess their costs and benefits. The National Regulatory Authority for Energy monitors the results registered within the projects regarding the implementation of intelligent metering systems.

After evaluating the results of the projects regarding the implementation of intelligent metering systems, the concessionaries operators propose to the ANRE plans for implementing the intelligent metering systems for the period 2017-2020 (up to January 10, 2017).

Using the results of pilot projects carried out by the concessionaries operators, ANRE performs (using an independent specialized consultant) a cost-benefit analysis on the implementation of the intelligent metering systems and then, based on this study, develops the national plan for the period 2017-2020 regarding the implementation of intelligent metering systems. In this purpose, it is essential that the concessionaries operators submit to ANRE all the required data and information, useful for achieving the cost-benefit analysis. Based on this analysis, ANRE approves until 31 March 2017:

- a national schedule calendar regarding the implementation of intelligent metering systems that contains the dates of the various implementation stages
- a national schedule calendar regarding the implementation of intelligent metering systems, containing details about each distribution operator investments, the amount and funding sources
- measures and means of information for the end customers.

The Order [1], amended and supplemented by the subsequent order [2], requires the concessionaries operators to display on their web pages information regarding the implemented intelligent metering systems (their number, technical data, the mandatory and optional features, the communication type with the subsystems that manage the information).

Both operators and concessionaries distribution suppliers are obliged to disclose in the electricity bills if there are implemented intelligent metering systems at the consumption place, in order to inform the end customer.

The Order [2] stipulates that at the request of the end customers connected to the energy grid, the transmission system operator can offer to the customers intelligent metering systems, complying to the specifications of the Order. The Order also stipulates that the implementing regulations of the intelligent metering systems may also apply to other distribution operators, outside the concessionaires, on their request.

The Order [2] contains five annexes.

Annex 1 provides a range of mandatory and optional features for the intelligent metering systems. The mandatory features of the intelligent metering systems take into account:

- the end customer (the intelligent metering system must: transmit to the end customer and to a third party designated by him, the system readings; update frequently the system readings, in order to facilitate energy savings)
- the concessionaire distribution operator (the intelligent metering system must: allow the concessionaire operator the remote reading of meters; facilitate the communication between the measurement subsystem located at the consumption place and the subsystem for the

transmission of information; readings must be performed frequent enough as to be useful for the network's management)
- the commercial aspects related to the energy supply (the intelligent metering systems must: support the use of advanced billing systems; facilitate the remote control of connecting, disconnecting and power limitations)
- the aspects regarding data protection and security (the intelligent metering systems must: ensure the secure transmission of data, prevent and report the unauthorized access)
- the decentralized production (the intelligent metering systems must: ensure the possibility of measuring the absorbed, delivered and reactive energy)
- the intelligent metering systems must facilitate the fast automatic identification of damages, reducing the necessary time to repair them; facilitate the monitoring of the energy's technical parameters
- the intelligent metering systems must allow, through their infrastructure, the integration into the transformer stations of balance meters (facilitating the losses identification).

The optional features of the intelligent metering systems aim:
- to achieve the communication with the receptors situated at the end customer's location and with other utilities' meters
- the information received from the meters must be stored by the data management subsystem for at least the billing, the payment or the claiming period
- the infrastructure of such systems should enable the installation of additional meters (without replacing the existing elements)
- the storage capacity of the measuring and information transmission subsystems must be large enough so that the data can be stored for a certain period of time.

Annex 2 refers to the description of pilot projects regarding the implementation of the intelligent metering systems. This Annex stipulates that the concessionaries distribution operators must send a series of information to ANRE, regarding the estimated data for the pilot projects that have to be endorsed and also data obtained after the pilot projects fulfillment.

These data contain information regarding the concessionaire distribution operator's name, the number of proposed and fulfilled pilot projects, the development areas of these projects, the technical parameters of the energy networks within each pilot project, the detailed features of the pilot project, showing that it meets the requirements.

Annex 3 specifies the criteria for approval of the pilot projects regarding the implementation of the intelligent metering systems in the energy field: the correlation of the corresponding investments of these projects with the provisions of the investment programs; the share of the total value of investments in the implementation of the intelligent metering systems, from the total investment annual plan; the comparative study of unit costs, providing necessary data for achieving the cost-benefit analysis; the mandatory use of balance meters; the analysis of costs arising from the investments in the distribution network in order to implement the intelligent metering systems.

Annex 4 presents general data of the implementation plan of the intelligent metering systems in the energy field that have to be completed by the concessionaires operators: data regarding the network in which the intelligent metering system will be implemented; the technical solution adopted for the implementation; data regarding the security of the intelligent metering system; the confidentiality; financial data; the additional estimated costs; the timing of the investment plan regarding the implementation of the intelligent metering systems, for each year during the 2017-2020 period; the percentage and the value (in thousands of lei).

Annex 5 defines a number of 29 indicators used to assess the intelligent metering systems' implementation. These indicators are divided into several categories, depending on the covered field: the

implementation status of the intelligent metering system; the intelligent metering system's structure; the economic effects of the intelligent metering system's implementation; the performance (in terms of quality) and the security.

The three percentage indicators that assess the implementation of the intelligent metering systems are:

- the implementation degree of the smart metering systems in the lease area, for the residential customers, computed as the ratio of the number of residential customers for which the smart metering systems have been installed and the total number of residential customers from that area;
- the implementation degree of the smart metering systems in the lease area, for the non-residential customers, computed as the ratio of the number of non-residential customers for which the smart metering systems have been installed and the total number of non-residential customers from that area;
- the implementation degree of the balance metering systems, computed as the ratio of the number of installed balance metering systems and the total number of balance metering systems planned to be installed, according to the intelligent metering system's implementation project.

In the following we present and analyze the types of electricity customers.

4 Types of electricity customers

The main participants at the retail electricity market are the providers, the end customers and network operators. The end customers buy electricity for their own consumption and eventually for the consumption of the end customers who are connected to their places of consumption. The end consumer of electricity is an individual or a legal person who consumes electricity under a contract whose electrical installations are connected to the source system of the supplier. Electricity consumers can be classified taking into account several criteria [5].

Thus, depending on the intended use of the consumed electricity, end customers fall into two categories [5]:

a) residential end customers;
b) non-residential end customers, meaning those customers who are buying electricity for their own use, different from household use (this category includes producers, suppliers, network operators that buy energy for their own use).

In what concerns the non-residential end customers, in terms of the power approved by the connection technical certificate, the consumption points can be of two types [5]:

a) with low consumption, if the approved power is less than or equal to 100 kW (in which case the customer will be called a small non-residential customer);
b) with a high consumption, if the approved power is greater than 100 kW (in which case the customer will be called a high non-residential customer).

In terms of the duration of electricity consumption, stipulated by the contract, the customers can be classified as [5]:

a) temporary customers;
b) permanent customers.

Depending on the number of consumption points, the electricity customers can be of two types, namely [5]:

a) customers having a single point of consumption;
b) customers having multiple points of consumption.

In the following, we examine the customers' requirements related to the available technical solutions that analyze their own consumption recorded by the smart metering systems.

5 The customers' requirements regarding the IT solutions for the analysis of their own consumption recorded by the smart metering systems

The requirements of the customers concerning the IT analysis solutions of their own electricity consumption recorded by the smart metering systems can be summarized as follows:

- the measurement and evaluation mechanisms must ensure the transparency of information regarding the electricity consumption and the production, transport and distribution costs, highlighted in the invoice issued by the supplier;
- the metered data must be stored for a reasonable period of time in order to support possible complaints;
- the smart metering system must allow the consumption assessment using multiple billing plans, achieving simulations that can substantiate an adequate consumption pattern, efficiently adapted to the goals and the means of accomplishing it;
- the smart metering system must allow the obtaining of consumption forecasts that have acceptable margins of errors (both technologically and economically) and the possibility to correlate the consumption's evolution with the production plans, the transporting capacities and / or with the distribution;
- the power quality must be monitored permanently, the technical and non-technical losses must be reduced;
- the system should safeguard the collected data and their processing results with a maximum security level, because by using these data one may deduce information that could shape specific consumer profiles or lifestyles.

In the following, we present and analyze a series of modernization trends in the electricity consumer's behavior.

6 Aspects regarding the emerging trends of the energy consumers' behavior

The energy efficiency improvement can be achieved through a harmonious combination of infrastructure investments and activities related to the consumers' behavior. By implementing a balanced system of investment and behavioral measures it is facilitated the energy saving, the sustainable development of business, of economy and of society as a whole.

An essential factor that determines the modification and modernization of the energy consumer's behavior lies in the human interaction with new technologies, with modern smart devices, with means of generating energy from own sources, with smart metering devices in the energy field, which generates an active role of the consumer regarding the power management.

When analyzing the impact of human interaction with new technologies, on the emerging trends of the consumers' behavior, the relevant dimensions are [6]:

- from the cultural point of view, the implementation and expansion of the new devices provide quick access to information. These devices have a strong social component among youth people (mobile phones, televisions, computers that contribute to the development of interpersonal communication), in opposition to a certain reluctance and even fear of technology among the elderly;
- regarding the comfort, the implementation of the new technologies brings modifications to the consumers' behavior and habits, to their daily activities; for example, the implementation of the intelligent metering systems offers to the consumer the indisputable advantage of controlling the energy consumption in real time;
- regarding the cognitive impact, the emerging technology brings advances to the human society as the consumers are adapting, keeping up with technology. An essential element that must be taken into account is the feedback stage that must take place in a short time interval after the consumption. For example, in the case of the smart metering devices, they provide real-time information regarding the consumption.

At the European level, many of the measures that have as a purpose the attaining of energy efficiency are based on implementing new technologies and on the consumer's accommodation to them. In reality, in many cases this interaction is an ongoing challenge, imposing the adapting of

decisions to the specific conditions of each consumer.

The issue of producing and using the energy in a more efficient manner represents a major concern at both international or national levels and also among consumers, whether they are industrial or residential ones.

The authority's involvement in achieving energy efficiency is noticeable by legislation and actions at all levels (local, regional, national or even European), while the consumer's awareness is achieved gradually, the changing of their behavior being less influenced by regulations, but rather by technological, economic and potential savings aspects.

In recent years, the fast technological development offers more and more efficient technical solutions, thereby influencing the end energy customers' behavior. Nowadays, the consumer has a wide range of options, from technical solutions that enable him to assume an active role in managing his consumption, to the use of alternative renewable energy sources.

7 Conclusions

Smart metering allows the customer to establish a power consumption strategy custom tailored to his own needs and to the dynamics of the consumption schedule, correlated with an adequate billing plan. On one hand, the smart metering systems assure through their implemented features that the customers have access to accurate real-time information and on the other hand, they provide useful information for improving the electricity distribution process and overall quality. In addition to this, by helping to improve the feedback mechanisms, the smart metering systems facilitate the development of new services for the end customers. The integration and deployment of smart metering in a power management system helps improve the communication and control possibilities between the customers and the suppliers, optimizing the electricity consumption along with its production and distribution process. Therefore, the existence of an adequate infrastructure for the development and implementation of an intelligent electrical network that facilitates the exchange of valuable information between the producer, supplier and customer becomes mandatory.

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