BUSSINES OPPORTUNITIES FOR RETROFIT HOMES WITHIN SMART METER IMPLEMENTATION CONTEXT

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Abstract:
The paper presents the state of the art for smart meter implementation across EU, in the context of smart home concept. Upcoming deadline of smart meter implementation rises a series of barriers and challenges, regarding the necessary communication infrastructure, consumers behavior and technical solutions available. Beyond changing the meter, the smart meter usage scenario should contribute to energy consumption reduction and allow consumer to choose the most fitted supplying contract type and to enhance the life quality. However, using prospected retrofit action for homes, several implementation scenarios are proposed, considering drawbacks of existing implementations. For a contextual approach, using IoT devices, an added-value chain of decision is foreseen, proposing to consumer actions rather than numbers indication of energy consumption. Because, most of households do not include a smart home gear, is necessary to retrofit them, in terms of sensors, communication and data exchange. Furthermore, using existing Romanian energy market experience, the implementation scenarios explored before are business modelled for different type of households' energy consumers. Even are started as different visions or initiatives, integration of various concepts, like smart city, smart home or smart metering is required to enhance consumer experience or increase the technology adoption.

Keywords: smart metering, smart home, smart city, IoT

1. INTRODUCTION

According to last available statistics (Enerdata, 2018), the world energy consumption reached in 2016 13 276 mtoe (millions tons of oil equivalent), with a slow 1% growth over 2015. Moreover, China is the biggest energy consumer since 2009, with 3 123 mtoe, representing 55% of total Asian energy consumption in 2016. However, the biggest growth rate, against 2015, is registered by India with 4.6%. The energy consumption breakdown by source reveals a distribution based on primary source: oil 32%, coal 27%, gas 21%, biomass 11% and electricity 9%.

A more-in-depth statistic, presented by BP (BP, 2017) shows an energy distribution breakdown, including electricity source. Although renewable energy is one of the hopes to reduce the carbon emissions, in 2016 lied on 419 mtoe, representing 3.15% from total. However, the carbon emission rose with 0.1% in 2016, being flat. Hydroelectricity is on 910,3 mtoe and nuclear energy recorded for 2016 is about 600 mtoe. European Union energy consumption is slow growing from 1626.7 mtoe in 2015, to 1642.0 mtoe in 2016. The consumption of energy reported by Eurostat (Eurostat, 2017) is divided between transport 33.1%, household 25.4%, industry 25.3%, services 13.6%, agriculture and forestry 2.2% and other 0.5% for 2015.

The Energy strategy for 2020 (European Parliament, 2010) stated a series of priorities regarding the future European development of energy market:

- *Achieving an energy efficient Europe*, having in mind statistics from above, a first action is targeting the energy efficiency improvement for transportation and buildings, regarding change-shifting of energy type and increasing efficiency. Also, this action is complemented by industrial sector energy efficiency increase in all supply-chain phases. A strong example of public sector is required, being recognized that almost 80% of total energy consumption is given by this sector.
- *Building a truly pan-European integrated energy market*, by sustaining pro-competitive measure, to avoid monopoly position, including in recently added Member States. An important reference was made to smart meter and power grids, needed to assure interoperability until 2020. New investments required to modernize and adapt existing infrastructure was assumed to be made from tariffs paid the users, raising up 1 trillion EUR.
- *Empowering consumers and achieving the highest level of safety and security*, again stressing the concept of smart grid, smart metering and billing, corelated with raising the consumer awareness regarding consumption reduction and facilitating switching between suppliers. Those specific actions came in the context of anticipated fossil resource shortening and rising of energy price from this kind of resources.
- *Extending Europe's leadership in energy technology and innovation*, envisaging the technological shift necessary, in accordance with Strategic Energy Technology (SET) Plan, including various technologies, regarding new type of fuels, including IT&C more intensive, under the for of smart grids, smart cities and intelligent networks, electricity storage and electromobility. This Plan is completed with large-scale European projects and measures to sustain long-term competitiveness. However, the projected use of 30% from total, by renewable energy requires a series of changes in energy supply-chain.
- *Strengthening the external dimension of EU energy market*, with a broad policy of collaboration, in the context of neighbors' market framework regulation alignment, promote privileged partnerships and enhance the low-carbon technology use, including nuclear technology.

The SET Plan (Directorate-General for Research and Innovation (European Commission), 2017), at the 10^{th} anniversary from the first release, emphasizes the EU achievement in the period 2010-2017:

- A higher role of renewable energies in total EU consumption of energy, from various sources: photovoltaic energy, with installed capacity of 100 GW with 4% consumption share, offshore wind energy with 486 GW installed capacity, ocean energy with a modest 20 MW installed capacity, but is planned that before 2050 to reach 100 GW installed capacity, geothermal energy with 20.8 GW installed capacity.
- Developing a consumer-centric energy system using smart technologies, in the paper context, a strong accent having smart cities and smart homes, advances with SAREF (Smart Appliances REFerence ontology) standard for IoT and the opportunity of cost reduction for sensors. However, smart projects funded by EU seeks various aspects of using IT&C in energy control, which is having a goal set up to 80 % until 2030. This control is targeting lighting, cooling and heating system automation. Beside energy consumers, SET also addresses the energy systems, with a target of 43% of renewables generation share up to 2030 and necessary changes using smart grids and their evolution to EU integrated energy systems.

- Increasing the efficiency of energy use, primary for buildings, by renovation of external envelope, develop new materials and technologies for buildings and using more efficient heating and cooling solutions, where 40% of energy is consumed. Although, also energy industry great consumers technologies are envisaged, the total reduction of energy use being 17%, from 2003 to 2013. The industrial sectors addressed in SET are cement, ceramics, chemicals, engineering, minerals and ore, non-ferrous metals, steel and water.
- Carbon capture, utilization and storage, targeting to sustain EU funded research, with a success reported of maximum 90% of capturing carbon process, cost of avoiding CO_2 decreasing from 50 EUR/t to 25 EUR/t in last decade. The carbon storage technology, by safe a permanent geological storage, has been tested using injection was successful with 80% rate at 500-800 m depth, according to CarbFix project results, developed in Iceland. Another line is to capture carbon dioxide from polluting industries (iron, steel, refineries and cement) and to be used in methanol synthesis, which later will serve as fuel.
- Nuclear power safety, even nuclear power energy production has decreased 1.4% every year since 2005, remain at 15% from total EU energy. Further safety plans are required to increase the population trust in this form of energy.

Starting from ambitious goal of EU, expressed into energy strategies for 2020 (described above) and 2050 to reduce the carbon emissions up to 20% until 2020 and 50% in 2050 and having in mind that China, which is the biggest consumer of energy relies today on fossil sources for energy production, a delicate balance should be followed between consuming limitation of energy and replace or improve the polluting energy production process.

One expressed measure for increase the efficiency of energy use in household and buildings, is dedicated to an extensive IT&C usage, for monitoring and controlling the lighting, heating and cooling in the perspective of preserve the life quality standards but also to reduce the energy cost and consumption. In the following, the smart city and smart home concept will be explored, in order to identify common elements of infrastructure and how an integrated architecture might be design, in the context of old households or buildings, which are the most important category today and which do not have sensors implemented.

2. SMART CONCEPTS AND FRAMEWORKS

Smart concepts gather various systems applied in different fields. The generic term of “smart” is associated to a system that can be able to make or to suggest decisions, based on various data collected and interpreted by decision, the key point being that user interactivity. A commonality of these systems is the extensive use of IT&C, especially features like sensors, networks, big data, machine learning, cloud computing, virtual reality, augmented reality etc. The level of use for smart systems might differ and literature (Talari et al., 2017) presents three layers of composition:

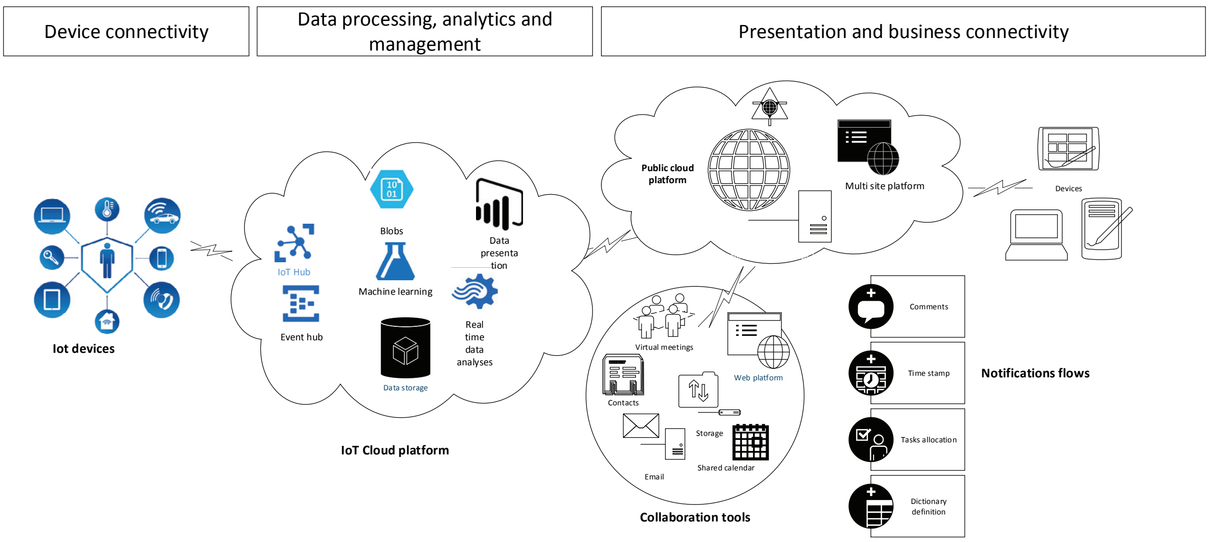
- Perception layer: including wireless and wired sensors, RFID, CCTV,
- Network layer: WiFi, Bluetooth, PLC, nG,
- Application layer: depending on user level and scope, smart city, smart home or energy consumption optimization, traffic jam reduction etc.

As technology blockchains the smart applications it is built on following blocks (Popa, Carutasu, Cotet, Carutasu, & Dobrescu, 2017) presented in picture 1:

- Device connectivity: IoT devices are connected to cloud using different networks and protocols, telemetry measured, and status change notification is sent to cloud gateway. From connection perspective, more sensors might be connected locally, using a local gateway, or directly to cloud, using WiFi or nG standards. Also, data sent should comply IoT exchange data standards (Ray, 2016),
- Data processing, analytics and management: the cloud platform comprises several different blocks:
  - IoT Hub, responsible with device two-way communication management, covering planning, provisioning, configuring, monitoring and retiring of devices connected to cloud. However, the IoT Hub receives data flow into input hub point and is forwarded to stream analytics block,
  - Stream analytics, which analyses the data flow according to multiple defined scopes. In most cases, data is routed for multiple purposes, having as goal the sensors status detection, enforce notifications or actions when conditions are met, storage of relevant data, time stamp or telemetry transformation, when data should be displayed into another scale,

    - Storage, using relational or non-relational database structure, date forwarded from the main stream by stream analytics is stored for long or short-term, depending on scope, in relational data storage or blobs,
    - Machine learning, which uses recorded data to detect behavior patterns or to predict future values or events, based on existing recorded history, the obtained results being further stored and used in application logic block,
    - Application logic, having as scope anomalies or malfunction detection, comparing actual data with detected patterns.
- Presentation and business connectivity, including several important features like:
    - Terminals management, in case of restrictive terminal access to application,
    - Users management, for establishing access rights for different level of information and the identification is used for notifying, alerting or collecting action decision from user
    - Multi-site and apps store, when the displayed content could be showed by a web page or a mobile app,
    - Collaboration tools, offering facilities for user in performing and monitoring tasks resulted from system notification, alerts or create a personal user history outside of the IoT cloud platform.

Picture 1: Proposed block diagram for smart applications



The concept of smart city reflects the usage of smart application in the context of city (Wu, Chen, Wu, & Lytras, 2018), having various goals optimization of resource usage or consumption, enhance the citizen awareness and participation to public decision or mining for trends in future developments of city services. Also, the smart home literature (Wilson, Hargreaves, & Hauxwell-Baldwin, 2017), (Alaa, Zaidan, Zaidan, Talal, & Kiah, 2017) indicates the smart systems that could be integrated into larger systems, but in this case the defined scope is on house level, even is targeting the same features regarding resource usage, safety and security or entertainment. Data collected at user level, could be further aggregated into useful information at home (which can be seen a group consisting of family members) or to city (as citizen) or governance.
Enforcing IT&C usage in daily life, to offer information, as aggregated data obtained from various sensors that will be further used in decision making process, at different levels (user, home, city, governance), using comparable patterns or predicted values, based on recorded history should enhance the consumption optimization and the life quality.
In table 1 are presented several common IT&C application, which can be identified as smart city dimensions (Talari et al., 2017), or smart home infrastructure (Alaa et al., 2017), the paper approach being to underline the application centric view instead of user level. Moreover, a prospective debate must explore what is the significance of data and application ownership and what privacy policy should be applied to overall application flow. The table presents also the functionalities for each user category and foreseen benefits. The generic term of “smart” being used not to emphasize the use of artificial intelligence or data interpretation collected from sensors, but in sense of clever use or resource consumption to obtain maximum benefits possible.

Table 1: Level of users of smart technologies

Application field	Governance	City	Home and building	User
Energy efficiency	Smart grid Energy policy Balance the national electrical energy system between production and consumption Forecasting the energy production and consumption	Smart grid Smart lighting Smart metering Forecasting the electricity consumption on city scale Strategy for city energy production facilities	Smart metering Smart cooling and heating Smart lighting Temperature monitoring Renewable energy production Energy efficiency monitoring	Reduce energy costs
Transportation and vehicular traffic	Traffic management policy Safety actions for multi-modal transportation Strategy plan to transportation development	Traffic management Traffic jam reduction Multi-modal public transportation management Mobile ticketing Highways and roads development plan	Smart parking lots	Smart route Multi-modal public transportation planning Travel scheduling Assisted driving Mobile ticketing
Environmental pollution control	Pollution map and action plan Strategy for pollution reduction	Data pollution records and maps Reduction pollution strategy Green-house gas monitoring Air pollution monitoring Noise pollution monitoring	Environmental data collection Pollution warnings	Pollution warnings
Water systems	National water production and supply policy	Water level Water analyses Water contamination Water production and consumption	Water leakage	Water contamination warnings
Security and surveillance systems	Emergency situations management Strategy development for decrease criminality and emergency situations	Public place monitoring People and object tracking Traffic police	CCTV Home breaking warning Surveillance systems Fire detection	Personal alert warning Emergency intervention request
Weather	Weather system Weather forecast	Weather warning Intervention plan	Weather data collection	Weather data display Weather warnings
Healthcare	Medical resources management and relocation Intervention plan for disasters and epidemics	Efficient management of medical resources Development plan for medical facilities	Family life parameters records Environmental records	Identification Personal medical records

		Intervention plan for disasters and epidemics		
Governance and polls	General election voting Taxes payment monitoring system	Polls for different city development plans and identification of city services miss functionalities Taxes payment monitoring system City services management		Participating to polls E-voting Taxes payment and access to city services
Social network and entertainment	Development of future development action plan using trends and incidence from social network posts subjects	Social network hub	Social network supporting Entertainment hub	Social network Entertainment services access

3. SMART METTERING AND ENERGY EFICIENCY

Smart meter technology aims to offer a system able to measure the utilities consumption automatically on hourly time and to be sent to utility supplier and advertise the consumer the values recorded and interpret those values in a way that the consumer may act to increase the efficiency of utilities usage. The system implementation supposes that the traditional meters to be replaced with smart meters, electronical devices able to communicate the hourly consumption, using a two-way communication channel to utility supplier. The system contains also an Advanced Metering Infrastructure (AMI), meaning a collection of hardware, software, communication displays, data management software and a business logic. The communication between smart meters and AMI can be realized using Power Line Communication (PLC), wireless networks or 3G, 4G. The values recorded and possible advices to change the taxation policy or other actions (Mogles et al., 2017) have to be displayed to the consumer using an In-Home Display (IHD) or personal displays (tablets, smart phones etc.).
Following the utility supply business perspectives, smart metering offers the possibility to introduce different taxation systems, in accordance with the price of utility on trade market. Especially for electrical energy, where the price is depending on hour and season, by a larger inclusion of renewable sources and impossibility to stock the electricity on values that can assure the balance between production and consumption, the smart metering might offer a better next-day forecast of electricity consumption from commercial buildings and households. The forecasted consumption levels might be used also in next month foreseen bills, for increasing the transparency of the process. The older billing process supposes that the consumer to predict a level of consumption by self-declaring statement and once at three months the energy supplier to make a regularization in accordance with onsite read values. Also, the consumer could have the possibility to communicate the meter index using a phone line or supplier website.
In EU smart metering system (European Commission, 2014) is presenting a set of minimal functionalities that should be addressed:

- To correspond to requirements of Commission (European Commission, 2012) regarding interoperability and adding functionalities to a later stage,
- To assure data protection and security,
- To offer a demand response and other type of services,
- To enable full benefits to consumers and energy market.

The EU smart metering implementation perspective is also given in the document, with a separate report for each country. However, the main findings of the report indicate the following:

- The energy saving is estimated to 0-5% for electricity and 0-7% for gas on EU level,
- The discount rate 3.1-10% for both,
- The cost per metering point 77-746 EUR for electricity and 100-268 EUR for gas,
- The benefit per metering point is estimated to 18-654 EUR for electricity and 140-1000 EUR for gas, all presented data being estimated for 95% penetration rate of smart meter and 30 years horizon.

A comparative study regarding smart metering in Brazil versus EU is given in (Carvalho, 2015). The operational benefits of smart metering is referenced in (Mogles et al., 2017) and (Sovacool, Kivimaa, Hielscher, & Jenkins, 2017) which presents a range of 67 potential benefits, having in sight short-term and long term scale and also underlying the challenges for smart metering implementation. The forecast of energy consumption using ANN for households is presented in (Raza, Nadarajah, Hung, & Baharudin, 2017) and for commercial buildings in (Pîrjan et al., 2017). In (Martín-Garín, Millán-García, Baïri, Millán-Medel, & Sala-Lizarraga, 2017) is described an environmental monitoring system used for old buildings. Moreover, the smart metering system under the actual definition is not referring to sensors usage for in house environmental conditions or tentative of appliance consumption planning for a better fit to chosen taxation plan. In the next section of the paper are explored the main options to extend the smart metering features and reflects over the smart home concepts in context of retrofit, by including sensing and making decision option for existing homes.

4. RETROFIT HOMES WITHIN SMART CITIES

To increase the efficiency of energy use in households, in perspective of above described systems, for old houses it should be addressed a series of issues, as business opportunities:

- Thermal envelop retrofit for building, with an expected energy savings up to 46% (Kim & Moon, 2009), largely implemented in EU funding program and not depending by smart meter implementation,
- Smart metering, for differentiated tax plan and accurate billing, with potential benefits described in (European Commission, 2012),
- Include sensors to detect internal environmental condition (temperature, humidity CO_2 concentration, atmospheric pressure), used for base advice, an estimated cost of 100 EUR (Martín-Garín et al., 2017) and a potential benefit from advertising the consumer regarding reference interior temperature deviance or CO_2 concentration from ventilation process up to 9% (Mogles et al., 2017),
- Smart lightning and retrofit home appliances with switches and advertising LED, using demand response, an example of appliance planning for washing machine, warm water boiler, clothes dryer or dishwasher is given in (Rastegar, Fotuhi-Firuzabad, & Zareipour, 2016), with an expected 7,5% cost reduction for energy used,
- Using renewable energy sources, as solar panels, heat pump, biogas, in this case for photovoltaic panels the consumer become supplier if energy produced is charged to supplier network, being needed a forecast for next day and long-term forecast to assess the benefits,
- Smart charging, for electrical vehicle, having the same demand response circuit of appliances, using intervals for which the cost of energy is cheaper,
- Decision support system (DSS), that might suggest to consumer various actions like: decrease the interior temperature to medical recommended values, change the ventilation time to optimize the energy lost during the process, advertise the hourly tariffs and recommend intervals for appliance function, choosing the supplier and tariffs according to consumption pattern etc.
- Automation for heating, cooling and ventilation, in this case the rules implemented into DSS command and control the functionality of above mentioned systems.

The actions described above, from business perspective, in close relations with EU regulation, can be implemented by:

- The smart metering, for most EU explored cases (European Commission, 2014), it is in the charge of Distribution System Operator, which recovers the investments, by tariffs, in this case data and data management system are owned by DSO, he consumer might have access to personalized services through web page or mobile application for choosing the tariffs, consumption and payment history and eventually some recommendation regarding a better fitting to tariffs plan,
- Include sensors, with elements described above, might be implemented by DSO as supplementary service, but also by an independent third party which, with the owner and DSO approval, might receive data from smart meter and using data collected from sensors, delivers to owner, notifications with basic advice regarding the measured values and potential actions that can minimize the cost (e.g. by maintaining the temperature constant during the day on 21C you might save a calculated savings of 15 EUR/week, in case of overheated household) and alerts regarding service delivery failings (electricity or gas failure),
- Smart lighting, retrofit home appliances and smart charging, also might be implemented by DSO or third party, by demand response technology, using different LED color or by self-automation of appliance, if it exists, in order to use energy at lower cost possible, where appliance

functioning could by postponed avoiding peak hours or higher tariffs, data regarding tariffs interval and necessary time of functioning for each appliance type being delivered by DSO and appliance supplier or historical records,

- Renewable energies, depending on system nature, the source (photovoltaic panels) might be included into national grid, in that case a special agreement should be established between building or household owner and DSO. A second type, as solar heating or heat pump, which produce heating agent need to be integrated into household heating system, necessitating additional controllers or sensors implementation, which can by done by a third party.
- Extended DSS implementation, depending on collected data from smart meter and sensors ownership, needs also a preliminary appliance retrofit, might be developed by DSO or independent third party which can act as local energy broker, offering best tariffs from different DSO's according to consumption pattern,
- Heating, cooling and ventilation systems automation, by DSS implementation requires a dedicated infrastructure, as resented in picture 1. Because of level of automation and complexity of cloud resources is recommended to be an issue addressed by systems suppliers or an independent third party, which can easily scale the application and administrate the hole business supply chain.

5. CONCLUSIONS

The overall level of energy consumption and production energy distribution show that largely the energy used is produced from primary resources (oil, coal and gas), the energy production processes highly contributing to green gas effect. The goals of EU to reduce the CO_2 and other green gases emissions, by 20% until 2020, is addressing a series of issues included in SET Plan. Part of this plan, smart metering offers the possibility to reduce also energy consumption and costs associated, by hourly prices and raise the awareness of the consumer regarding energy consumption. Furthermore, the smart metering system allow to a better prediction and peak hours avoidance for DSO but also to use additional products or services described above.

Regarding smart framework, the explosive use of IoT and sensors, integrated into cloud architectures, emphasize several challenges for future implemented smart infrastructures. The main challenge is data ownership and security, targeting in the future more sensors deployed in the field, the key question is about the accessibility and resource management. The second challenge among multiple systems is the identification of users, as figured in table 1, same users might gain access to different applications or various application might collect data form the same sensors, facts that open the idea of federative ownership. Largely, the smart metering services to add more value to customer, should be enhanced with sensor deployment and DSS implementation. The authors centralized the main dimensions of smart framework and proposed an application centric- view block diagram. In this context, were identified also the retrofit homes initiatives and assessed the economic impact. Furthermore, the authors proposed future business applications of smart metering, by actors' identifications and main service functions.

In the future work will be closely addressed the sensors deployment, DSS designing and implementation and cloud structures that the application should rely on.

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