Monitoring and control platform for energy efficiency in smart buildings

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4 authors:

Pedro S. Moura
University of Coimbra

Gregorio López
Universidad Pontificia Comillas

Jose Ignacio Moreno
University Carlos III de Madrid

Aníbal T. de Almeida
University of Coimbra

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Pedro S. Moura
Institute of Systems and Robotics
University of Coimbra
Dep. Electrical Engineering
Polo II, 3030 Coimbra
Portugal
pmoura@isr.uc.pt

Gregorio L. López
Telematic Engineering Department
Carlos III University
Avenida de la Universidad 30
28911, Leganés
Spain
gregorio.lopez@uc3m.es

José I. Moreno
Telematic Engineering Department
Carlos III University
Avenida de la Universidad 30
28911, Leganés
Spain
joseignacio.moreno@uc3m.es

Aníbal T. de Almeida
Institute of Systems and Robotics
University of Coimbra
Dep. Electrical Engineering
Polo II, 3030 Coimbra
Portugal
adealmeida@isr.uc.pt

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Abstract

The increasing energy consumption in the residential sector and the growing penetration of renewable generation in buildings have been leading to the need of smarter buildings. In order to reduce the energy consumption, optimize the consumption to achieve lower costs, and to ensure the local generation and consumption matching, in-house monitoring and control systems are needed.

This paper presents a novel energy monitoring and control system developed under the European FP7 project ENERsip. Such a system is integrated at the edge of the service-oriented M2M-based platform for energy efficiency within energy-positive neighbourhoods with the main goal of reducing electricity consumption by increasing the energy consumption awareness of the users, by acting automatically on the demand side, and by coordinating electricity consumption with the in-building and neighbourhood positive-energy generation facilities.

Introduction

The electricity consumption in Europe has been steadily increasing, mainly due to the consumption in buildings (Figure 1). Although significant improvements regarding energy efficiency have been achieved in appliance technologies, the end-use electricity consumption in buildings has still increased, particularly in households. This is in part due to the fact that electricity consumption in households is not individually very significant and therefore the users' awareness and the availability of energy management systems are lower than in large buildings and industry. However, the global electricity consumption is very significant and has been increasing due to the widespread utilization of new types of loads and the requirement of higher levels of comfort and services (Firth *et al.,* 2008).

The new loads are mainly electronic loads (mostly entertainment and ICT) which represent more than 21 % of the overall consumption in EU households (de Almeida *et al.*, 2011), a significant percentage of which is standby and other non-active modes. The standby energy consumption is increasingly important, representing about 7 % of the total annual electricity consumption per household (Patrão *et al.*, 2011).

The loads with the highest share in the households' consumption are lighting and cold appliances (refrigerators and freezers). HVAC (Heating, Ventilating, and Air Conditioning) loads have also shown high consumptions and an increasing penetration rate in households. Other loads, such as washing and drying appliances, have a non-optimized operation, presenting high energy consumption at peak hours (Figure 2); whereas they may be shifted to other periods. However, if properly controlled, such loads can be used as a DR (Demand Response) resource (Kowli *et al.*, 2010). The washing and drying appliances can be rescheduled to periods of lower energy consumption. The thermal loads (cold appliances, HVAC, and water heating) can be interrupted during shorts periods of time, without major reductions of service quality, to avoid the most unbalanced situations between generation and consumption, compensating the effects of the variability and randomness of the renewable resources availability (Moura and de Almeida, 2010).

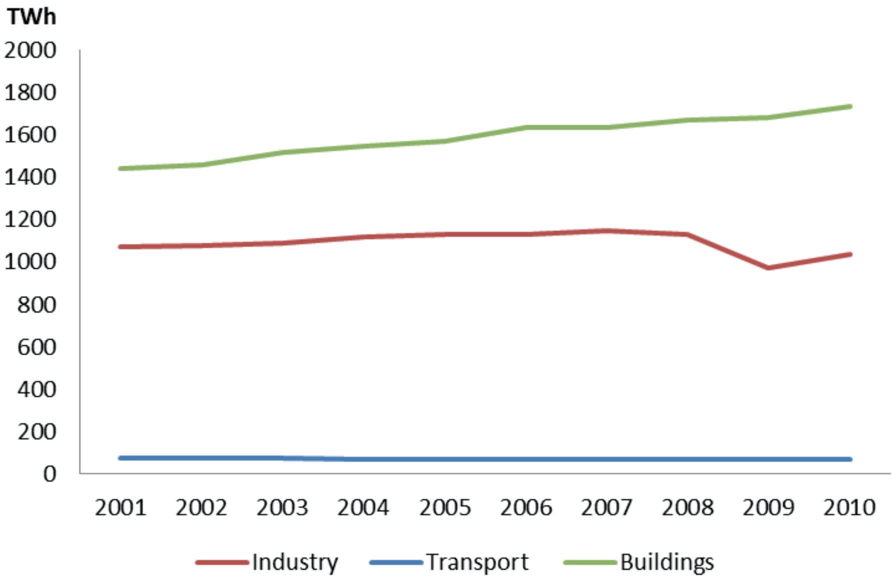

Figure 1. Electricity consumption in EU (Eurostat, 2012).

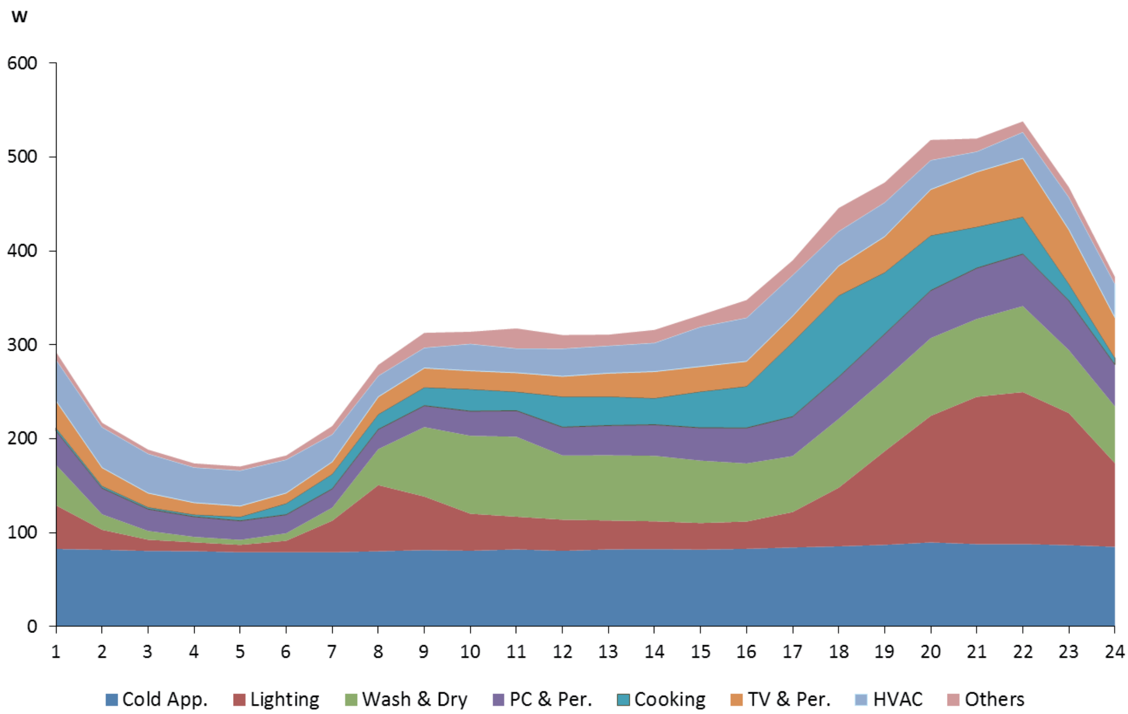

Figure 2. Load profile of an EU average household (de Almeida et al., 2011).

Given those increasing consumptions and the difficulty in identifying the major contributors, in-house monitoring and control systems are needed. Such systems must have the capability to monitoring and control individual appliances, to enable the identification of unwanted consumptions, increase the user awareness and to give the users some measure of automated control over each individual load, providing means to participate in Demand Response programs.

Furthermore, the presence of electricity generation sources (mainly photovoltaic) in households is steadily increasing. Such local generation is connected to the electricity distribution grids or even used to self-consumption infrastructures (Claudy *et al.*, 2011). However, such distributed energy generation infrastructures introduce novel challenges due to the high intermittence and uncontrollability of renewable resources and due to the mismatching between the local generation and residential consumption profiles. Thus, monitoring systems for local electricity generation are needed to provide the required information to ensure the matching between local generation and consumption, which can be achieved not only by using energy storage devices, but also by controlling the demand profile.

To solve those problems, several EU R&D projects were underway, dealing with different pieces of the issue, but none of the projects addresses this topic holistically, providing a comprehensive solution to monitor and control consumption and generation infrastructures, including not only the required M2M communications infrastructure, but also the IT system and user interfaces that can be used in existent buildings without the need of smart meters, smart controls and automation.

This paper presents a novel energy monitoring and control system developed under the ENERsip project (ENERsip, 2012) which fills the gaps of the existent projects. ENERsip is a project funded under the FP7 in the "ICT Support to Energy-positive Buildings and Neighbourhoods" programme, which aims to design, develop, and validate a service-oriented M2M-based energy monitoring and control system for energy grids and decision makers. Such a system is integrated at the edge of the service-oriented M2M-based platform for energy efficiency within energy-positive neighbourhoods with the aim of reducing electricity consumption by increasing the energy consumption awareness of the users and influencing their behaviours, by acting automatically on the demand side, and by coordinating electricity consumption with the in-building and neighbourhood positive-energy generation facilities.

The remainder of the paper is structured as follows. Section 2 presents the architecture of the ENERsip system, explaining the functionalities and advantages in a smart grid context. The Energy Services ensured by the ENERsip system are presented in Section 3, highlighting the importance of such services to increase the energy efficiency, achieve cost savings, and ensure the electric grid reliability. Section 4 presents the assessment of potential impacts ensured by such services on the average consumption profile in an EU household. Finally, Section 5 summarizes the paper, emphasizing its main conclusions.

System Architecture

Figure 3 provides an overview of the system architecture designed to achieve the aforementioned goals (López *et al.*, 2011a). At the highest level of abstraction, the ENERsip system architecture is composed of four domains, namely the User Domain, the Information System Domain, the Neighbourhood Domain, and the Building Domain.

Getting deeper into the details, the User Domain, as it name suggests, models the user side of the platform, encompassing the UII (User Intuitive Interfaces), which are basically web-based interfaces that allow users to interact in a human-friendly way with the platform (e.g., monitoring and controlling their in-home appliances remotely or getting feedback on their consumption patterns and on how to improve them in order to reduce their overall electricity consumption).

The Information System Domain is where the energy intelligence of the platform resides. It comprises two modules: the PS-BI (Power Saving – Business Intelligence) and the UAP (User Application Platform). The PS-BI is responsible for processing all the information about consumption and generation and making the appropriate decisions based on global optimizations at district level; whereas the UAP works as a kind of high-level middleware, adapting and serving the information coming from the PS-BI to the UII and vice versa.

In order to gather all the information about consumption and generation in the district and to carry commands to the appropriate actuators, the ENERsip system architecture tightly relies on a hybrid and hierarchical M2M communications in-

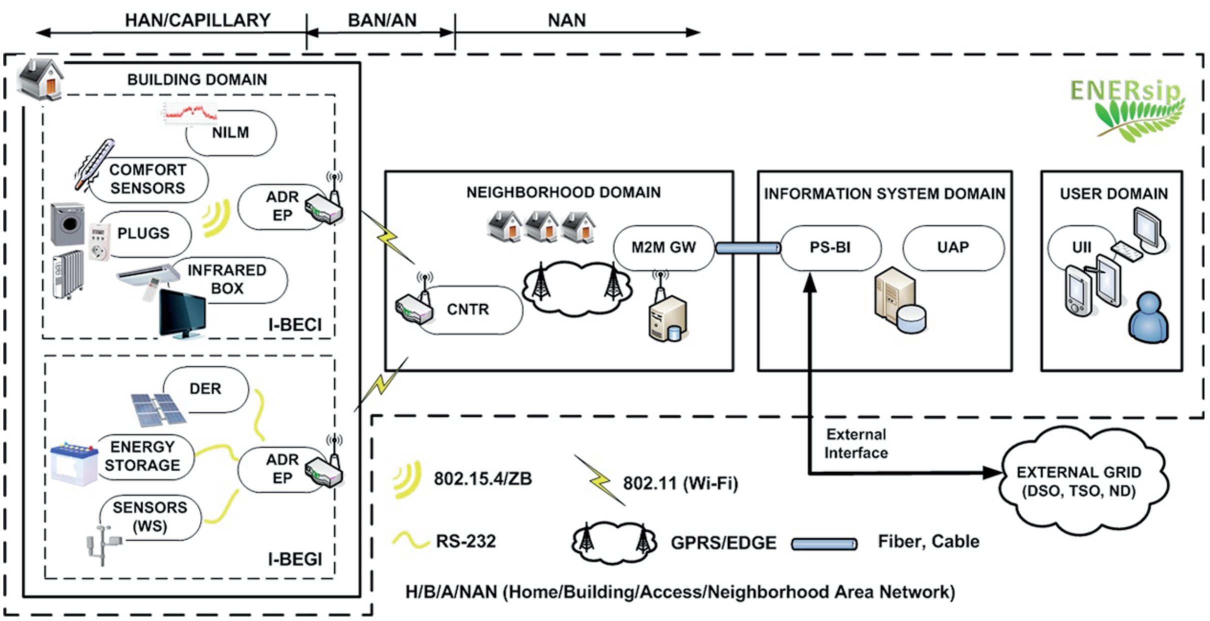

Figure 3. System architecture (López et al., 2011a).

Figure 4. I-BECI architecture (Carreiro et al., 2011).

frastructure which enables the required real time bidirectional communications. As it is shown in Figure 3, the Neighbourhood Domain comprises the core of such a M2M communications infrastructure; whereas the Building Domain represents its "fingers" – or "capillaries", as in ETSI (European Telecommunications Standards Institute) terminology.

The Neighbourhood Domain is composed of an M2M Platform and a network of CNTRs (Concentrators). The M2M Platform routes commands coming from the Information System to the appropriate CNTR and forwards data coming from the CNTRs to the Information System. Every single CNTR manages, in turn, a set of consumption and generation infrastructures through the so-called ADR EPs (Automatic Demand Response End Points). Thus, the CNTRs forward consumption and generation data coming from the ADR EPs to the M2M Platform and route commands coming from the M2M Platform to the appropriate ADR EPs.

The Building Domain comprises the so-called I-BECI (In-Building Energy Consumption Infrastructures) and I-BEGI (In-Building Energy Generation Infrastructures), which represent the in-house consumption monitoring and control system and the local generation facilities, respectively.

Figure 4 shows the I-BECI architecture, which is composed of the following devices: the Plugs, the Infrared Box, the NILM (Non-Intrusive Load Monitoring) module, the Comfort Sensors, and the ADR EP-C (Carreiro *et al.*, 2011).

The Plugs work both as sensors and actuators. On the one side, the Plugs act on the power supply of the appliances by cutting it OFF or ON. On the other side, the Plugs measure the electricity consumption of those appliances and send it to the Information System, allowing accurate monitoring and abnormal behaviour identification. The Plugs constitutes an important bridge technology. In the future, appliances are expected to have their own communications and actuation circuitry, allowing them to communicate directly with the home energy gateway (in this case, the ADR EP). However, the Plugs enable the integration of legacy appliances into the in-house monitoring and control system right away, thus making energy efficiency a reality today, before the "smart appliances" come to the market.

The IR Box enables managing the IR-controlled appliances remotely. The IR Box represents a key element of the I-BECI, since it allows remotely controlling HVAC systems (which represent one of the main opportunities to reduce the electricity consumption within households, as it has already been mentioned) and multimedia devices such as TVs or DVDs (which present standby consumptions). Again, the IR Box constitutes an important bridge technology, since it allows integrating the huge number of already installed IR-controlled equipment into the I-BECI (each IR Box can control all the IR-controlled appliances of the same room). It also ensures a higher degree of control, since with the IR Box it is possible to control the temperature of HVAC systems and not just the ON/OFF control of the appliances as with the Plugs.

The NILM module also represents a key element to enable backward compatibility, since it allows identifying (based on electrical signature) the appliances which are running, even if they are not equipped with a plug with sensor and communication capabilities. The theoretical NILM approach determines when a specific appliance is turned ON based just on its electrical signature, by applying non-supervised Digital Signal Processing methods to the overall electrical signal (Warren and Brandeis, 1989). However, due to the complexity of such methods, in the ENERsip project the user will inform the NILM module about the appliance which has just been turned ON in order to help it to learn its electrical signature, based on the data received from each plug.

The Comfort Sensors measure different environmental variables, such as temperature, relative humidity or CO_2 concentration, which are taken into account when achieving energy savings without compromising the users' comfort levels. For instance, the data acquired by a CO_2 concentration sensor can be used to control the HVAC equipment in order to reduce its electricity consumption as follows. When the CO_2 concentration in a room is below a maximum acceptable value, the HVAC can cool the air from inside the room, which requires much less electricity than taking it from outside, since it is not so hot. Only when the CO_2 concentration is above such a threshold, the HVAC will cool the air from outside, until CO_2 concentration goes below the maximum acceptable value again. A temperature sensor can be also used to control the HVAC equipment efficiently and to integrate it into DR programs by providing feedback on the actual temperature in a room, allowing actuating on the HVAC consequently.

The ADR EP-C works both as network coordinator and as communications gateway. It is equipped with multiple hardware interfaces and it supports two different wireless technologies: IEEE 802.15.4/ZigBee and Wi-Fi (IEEE 802.11). The Wi-Fi network interface is used to communicate with the M2M communications infrastructure, through the appropriate CNTR, in order to exchange information upstream with the remainder of the platform. The ZigBee network interface is used to communicate downstream with the I-BECI devices, such as sensors and actuators.

Figure 5 shows the I-BEGI architecture, which is composed of Energy Generation Equipment, Sensors, and the ADR EP-G (Pérez *et al.*, 2013).

The Energy Generation Equipment includes Photovoltaic Panels and µWind Turbines, which represent two of the most extended technologies in buildings. Both the Photovoltaic Panels and the µWind Turbines are equipped with Inverters, which play a double role: on the one side, they adapt the electrical signal (i.e., converting DC into AC) and, on the other side, they work as RTUs (Remote Terminal Units), measuring some key parameters associated to the generation equipment and sending them to the ADR EP. The Photovoltaic Panels are also equipped with panel temperature sensors, since this parameter influences their performance. Finally, the Energy Meters measure the energy that is generated by the installation.

The main objective of the Sensors is to measure variables related to weather conditions (e.g., temperature, humidity, wind direction and speed and solar irradiation) and electrical variables (e.g., DC current or voltage, AC current or voltage) and send them to the Information System in order to allow accurate status monitoring and accurate generation forecast, which are two key parameters when operating DR events. The set of sensors in charge of monitoring weather conditions are integrated all together into the same Weather Station and the set of sensors in charge of measuring electrical variables are integrated into the same Network Analyser.

The ADR EP-G is equipped with multiple hardware interfaces and implements multi-protocol features in order to communicate, on the one side, with the I-BEGI equipment (using proprietary application protocols such as Fronius or Davis) and, on the other side, with the Information System through the M2M communications infrastructure (using the ENERsip proprietary protocol on top). As a result, the ADR EP enables managing in a uniform way the wide variety of devices within the I-BEGI, hiding this complexity and heterogeneity to the Information System, which is able to manage whatever equipment within such infrastructures using the same protocol.

Energy Services and Benefits

ENERGY SERVICES

The ENERsip platform is primarily targeted at owners of buildings with not only energy consumption, but also with local energy generation, the so-called *prosumers*, as coined by Alvin Toffler. However, it can be used by all owners of residential and even commercial/tertiary buildings, which can be divided into Residential Consumers (RC), Residential Prosumers (RP), and Commercial Prosumers (CP). Other key target is the Distribution and Transmission System Operators (DSO), with several services designed to the grid management, but such services

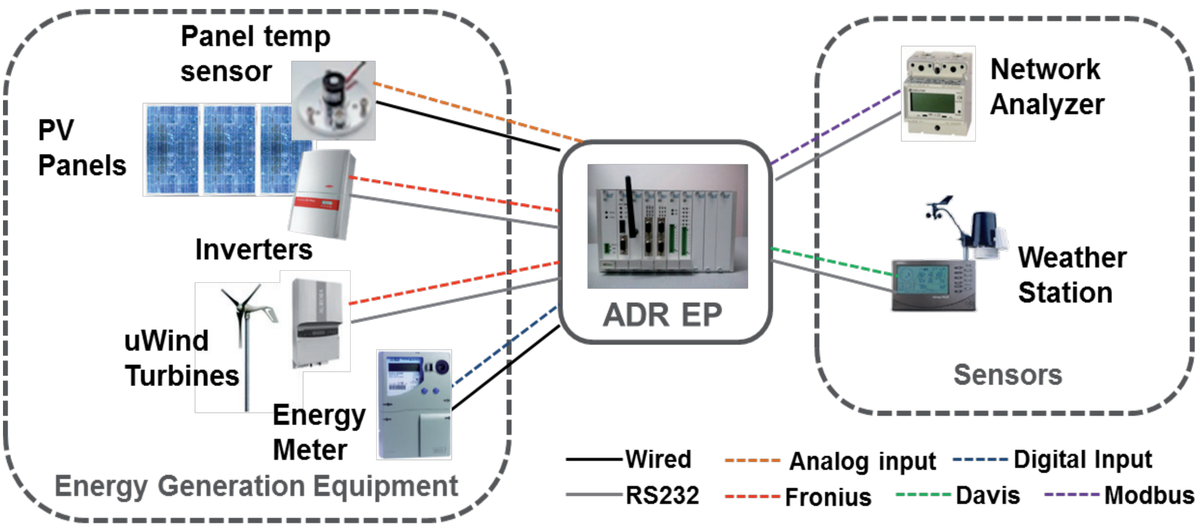

Figure 5. I-BEGI architecture (Pérez et al., 2013).

Table 1. ENERsip User Segments and Service Types Matching.

	RC	RP	CP	LEP	ACP	DSO
EMVR	X	X	X	X	X	X
RACA	X	X	X	X		
LM	X	X	X			X
MEM		X	X	X	X	
DSO						X

could also be used by other stakeholders, such as the Local Energy Producers (LEP) and mainly by third party service providers, such as Aggregators of Consumption and Production (ACP).

The several user segments will benefit with different energy services, such as: Energy Monitoring, Visualization, and Reporting (EMVR); Remote Access and Control of Appliances (RACA); Load Management (LM); Microgrid Energy Management (MEM); and Distribution System Operation (DSO). Table 1 shows the mapping of service types onto user segments (López *et al.*, 2011a).

Energy Monitoring, Visualization, and Reporting

Residential and commercial end-users are provided with a range of energy monitoring, visualization, and reporting services, giving them near real-time information about their energy consumption or generation, prices, generation forecast and environmental impact. This information is provided at different levels of granularity, starting from the aggregated data at the whole building level, down to the detailed information about each individual appliance. The aggregator and the DSO can also receive part of such information, depending of the contract with the end-user.

Remote Access and Control of Appliances

Residential and commercial end-users are provided with a group of services allowing them to remote control the in-building appliances through a web-based interface. Using such interface, the user will have the possibility to create an initial configuration of the network of energy consuming devices, remotely switch ON or OFF devices, to adjust their settings (e.g., the air conditioning operating temperature) and to configure rules that will apply pre-defined actions (e.g., reschedule of the washing machine). With the energy monitoring service, the user can identify appliances which are unnecessarily turned ON and turn them OFF using the remote control services, avoiding unnecessary consumptions. Additionally, the remote control capability will facilitate the participation in DR programs.

Load Management

The load management functionality offered by the ENERsip platform enables the participation in Demand Response programs, since the user will be able to specify the devices to be included in the automated load management program and manually override it. The load management capability brings economic advantages to the users and additional control and optimization capabilities to the DSO.

Microgrid Energy Management

The microgrid energy management service works at the local communities and neighbourhoods level, where multiple consumption, generating and storage units might be running. The DSO or the Aggregator receive real-time monitoring data from the consumption and generation sides, at the local communities' and neighbourhoods' level, improving the balance between generation and consumption in the microgrids.

Distribution System Operation

The DSO receives near real-time information about generation and consumption of electricity in a given location, highlighting the deviations from the expected energy consumption behaviour and providing accurate short-term forecasts of the energy generation. Such information will be very important for the DSO to the planning and dispatching of the generation resources. However, the most important impact of this service is to obtain the required conditions to operate DR programs, which force consumption reductions at near real time in critical situations.

POTENTIAL BENEFITS

The above energy management services will ensure different benefits not only to the stakeholder using the system, but also indirectly to other electricity consumers and to society. The main benefits are energy and cost savings. The achieved energy savings can be direct or indirect savings:

- The automated actions ensured by the remote access and control service can ensure direct savings by turning OFF the selected appliances during the pre-defined schedule to avoid standby and other unwanted energy consumptions.
- The indirect energy savings can only be achieved by influencing human behaviour. The real-time monitoring of the energy consumption (including the consumption of individual appliances) will increase the awareness of the users to the energy consumption and associated costs (Darby, 2010), leading to lower energy consumption:
  - by identification of appliances which are unnecessarily turned ON and turn them OFF, using the remote access and control service;
  - by identification and replacement of inefficient appliances.

All the energy savings will lead to cost savings. However, it is possible to achieve cost savings without energy savings, by rescheduling several appliances (e.g., washing machines) to periods with lower energy costs, through the remote access and control service. Other option to ensure lower costs is to maximize the self-consumption of local energy (if the tariffs provide any incentive to do it), by rescheduling appliances to periods with higher local generation (forecasted by the energy monitoring service). The participation in DR programs, using the load management service to turn OFF some appliances (e.g., the refrigerator) during some minutes will also ensure the economic benefits offered by the utility to the consumption reduction in critical periods.

However, the provided energy services can also ensure other indirect benefits (Moura *et al.*, 2012), such as the improvement of the electric system reliability and the reduction of GHG (greenhouse gases emissions). All the energy savings will lead to lower GHG emissions and to higher grid reliability, due to the lower load requirements. Additionally, the reschedule of consumptions to periods with higher renewable generation will ensure lower GHG emissions.

The matching between generation and consumption, ensured by microgrid energy management and DSO services, will decrease the power flows between the grid and the household and also contribute to the integration of large scale renewable intermittent resources (using DR actions to balance the variability and unpredictability of some renewable resources), thus increasing the grid reliability. Simultaneously, the matching between generation and consumption reduces the large scale generation of electricity and therefore the associated GHG emissions.

Assessment of Impacts on the Load Profile

The ENERsip system was validated in two independent stages (López *et al.*, 2011b). First, the Consumption Pilot was focused on testing the consumption system components in a controlled environment (namely, a laboratory from the University of Coimbra), between October 2011 and January 2012. Next, the Demonstration Pilot was focused on validating user requirements and demonstrating the ENERsip platform daily operation in real environments using real equipment. The Demonstration Pilot was deployed in Israel Electric Corporation premises and involved three different sites, geographically located in different places, equipped with real consumption and generation equipment, and running between January and August 2012.

Finally, the potential benefits and performance of the ENERsip platform were evaluated by means of simulations. On the one side, the Network Simulations focused on evaluating the performance of the ENERsip communications infrastructures based on a model that considers bidirectional real-time communications in short-term and long-term scenarios (López *et al.*, 2012). On the other side, the Energy Services Simulations focused on evaluating the energy and cost savings achieved through the automated coordination and scheduling of energy loads, taking into account different times of the year and different locations (and thus different weather conditions and different amounts of generated energy), different countries (with their typical tariff structures and regulatory conditions), and different configurations (e.g., different types of customers, different sets of appliances). The obtained results clearly show that the potential energy and cost savings with ENERsip can achieve 30 % in most of the cases.

However, in this section the objective is not to evaluate the impacts on typical scenarios to individual users, but to evaluate the aggregated impact achieved with a large-scale utilization of the system. Therefore, the objective is to assess the impact on the load profile of an EU average household, presented in Figure 2. In such figure the loads are grouped in 8 types (cold appliances, lighting, washing and drying, ICT, cooking, audio-visual, HVAC and others), but there are available average load profiles, with different load profiles to working days and weekends, from each main appliance (de Almeida *et al.*, 2011) out of a total of 26 (freezer, refrigerator without freezer, refrigerator with freezer, lighting of living room, lighting of secondary rooms, washing machine, clothes dryer, dishwasher, desktop PC and monitor, laptop PC, printer, WLAN, router, microwave oven, electric cooker, kettle, TV CRT, TV LCD, TV Plasma, settop box, DVD player, HI FI Radio, HVAC, water heater, vacuum cleaner and phone charger).

In such assessment, the indirect impacts, dependent on the user behaviour were not considered (to assess the ensured impact and not the maximum potential), being the assessment restricted to the automated actions which will lead to the following impacts: reschedule of appliances, reduction of standby consumption, Demand Response, and self-consumption. Therefore, in such conditions the system has impact over the washing and drying, ICT, audio-visual, HVAC and cold appliances, but not over lighting (the ENERsip system do not have included any lighting control), cooking and others (since they are mainly not controllable appliances and highly dependent of the users' behaviour).

To assess the economic impact, the Portuguese tariff with a higher number of allowed time periods to residential customers was used (Figure 6), to increase the possibilities of rescheduling. The option with different time periods between working days and weekends was used, to take advantage of the availability of different load profiles.

RESCHEDULE OF APPLIANCES

The reschedule of appliances was evaluated considering the automated control of washing and drying appliances, from On-peak to Mid-Peak and Off-Peak periods. The objective of the assessment was not to evaluate the maximum potential, but to evaluate an average impact. Therefore, the entire consumption of the appliances was not rescheduled since the users have the possibility to overwrite the system control and in different days they can have different hourly needs and behaviours. As main restriction, it was avoided a high consumption during sleeping hours. The consumption variations during the On-peak to Mid-Peak were also maintained, since it is expected that the hours with higher consumption without control, in such periods, should also be the same as with control. Figure 7 presents the achieved impact to washing and drying appliances during working days. The consumption during Off-Peak periods was increased from 8 % to 40 %, achieving a cost reduction of 15.3 %.

REDUCTION OF STANDBY CONSUMPTIONS

To the audio-visual and ICT appliances it is possible to avoid the standby consumptions, by programing the system to turn OFF the appliances during the periods when they are not needed. The study used as reference to the load profiles (de Almeida *et al.*, 2011) also presents the average yearly standby consumption to each appliance. Such standby consumptions were used in the assessment, reducing the consumption in the load diagrams (with higher values in hours when the use of each appliance is lower and therefore the standby consumption has a higher impact). However, in a realist scenario is not expected that all standby consumption could be removed. Therefore the impact of the standby control was reduced in some periods of time, because if an appliance presents an intermittent operation the potential to define periods to turn OFF the appliance is lower. To audio-visual appliances the yearly average standby consump-

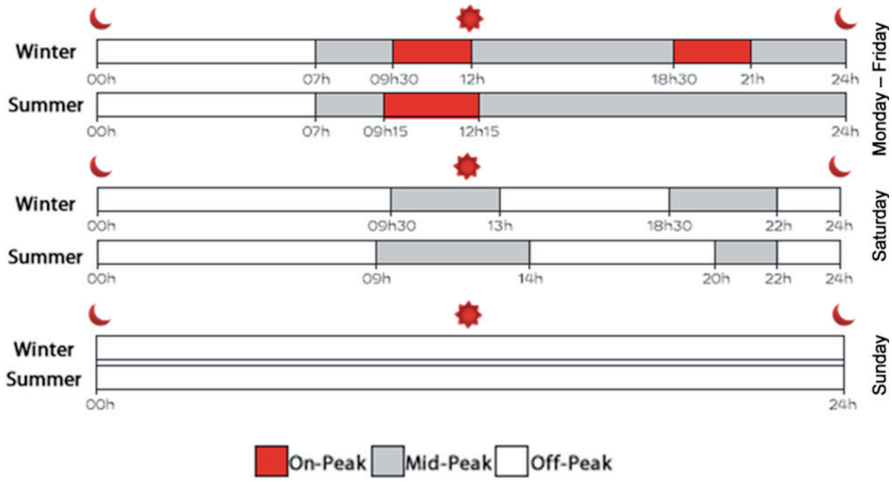

Figure 6. Time periods of the tariff used to the assessment.

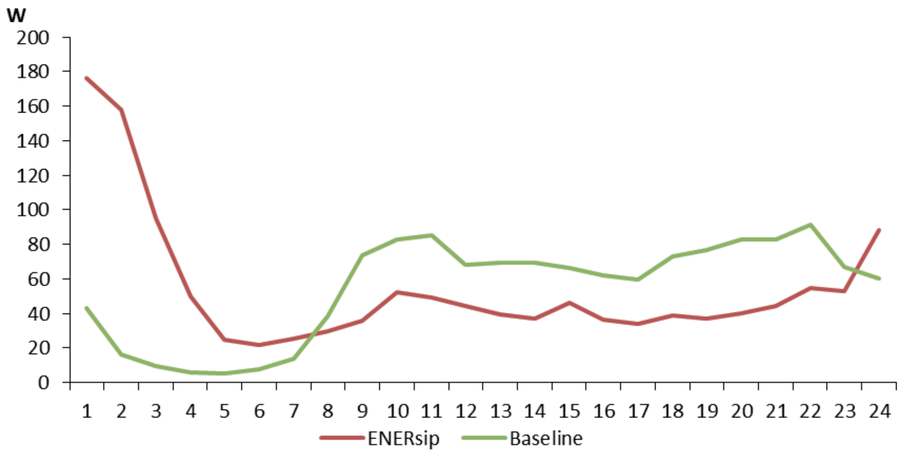

Figure 7. Impact of ENERsip on washing and drying appliances.

tion of the baseline scenario is 17.5 % of the total consumption of such appliances and with the described strategy a reduction of 14 % was considered. Figure 8 presents the achieved impact to audio-visual appliances during working days.

To ICT appliances the yearly average standby consumption of the baseline scenario is 26 % of the total consumption of such appliances and with the described strategy a reduction of 17 % was considered (the lower impact is due to the more intermittent operation of ICT appliances, when compared with audio-visual appliances). Figure 9 presents the achieved impact to ICT appliances during working days.

TOTAL IMPACT AND DEMAND RESPONSE

Figure 10 presents the overall impact achieved with the reschedule of appliances and reduction of standby consumption. The main impact to the users is the achieved energy savings and in this average conservative scenario a reduction of 5.8 % is ensured (€20), with a reduction of energy consumption of 3.2 % (86.3 kWh/year). However, a peak load reduction of 7.8 % (42 W) is achieved and such reduction can be improved using the Demand Response service. Considering a reduction of 50 % of the HVAC consumption and the turning OFF of the cool appliances during the peak load (22:00), it is possible to reduce the peak load in 11.6 % (changed to 21:00) and in 26.7 % during the DR action without a major reduction of quality of service (Figure 10). Such possibility could not only ensure reliability benefits to the grid management, which can be used in critical situations, but also economic benefits to the user.

SELF-CONSUMPTION

The impact of the generation/consumption matching was also assessed with a scenario of self-consumption. Considering the use of photovoltaic panels, an average profile to generation in EU was used. The power of the photovoltaic panels (1,945 W) was determined to ensure that the average yearly generation is the same of the average household consumption. Therefore, it represents a zero-energy building scenario.

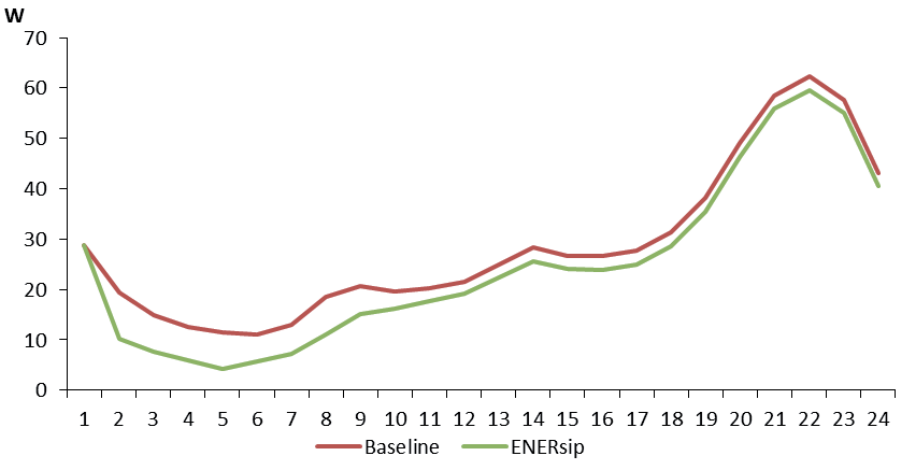

Figure 8. Impact of ENERsip on audio-visual appliances.

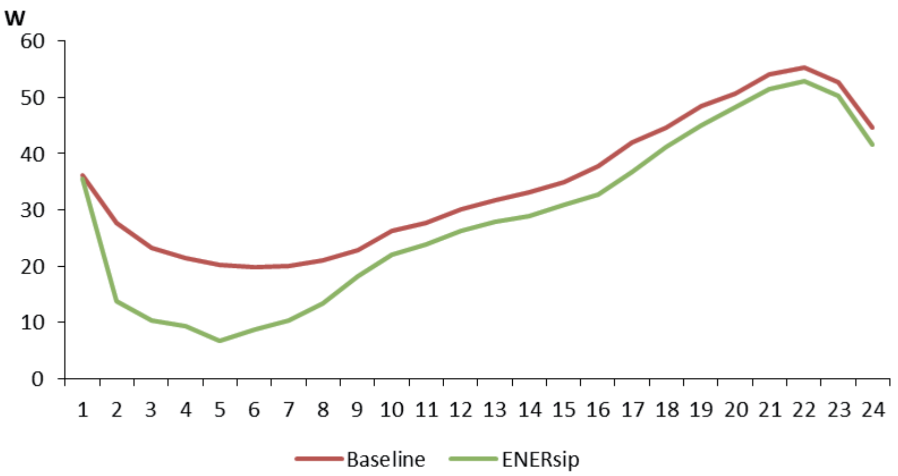

Figure 9. Impact of ENERsip on ICT appliances.

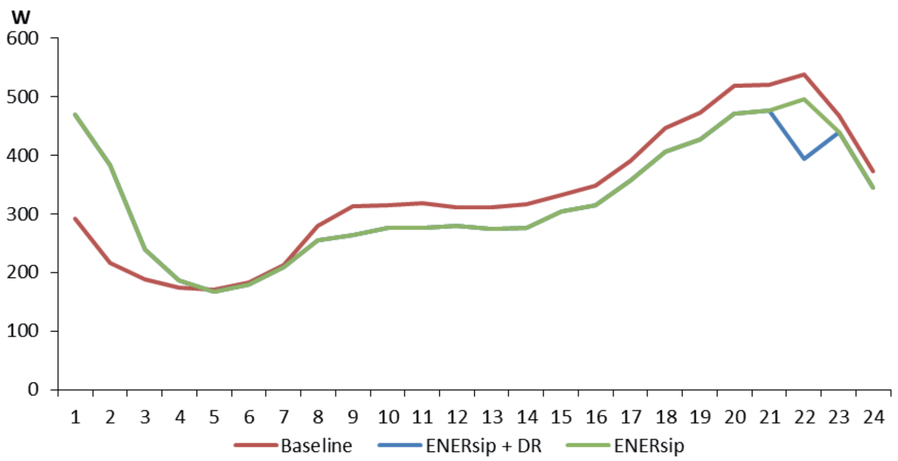

Figure 10. Impact of ENERsip on the average load profile.

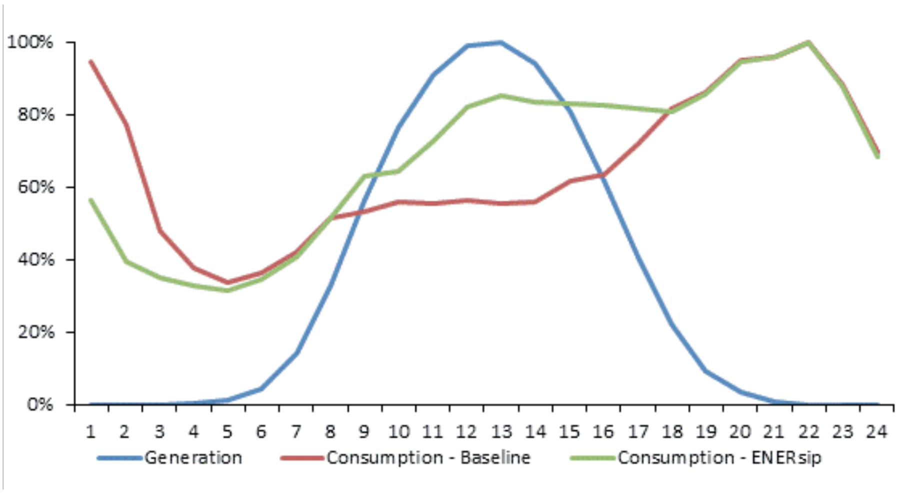

Figure 11. Impact of ENERsip on generation/consumption matching.

To increase the self-consumption, the reschedule of washing and drying appliances was used to increase the average consumption during the hour of higher local generation (using the same restriction of section 4.1). As result the self-consumption of the local generation was increased by 20 %, achieving a self-consumption of 53 % of the total demand (Figure 11). The improvement of the generation/consumption matching can also be observed by the increase of the correlation between the generation and consumption, which was -30 % in the baseline and was increased to 33 % with the optimization provided by ENERsip.

Conclusions

This paper presents the monitoring and control platform designed and developed under the EU FP7 project ENERsip, whose main goal is to optimize, in near-real time, and to save energy by remotely monitoring, controlling and coordinating energy consumption and generation within the energy-positive neighbourhoods of the future Smart Grid. All the parts of the ENERsip system are already developed and integrated.

The system was validated and evaluated by mean of pilots and simulations, where it was demonstrated the potential to achieve energy and cost savings up to 30 % in most of the cases. However, the objective of this paper was not to demonstrate the potential savings, but the minimum savings ensured by the system without taking into account any positive behaviour of the user to improve such savings. Therefore, only the automated actions directly ensured by the system to the reschedule of appliances and standby reduction were considered. Such services are able to ensure an energy consumption reduction of 3.2 % and a cost reduction of 5.8 %.

Such numbers are not enough to ensure the cost-effectiveness of the system and therefore the services to provide information to the users to increase their awareness and change their behaviours are crucial. Nevertheless, the main incentive to change behaviours and to increase the optimization impact is by providing tariffs with more time periods and ideally real-time tariffs.

The main direct impacts and benefits brought by the system are ensured by the Demand Response and energy generation/consumption matching services, which provide very important benefits to the electric grid management and therefore environmental and economic benefits. Nowadays, the existent tariff schemes in most countries do not provide enough incentives to the user to maximize the self-consumption of the local generation and to reduce the consumption in critical situations. However, due to the increasing penetration of local generation with intermittent patterns, this situation will change in a near future, giving momentum to monitoring and control systems as ENERsip.

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