CONCLUDING REMARKS FROM THE IMPLEMENTATION OF SMART LOW-ENERGY DISTRICTS IN THE GROWSMARTER PROJECT

ALAIA SOLA, MANEL SANMARTI & CRISTINA CORCHERO
Energy Systems Analytics Research Group, IREC Catalonia Institute for Energy Research, Spain

ABSTRACT

As large consumers of energy, cities offer the opportunity for significant energy savings in relation to the implementation of energy-efficiency measures. In this context, the cities of Barcelona, Cologne and Stockholm, together with a diverse group of stakeholders from public and private sectors, joined to create the GrowSmarter project. GrowSmarter seeks to demonstrate and stimulate the uptake of Smart Solutions in energy, infrastructure and transport, to provide other cities with insights and create a ready market to support the transition to a sustainable Europe. With the objective of promoting and developing low-energy districts, a set of solutions were tested aiming to reduce their environmental impact. These are classified in three blocks: building energy retrofitting, energy consumption visualization platforms and local energy generation with smart management. All these actions have been technically and economically evaluated in GrowSmarter, and the results are presented in this article. The project has analysed different impacts of active and passive retrofitting measures in building energy performances and the feasibility of the proposed business models behind them. Energy visualization platforms have proven to be a promising tool to engage end users, but there is still work to do to define successful business models. The assessment of the deployment of local energy generation units shows that the corresponding regulation differs to a significant extent among countries. A clear and harmonized regulation according to the current state of technology is required in order to fully deploy distributed energy resources at commercial level. Finally, besides guaranteeing the correct implementation and operation of energy-efficiency measures, communication and information campaigns are key to build trust and ensure user acceptance. Working on building users' awareness and acceptance has proven to be a must in order to succeed in making low-energy districts the preferred path in urban development.

Keywords: smart city, energy efficiency, energy retrofitting, HEMS, local energy, low-energy districts, H2020.

1 INTRODUCTION

Approximately 70% of the world population will live in urban areas by 2050, according to UN predictions [1]. This means that cities are very likely to be one of the largest groups of energy consumers in the world and, therefore, potentially one of the biggest emitters of greenhouse gases. To address this challenging forecast, municipal governments around the world are developing ambitious programs for long-term emission reduction. This implies a change in the energy model of cities towards a more sustainable one, which is one of the main characteristics behind the concept of 'smart city'.

Across Europe, cities are adopting smart and sustainable development programs. In order to promote this development, the European Commission launched in 2012 the European innovation partnership on smart cities and communities [2], which joins together European cities, industry leaders and representatives of civil society to make urban areas smarter. In addition, there are various European funding programs and instruments that support the transition to smart cities, such as the Horizon 2020 and COSME programs [3,4]. In this way, the European Union is promoting the demonstration of the technical and economic impact of various solutions towards the smart and sustainable development of cities.

ISSN: 2398-2640 (paper format), ISSN: 2398-2659 (online), http://www.witpress.com/journals
DOI: 10.2495/EI-V3-N2-112-119

Developing low-energy districts is one of the main action areas to be addressed in order to transform cities towards more sustainable ones. In fact, the European construction sector faces a major challenge to reduce the emissions by almost 90% in 2050. This requires new innovative solutions and services to be rapidly implemented in the market, such as affordable and sustainable building energy retrofit solutions at a large scale.

2 THE GROWSMARTER PROJECT

The Municipalities of Barcelona, Cologne and Stockholm, together with a diverse group of partners from public and private sectors, have been leading since 2015 the GrowSmarter project [5] funded by the Horizon 2020 program of the European Commission. Horizon 2020 is a program designed to support R&D activities and aimed at researchers, companies, technology centres and public entities. Within this program, GrowSmarter belongs to a specific call named 'smart and sustainable cities' [6] (SCC1), which aims to promote demonstrative or 'lighthouse' projects. The main objective of this type of project is to connect cities, industry and citizens in order to demonstrate in real life a variety of technical solutions and business models to build smarter cities, which are scalable and replicable. Towards this aim, GrowSmarter has implemented and demonstrated the viability of '12 smart city solutions' in the fields of energy, infrastructure and transport.

2.1 Low-energy districts in GrowSmarter

Identified as one of the instruments to improve the quality of life of citizens, energy efficiency in buildings has become one of the main features of smart cities. This article focuses on the outcome of the work performed within the GrowSmarter's energy work package called 'low-energy districts', whose main objective is the deployment of energy-efficiency measures to reduce the environmental impact of the existing building stock in cities.

In total, 123,000 m^2 of constructed surface area have been retrofitted among the three lighthouse cities, involving private and public buildings, as well as commercial and residential buildings. Modern houses are highly energy efficient, but one-third of Europe's housing stock was built between 1950 and 1970 when the technologies and materials used were much less efficient. By refurbishing these older buildings using new construction techniques and installing new efficient equipment, the amount of energy they use can be substantially reduced.

The project has also promoted the deployment of Home Energy Management Systems (HEMS) in the three cities to raise awareness about responsible energy consumption among citizens and give tools for appliances' automation. Providing information on real-time energy usage to tenants is a key tool to help them see and reduce their own environmental footprint. Moreover, in Barcelona and Stockholm, energy surveillance platforms have also been installed in commercial buildings, with the aim of simplifying their operation and maintenance and identifying potential energy-efficiency improvements.

Finally, the integration of local energy generation in buildings has been demonstrated in the three cities with different approaches: on-site renewable electricity generation with photovoltaics (PV) with batteries under smart control, connection of buildings to district heating and cooling (DHC) networks and combination of PV, heat pumps and DHC together with storage under smart control.

By deploying the aforementioned solutions, all three lighthouse cities demonstrate the feasibility and real impact of a set of available innovative technologies. This contributes to the transformation of the existing city building stock towards low-energy districts.

3 LESSONS LEARNED AND RECOMMENDATIONS

This section presents the lessons learned and recommendations gathered by the private and public stakeholders during the 3 years of implementation. To date, the GrowSmarter project is facing its last stage, where all measures are completely executed and the monitoring phase has been running for more than 1 year. This will allow to draw future results on the technical and economic performance of each technology in the three cities.

3.1 Lessons learned and recommendations to industrial partners

3.1.1 Building energy retrofitting

In GrowSmarter, industrial partners such as utilities and project development and construction groups have implemented retrofitting actions to upgrade the energy performance of existing residential and commercial buildings. The casuistry in each of the three lighthouse cities is different in terms of municipal regulations, climate and the proposed business models behind an energy retrofitting project. However, in general, energy audits during the design stage are fundamental to adjust the technical solutions to each specific building. It is also recommended to evaluate the possible sources of energy in the surroundings of buildings or facilities to look for waste heat integration solutions that can benefit multiple actors. In the case of Stockholm, the energy assessment of surroundings allowed recovering residual heat from a data centre to heat up a commercial building retrofitted by the Municipality.

In mild climates, such as the Mediterranean, energy savings from passive energy retrofitting (i.e. improvement of building thermal envelope) have proven very long payback time compared to similar actions in cold climates. If public subsidies or funding are not available, adding active solutions (e.g. replacement of old Heating, Ventilating and Air Conditioning (HVAC) and lighting equipment by new equipment with higher energy efficiency) to the passive measures has evidenced to be an alternative to shorten the payback time. In those cases, the monetization of the revaluation of the property after energy retrofitting is also crucial to help reaching the economic feasibility of passive measures. Related to commercial buildings, the project has tested in Barcelona a business model in the form of a private Energy Services Company (ESCo) participation in already approved structural refurbishment projects. This approach has shown to be a good opportunity to include energy-efficiency measures that would otherwise be omitted in commercial buildings renovation plans. The collaboration allows sharing costs between the constructor and the ESCo during the renovation works, besides adding a stronger commitment to guarantee a predefined energy savings target. In Cologne and Stockholm, large retrofitting projects have been implemented in residential settlements which involved the retrofitting of several buildings owned by the public administration. In these cases, avoiding multiple ownership in the residential sector has shown to facilitate the implementation. In order to promote the retrofitting of multiownership residential buildings, it is important to explain the added value of implementing energy-efficiency solutions compared to simple building retrofitting. The message on energy retrofitting value has to be broadened by a variety of arguments: (1) saving money, (2) better indoor climate, (3) getting more control of your energy use, (4) reducing the environmental impact, (5) increasing the asset value.

3.1.2 Home automation tools and energy surveillance platforms

The market of smart services at home has also been explored in the three lighthouse cities through the installation of HEMS prototypes in the project. These tools are able to offer different services other than real-time energy consumption visualization (e.g. remote control of appliances through smart plugs). However, in order to offer energy bill reduction to clients, the access to granular energy consumption data is crucial as well as the increase of users' awareness. Therefore, both qualitative data and an active user are required. Teaching the tenants how to use the smart home solution (and the associated costs of the information campaigns) is an essential and sometimes obviated activity to guarantee the success of HEMS. In fact, one of the barriers encountered in the project has been social acceptance towards this type of tools. Data protection laws must be complied, and therefore each user/client must give permission for the treatment of his or her granular energy consumption data. For example, the prototype of the smart home system offered in Cologne could not be widely deployed because the targeted tenants were not interested in this kind of technology and did not give their consent to install uncertified electricity meters to obtain detailed data. This limited to a large extent the potential functionalities of the tool. An intensive market study to investigate the interests of target residents is crucial, which in turn must be accompanied by engagement campaigns to raise interest among potential clients. In reference to the state of technology, HEMS deployed in the project have shown some technical complexity related to maintenance, data communication and technology obsolescence. Notwithstanding, it is expected that the open home net will become a more common infrastructure in apartments, offering shared sensors and actuators. By sharing the sensors needed to provide different services in apartments, it will be possible to add many services to a lower cost and facilitate the upscaling of smart home systems. Depending on the price of electricity in each country, reaching a break-even between the potential electricity savings offered by the HEMS and the price that clients have to pay for the service may be hard to achieve. Therefore, in order to enhance the economic feasibility of energy consumption visualization platforms, it is advisable to find synergies with other home services and look for opportunities to sell the platforms with integrated services packages.

3.1.3 Local energy generation

In the framework of promoting distributed local energy generation in the city, the project has tested the integration of advanced control systems to benefit from intelligent management of PV, heat pumps and battery systems based on weather and consumption forecasts, among others. Smart control of distributed electricity generation is a technology under development these days, and the experience in GrowSmarter has shown that the variability of communication protocols among battery and inverter manufacturers is a barrier to the technical feasibility of smart external control. Controlling the devices as planned by the energy management system definition has proven technically feasible, but still challenging. The current state of technology does not always guarantee that the equipment will respond to the external commands as expected.

Smart control of local energy generation units also allows the characterization of how the electrical power is used over time in both residential and commercial buildings. This information can be used to search for new businesses and offer services of power equalization among different types of buildings. Finally, smart management has also been applied to existing district heating (DH) networks in Stockholm, where DH technology is very well-established. In this case, the economic feasibility and positive environmental impact of recovering waste heat from a data centre and a supermarket into the DH network has been proven. This innovative business models allows the heat suppliers to avoid cooling system costs and get benefits instead.

3.2 Lessons learned and recommendations to local governments

3.2.1 Social acceptance

Local governments are important players to reduce social barriers for the implementation of solutions towards low-energy districts. Public administration should not only be a source of incentives or promotion of energy-efficiency solutions for the city building stock but also of campaigns for citizens' awareness and engagement in energy-efficiency matters. Social acceptance has been found as one of the main challenges in GrowSmarter. The implementation of energy-efficiency measures in buildings has a direct impact in citizens' quality of life.

3.2.2 Regulation

As observed in Growsmarter, the impact of local regulation can play a significant role to both foster or suppress building energy retrofitting upscaling. Examples of good practices are the enforcement of building codes and the promotion of the connection of buildings to efficient district energy networks in the areas of the city where the infrastructure is available. In Barcelona, for example, an ordinance requires most of the new and retrofitted buildings to include solar PV on their rooftops, having a positive impact on the path to low-energy districts.

In large-scale home renovation plans which involve multiple building owners, the role of the administration can have a very positive impact as a trustful actor that encourages citizens to get on-board. Campaigns promoted by the Public administration generate more trust among citizens in front of privately promoted campaigns. In this sense, involving the public sector (i.e. city municipalities) with a leadership role in large-scale building energy retrofitting projects is seen as a promising tool to upscale energy retrofitting among multi-ownership buildings. The leadership role by the administration may involve functions such as managing the grants, proposing the most appropriate financing for the owners, managing the payments and delays, etc.

3.2.3 Public housing

In the three lighthouse cities, public housing has been retrofitted to reach energy savings at different levels. Public housing owners are key institutional stakeholders to be mobilized to reduce the energy consumption of the residential sector. As long-term managers of their housing stock, public housing owners have to anticipate upcoming regulations on (existing) buildings in order to avoid any extra costs of future refurbishments. The decision-making capacity and technical expertise in this sector are high.

Tenants of public housing have to be kept informed right from the very beginning of the process to foster acceptance and avoid the "rebound effect" (offset of the beneficial effects of the energy retrofitting due to behavioural responses) and effectively achieve energy savings. It is recommended to pursue the creation of a sense of ownership and understanding among tenants.

3.2.4 Heritage buildings

In Stockholm and Barcelona, the energy retrofitting actions have also targeted heritage buildings which have become public commercial buildings. These projects have shown that municipal regulations can enable the implementation of energy-efficiency criteria and on-site renewable energy generation in heritage buildings, instead of restricting their technical feasibility with protective regulations. In general, it has been observed that there is a lack of regulatory initiatives in the lighthouse cities for reconciling energy efficiency/renewable energy with heritage conservation concerns, which could broaden the possibilities for the modernization of listed buildings in cities. It is important to avoid too many exceptions in the energy savings obligations of building renovation, because making heritage buildings sustainable is just as important as preserving their history. Using public municipal buildings as showcases for low-energy building design is seen as a useful tool to encourage private actors to invest in building energy performance upgrade and citizen engagement in general.

3.3 Lessons learned and recommendations to regional and national governments

3.3.1 District-scale energy renovation plans

Municipalities cannot face alone the promotion of district-scale energy retrofitting projects through investments or subsidies. Notwithstanding, regional and national incentives can bring an opportunity for municipalities to promote the decrease of the environmental impact of their building stock. In order to fairly quantify public subsidies and investments in the development of regional and national strategies, health benefits and the associated cost savings for the public healthcare system must be accounted. In fact, it is essential to assess and include all the externalities of energy retrofitting projects, i.e. social benefits in the form of non-economic benefits. District-scale energy renovation plans have several social benefits for citizens other than economic savings, e.g. increase of buildings' value or the prevention of young people to leave their neighbourhood.

It is recommended that subsidies for the residential sector are quantified considering the potential energy savings calculated based on real demands. The deployment of retrofitting actions in Barcelona has shown that the heating demands of residential buildings are often overestimated in mild climates due to the absence of heating system use by dwellers. Theoretical ratios do not represent the real energy consumption of a large share of the dwellings and, therefore, the impact of energy retrofitting works is sometimes lower than expected.

3.3.2 Local energy generation in urban environment

The upscaling and economic feasibility of local energy generation is highly dependent on national regulation. The smart management of on-site solar energy generation, heat pumps and/or battery storage demonstrated in GrowSmarter offers a new approach to integrate buildings in local energy communities, thus exploiting building flexibility and maximizing the investment in solar power. The associated benefits for the end user will increase when national regulation includes demand–response aspects, and this in turn will boost the scalability potential of smart home service. Using the tool for demand–response at the overall building level (and not at the apartment level) is seen as a promising service to increase the tool's replication potential. In fact, the current lack of flexibility to trade with energy and the sometimes unpredictable changes of laws build a state of no legal security for the scalability of local renewable electricity generation in cities, which claims for a political change. Regulation in electricity self-consumption (and electricity markets in general) differs in European countries. A regulation-free zone to prove hypotheses for local energy communities in the urban environment would contribute in the more restrictive countries to demonstrate the technical and economic feasibility. In a similar way, only if regulations are harmonized and updated according to the current state of technology, the exploitation of data from smart meters can be fully deployed. In practice, it is still not possible to consider a single model throughout the European Union that allows the scalability of products and services associated to the use of detailed electricity consumption data from smart meters (dependent on the regulatory frame and the available IT infrastructure in each country). A non-discriminatory access to data from smart-metering systems would avoid duplication of devices for the detailed monitoring of electricity consumption at dwelling level.

4 CONCLUSIONS

The deployment in the three lighthouse cities of a variety of energy-efficient solutions aiming at lowering the environmental impact of the districts has led to several learnings and recommendations for the future.

It is well known that, in general terms, a modernization of the existing building stock in European countries is required. In this line, it is expected that building retrofitting strategies will not only address renovation but also improvement of the energy performance of the existing buildings. Towards this end, energy retrofitting actions complemented by the use of information technologies to promote user behavioural change and local energy generation show a great potential to significantly benefit society. Those benefits are defined in terms of saving energy, money and emissions; increasing property value; creating jobs in the building sector and improving living conditions (and related economic savings for healthcare system).

In reference to building energy retrofitting, the technology is generally well established. In GrowSmarter, it has been observed that passive measures (upgrade of building thermal envelope) alone sometimes present very long paybacks in mild climates. The addition of active measures to passive energy retrofitting has evidenced to be a good alternative to shorten the payback time. In this sense, because the definition of the business model for building energy retrofitting interventions is a key factor to upscale the solution, several business models were tested in the project. Public–private agreements have shown a good acceptance by citizens in case of targeting multiowner private residential buildings since the public administration generates trust among neighbours in front of privately promoted campaigns.

The regulation in local generation and electricity self-consumption (and electricity markets in general) differs to a significant extent in European countries. Clear and harmonized regulation according to the current state of technology is required in order to fully deploy at commercial level distributed energy resources and the use of data from smart meters. In practice, it is still not possible to consider a single model throughout the European Union that allows the scalability of products and services associated to local energy generation and communities.

HEMS deployed in the project have shown high technical requirements (maintenance, data communication and technology obsolescence) but are considered a promising tool to engage building users towards an energy-efficient behaviour. However, in order to enhance the economic feasibility of these platforms, it is advisable to find synergies with other home services and look for opportunities to sell the platforms with integrated services packages.

Finally, the executed interventions within the GrowSmarter project have demonstrated that we need to put urban citizens at the centre of all the actions in order to succeed. Communication, information and user engagement is key to build trust, together with educating citizens and guaranteeing the correct implementation and operation of energy-efficiency measures. We need building users' awareness and acceptance to make low-energy districts the preferred development path for our society.

ACKNOWLEDGEMENTS

This research has been financially supported by the research and innovation programme Horizon 2020 of the European Union under the grant agreement nr. 646456 (GrowSmarter) as well as the GEIDI project (ref. TIN2016-78473-C3-3-R) financed by the Ministry of Economy and Competitiveness of Spain and the Generalitat de Catalunya (2017 SGR 1219).

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