Transforming cities for a smart, sustainable Europe

IMPLEMENTING LOW ENERGY DISTRICTS IN EUROPEAN CITIES – CONCLUSIONS FROM GROWSMARTER

D2.6. CONCLUDING REPORT WP2

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EXECUTIVE SUMMARY

This report presents the conclusions following the demonstration of 19 measures implemented in the three "Lighthouse Cities" of Barcelona, Cologne and Stockholm, which address the topic of Low Energy Districts in the GrowSmarter project. The measures together make up four out of the twelve "Smart Solutions" defined in the overall GrowSmarter project. The four Smart Solutions address the topics of (1) building energy retrofitting, (2) building information and monitoring platforms, (3) building-integrated energy generation, and (4) connection of buildings to thermal energy networks.

Two of the proposed Smart Solutions have been focused on lowering the energy demand of existing buildings. In the European context, it is well known that a modernization of the existing building stock is required. In this line, it is expected that city building retrofitting strategies to come will not only address the renovation of the structure of buildings but also the improvement of their energy performance in order to advance to Low Energy Districts. To encourage the replication and creation of city-wide retrofitting strategies, it is worth noting that energy retrofitting actions – complemented by the use of information technologies and smart energy management – have shown to bring about both tangible and intangible benefits (to the owner, tenants and society): saving energy, money and emissions; increasing property value; creating jobs in the building sector; and improving the living conditions of citizens (which relate to economic savings for the healthcare system).

Besides reaching a lower building energy demand, taking advantage of the currently unused local energy resources is considered as a crucial step towards achieving Low Energy Districts. GrowSmarter has therefore demonstrated two Smart Solutions that aim at contributing to the increasing decentralisation of energy generation in cities. In general terms, this is possible with the progressive transformation of common buildings into 'prosumer' buildings – which both produce and consume energy – from neighbourhood, to district, and finally city level. This does encourage the development of controllers to optimally manage the energy flows of building consumption and renewable energy generation. In addition, the Smart Solutions have also covered the interaction of those energy flows with the urban networks as well as the search for waste heat integration possibilities between buildings.

This report begins with a general introduction and overview of the 19 demonstrated measures addressing Low Energy Districts in GrowSmarter, and proceeds with a one-page description of each measure. The particular lessons learned and conclusions collected from the demonstration of each measure are shortly described in the one-page description. The measures demonstrated in this package of the project are grouped (based on their nature) in three topics, namely, (1) Energy retrofitting of buildings, (2) Home and Building Energy Management Systems, and (3) Building-integrated local energy generation and Smart control. Finally, recommendations targeting the different groups of stakeholders needed for the future roll-out of Smart Solutions are provided, which aim at facilitating and accelerating the roll-out of each type of measures across European cities.

CONTENTS

LIST OF ABBREVIATIONS

BEMS	Building Energy Management System
BIPV	Building-Integrated Photovoltaics
B2B	Business-to-Business
B2C	Business-to-Consumer
CO_2	Carbon dioxide
DBO	Design Build Operate
DER	Distributed Energy Resources
DHC	District Heating and Cooling
DH	District Heating
DSO	Distribution System Operator
EPC	Energy Performance Contract
ESCo	Energy Services Company
EU	European Union
FTP	File Transfer Protocol
GDPR	EU General Data Protection Regulation
HEMS	Home Energy Management System
HVAC	Heating, Ventilating and Air Conditioning
ICT	Information and communications technology
IT	Information technology
IoT	Internet of Things
KPI	Key Performance Indicator
M&V	Measurement and Verification
nZEB	nearly-Zero Energy Building
O&M	Operation and Maintenance
OpenDH	Open District Heating
PPP	Public-Private Partnership
PV	Photovoltaic
RE	Renewable Energy
ROI	Return on Investment
VAT	Value-added tax
WP	Work Package

1 INTRODUCTION

Across Europe, cities are embracing the pursuit of smart and sustainable development. Transformative action is required to reshape processes and practices influencing the design, construction and end-use of urban infrastructure. In this context, the cities of Barcelona, Cologne and Stockholm, together with a diverse group of public and private sector partners, formed the GrowSmarter project. GrowSmarter demonstrated '12 Smart solutions' in city energy, infrastructure and transport, to provide other European cities with insights and create a ready market to support the transition to a smart, sustainable Europe.

The measures demonstrated in this package of the project are grouped (based on their nature) in three topics, i.e. Energy retrofitting of buildings, Home and Building Energy Management Systems, and Building-integrated local energy generation and Smart control.

This report presents experiences from the implementation and evaluation of Smart city solutions addressing the field of *Low Energy Districts* in GrowSmarter. The other two main topics, i.e. *Integrated Infrastructures* and *Sustainable Urban Mobility*, are covered in separate concluding reports. Each Smart solution is divided in several measures implemented by different partners of the GrowSmarter consortium.

This report is based on the analyses of interviews and group meetings with Measure Leaders and other project participants, along with project reports and other relevant source material. In total, experiences from 19 measures are described to inform key conclusions and recommendations to policy-makers. The measures are clustered into three topics based on their nature:

- Measures on Energy retrofitting of buildings: *Efficient and smart climate shell refurbishment (Smart Solution 1)*
- Measures on Home and Building Energy Management Systems: *Smart, energy saving tenants (Smart Solution 3)*
- Measures on Building-integrated local energy generation and Smart control: *Local Renewable energy production (Smart Solution 4)* and *New business models for district heating and cooling (Smart Solution 6)*

The report begins with a general introduction and overview of the measures addressing *Low Energy Districts* in GrowSmarter, and proceeds with one-page descriptions of each measure where the lessons learned and conclusions collected for each measure are also shortly described. Next, recommendations on how to facilitate and accelerate the roll-out of each group of measures are given, addressing them based on each target group of stakeholders. Finally, the conclusions of the work done in *Low Energy Districts* are summarized.

For more information regarding the details of each measure, as well as their technical and financial evaluation and business models, please refer to the separate publically available ***factsheets***, ***implementation reports, D5.4 Final report on results of technical and social validation,*** and ***D6.4 Smart City Market Introduction.***

Table 1: Short description of the aim of the Smart solutions and measures in GrowSmarter WP2

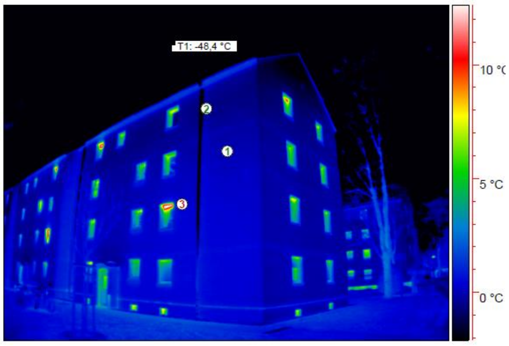
Solution	Measure #	City	What is it?	Aim
SS1. Efficient and smart climate shell refurbishment	1.1.	BCN	Passive energy retrofitting of social housing (207 dwellings)	Increase tenants' comfort and decrease building thermal energy needs
	1.1.	BCN	Integral retrofitting of 2 heritage buildings for their tertiary public use	Demonstrate the compatibility of energy efficiency and RE with heritage conservation
	1.1.	BCN	Energy retrofitting of 4 private residential buildings (83 dwellings)	Explore the ESCo model to promote energy retrofitting in the residential sector
	1.1.	BCN	Energy retrofitting of 3 private tertiary buildings: hotel, sports centre, educative centre	Demonstrate the feasibility of executing energy efficiency by an ESCo as part of an integral refurbishment
	1.1.	STO	Smart energy management in a condominium (56 dwellings)	Secure energy savings from energy-consuming facilities at building level via monitoring and control
	1.1.	STO	Energy efficient refurbishment of public housing (323 dwellings)	Integrate energy efficiency and REs into a full-scale renovation of residential buildings
	1.1.	STO	Energy retrofitting of 2 public tertiary buildings	Improve the energy performance of public-owned buildings
	1.1.	COL	Energy efficient refurbishment of public housing (687 dwellings)	Integrate energy efficiency criteria in the renovation of an overall residential neighbourhood
SS3. Smart, energy saving tenants	3.1.	BCN	Open city Energy consumption visualization for residential sector	Empower citizens with energy consumption information to reduce domestic demand
	3.1.	BCN, STO, COL	Home energy management systems for smart control of domestic appliances	Influence tenants' behaviour through individual energy data and increase the comfort by remote control of domestic appliances
	3.1. & 4.2.	STO, BCN	Energy visualization platforms for building energy management	Improve building energy performance by helping the decision-making in O&M
SS4. Local Renewable energy production	4.1. & 4.2.	STO, BCN	PV and storage installations with smart management in buildings	Demonstrate the intelligent management of local RE generation by maximizing battery usage
	4.1.	COL	Energy management system at neighbourhood level	Optimise on-site electricity and heating generation &s storage to maximize energy self-sufficiency of a neighbourhood
SS6. New business models for district heating and cooling	6.1.	STO	Waste heat recovery into existing District Heating networks	Recover surplus heat into existing DH networks to meet local energy demands
	6.3.	BCN	Local energy generation towards nearly-Zero Energy Building	Demonstrate the use of local energy through DHC networks to contribute to reaching nZEB status

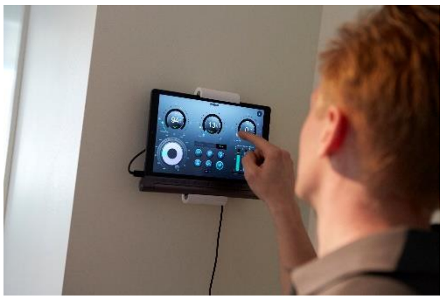
2 FIVE YEARS OF WORK: ACTIONS AND ACHIEVEMENTS

This concluding report covers the topic of *Low Energy Districts* in GrowSmarter, with 19 measures ranging from the energy retrofitting of different types of buildings and with different scopes, the smart control of on-site renewable energy generation and storage in buildings, the connection of buildings to District Heating and Cooling systems, and the installation of smart energy management systems at both dwelling and building level.

This Chapter presents information about the implementation, technical feasibility and replication potential of the measures in the three Lighthouse cities, along with key lessons learned. The sources of information to complete this Chapter are both the interviews with each GrowSmarter's Measure leader and the results published by the economic and technical evaluation studies performed in GrowSmarter.

Tables 1 is aimed at enabling readers to quickly identify the measures they want to learn more about and turn to the relevant pages. The rest of Chapter 2 consists of one-page summaries describing each measure. Please also refer to the report D2.3 Implementation Report for more in-detail views regarding each measure's implementation information.





1.1 Measures on Energy retrofitting of buildings (Smart Solution 1)

Measure 1.1 Energy efficient refurbishment of social housing in Barcelona

Barcelona Municipality aims to energetically upgrade the existing residential stock of its property in order to ensure a better quality of life of residents, lower the environmental impact of the assets, and ensure a better quality and safety of the architectural heritage.

What did GrowSmarter do? Within the scope of a broader action plan, the Municipal Housing and Renovation Institute of Barcelona promoted the passive energy refurbishment of a building of its property in Passeig Santa Coloma (207 dwellings). External thermal insulation was added to the retrofitting of the deteriorated existing façade, and all blinds were replaced by more isolating blinds. The resulting impact is a proven increase of the indoor comfort of tenants through indoor comfort survey campaigns done before and after the intervention, and the reduction of heating energy consumption of the building.

Lessons learnt: The Municipality gained new insights into user interaction aspects, such as the need for a very early integration of representative neighbours into the project board in order to minimize social barriers and guarantee a majoritarian acceptancy of the retrofitting action. Price-dumping in public tenders is a significant risk for this type of contracts. Guarantees and non-dumping strategies are recommended.

Potential for upscaling and replication: In order to lower investment cost and foster replicability, adapt public policies to include energy efficiency criteria when the need for building structural refurbishment arises in the social housing sector.

IMPACT

- ✓ *30% of heating energy savings*
- ✓ *Proven improvement of indoor thermal comfort in winter*

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

External Thermal Insulation Composite Systems (ETICS) are a proven technology to reduce building thermal load, however the impact has been lower than expected in this building because the baseline energy demand was overestimated. The reported increase of indoor thermal comfort has increased tenants‘ quality of life.

ECONOMIC FEASIBILITY

The owner (local authority) invests in upgrading building energy performance but does not directly benefit from energy savings nor raise rents to balance. However, reducing tenants' energy bills is a way to secure the solvability of the formers, limiting the unpaid rents.

A good technical solution can be inefficient without a simultaneous tenant education

REPLICATION POTENTIAL

Municipal social housing owners are key institutional actors to be mobilized to reduce the energy consumption of the residential stock in cities. The decision-making capacity in the social housing sector is normally high, which facilitates reaching quickly a very large number of dwellings with a single action.

Measure 1.1 Energy efficient refurbishment of public tertiary buildings in Barcelona

Barcelona Municipality has implemented policies to protect the industrial heritage of the city by retrofitting abandoned heritage buildings of its property and transforming them into highly energy-efficient buildings with local energy generation.

What did GrowSmarter do? The Municipality has integrally retrofitted two abandoned textile factories to become two new public tertiary buildings, that is, Library Les Corts and Ca l'Alier (R&D centre that hosts both public and private entities). Both buildings obtained very good scores in internationally recognized building energy performance certificates. For Ca l'Alier, the Municipality used a Public-Private Partnership (PPP) to co-fund the intervention. The energy efficiency actions include thermal envelope upgrade, high-efficiency HVAC, BEMS, photovoltaics (PV), connection to an efficient District Heating and Cooling network (Ca l'Alier).

Lessons learnt: Working together with the Urban planning department of the Municipality already from the design phase of the project is strongly recommended in order to select the most appropriate innovative technologies that allow respecting the historical value. Energy efficient renovation of built heritage brings a more attractive use and better occupation of these buildings while assuring a reduced energy bill. However, in terms of public building operation, training of Operation and Maintenance (O&M) staff is crucial to ensure an optimal energy management of the building which will *actually* lead to high energy performance.

Potential for upscaling and replication: Due to the high initial investment, all externalities must be taken into consideration when assessing the replicability of this type of action. Public-Private partnerships are one path to explore to find the required initial funding. Studying the potential role of the building in a local energy community is recommended, since this kind of buildings can normally host large energy generation plants (photovoltaics) which may bring economic benefits from selling or exchanging the surplus electricity in the neighbourhood.

IMPACT

- ✓ ***Library**: 48% of heating savings*
  12% of cooling savings
- ✓ ***Ca l'Alier**: under commissioning*

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

Although technically feasible, passive measures must be adapted as heritage buildings limit any retrofit action affecting the external envelope. Integration of local energy generation respecting heritage preservation is feasible.

Public heritage buildings can be used as energy efficient showcases. Adapting local building regulations help fostering replicability

ECONOMIC FEASIBILITY

In this case, the economic driver for the retrofitting action with high energy efficiency criteria is the creation of new public facilities to be used as showcases.

REPLICATION POTENTIAL

Public heritage buildings can be used as showcases for social awareness on energy efficiency. Adapting local building regulations can foster the replication of heritage buildings energy retrofitting.

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Measure 1.1 Energy efficient refurbishment of private residential buildings in Barcelona

Energy retrofitting of private single- and multi-owner residential buildings (with active and passive solutions) of different typologies and locations in the city by a private Energy Services Company (ESCo) that applies Energy Performance Contracts (EPC) through both public-private and private-private agreements. The ESCo verifies and guarantees savings.

What did GrowSmarter do? The Spanish energy company Naturgy has implemented retrofitting actions with the aim of lowering the energy consumption of nearly 20,000 m2 of residential floor in Barcelona (4 separate residential buildings named Canyelles, Ter, Lope de Vega and Melon District). This corresponds to 83 dwellings and 500 student rooms. Thermal envelope upgrade was implemented in the 3 former buildings while also active solutions (replacement of boilers and efficient taps) were implemented in Canyelles. The building Melon District was connected to the local DH network (replacing the old electrical heating system and gas boiler for hot water).

Lessons learnt: The implementation of information campaigns among tenants helps to raise awareness about the benefits of an energy refurbishment (i.e. enhance on indoor comfort, increase on property value, etc.) and teaches them to operate the new buildings in order to minimize rebound effects (the reduction in expected gains from new technologies that increase the efficiency, because of behavioral responses). It is advisable to make an accompaniment throughout all the process and educate on good practices.

Potential for upscaling and replication: Subsidies from supra-municipal funds are important to upscale this solution. The approach of the private ESCo is to partner with contractors in retrofitting projects (to act as the energy expert that guarantees energy savings are achieved).

IMPACT

- ✓ ***Canyelles:*** *34% of heating & 39% of cooling savings*
- ✓ ***Ter:*** *22% of heating & 18% of electricity savings*
- ✓ ***Lope de Vega:*** *22% of heating, 38% of cooling & 13% of electricity savings*

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

Retrofitting measures were technically feasible. The so-called "rebound effect" and the sometimes lower demand of residential buildings in mild climates (compared to theoretical demand ratios) had a significant impact on the energy savings from retrofitting. Awareness actions among tenants help to decrease the rebound effect and increase savings.

Low interest rate financing options are crucial to scale up energy retrofitting in the private residential sector

ECONOMIC FEASIBILITY

The measure has room to improve its revenues by identifying all the free-riders who benefit from the positive indirect impacts (i.e. inhabitants benefitting from better indoor air quality or administration benefitting from lower health system costs). If residents do change their consumption habit (likely to happen as the cost of achieving better comfort levels is lower than before) revenues from energy savings are decreased and the economic feasibility of the measure is lowered.

REPLICATION POTENTIAL

To replicate the measure, economies of scale (the combination of structural and energy retrofitting works or community scale refurbishment) is seen as a good option to explore. Shared costs reduce the investment and implies that tenants are prepared for the possible disturbances.

Measure 1.1 Energy efficient refurbishment of tertiary buildings (hotel, sports centre, educative centre) in Barcelona

Energy retrofitting of tertiary buildings through a Business-to-Business (B2B) service offered by a private ESCo through an EPC. The aim of the contract is to implement active and passive solutions to lower the energy demand of the buildings and guarantee that energy saving targets are achieved through Measurement and Verification (M&V) plans.

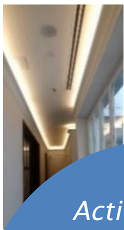
What did GrowSmarter do? The Spanish energy company Naturgy implemented retrofitting actions on over 10,500 m2 of tertiary floor (the sports centre CEM Claror Cartagena, the hotel H10 Catedral, and the educative centre Escola Sert). The intervention in the sports centre involved upgrade of roof insulation, efficient dehumidifier with heat recovery, heat pump for simultaneous heating and cooling, condensing boiler, LED lighting and BEMS. The intervention in the hotel included efficient HVAC system and lighting, high-efficiency windows, rooftop insulation and BEMS. In Escola Sert, Building-Integrated Photovoltaics (BIPV) were installed on the facade and a BEMS was installed. The interventions in both the hotel and the educative centre were executed by the ESCo in parallel with the building structural refurbishment.

Lessons learnt: To guarantee the expected energy savings of retrofitting projects, establishing minimum quality levels and performance-related penalties in the contract with the installers is a good practice. Wrong installations showed to have a huge impact on energy savings. The indicators to assess energy performance should be carefully reviewed by the ESCo and facility managers so every stakeholder understands all the variables behind them.

Potential for upscaling and replication: For public tertiary buildings with private operators, one aspect that impacts the feasibility of energy refurbishment is the landlord-tenant split incentive issue (a circumstance in which the flow of investments and benefits of the intervention are not properly rationed among the two parties). The company operating the facility may not invest on energy efficiency measures due to a too short concession period to recover the upfront costs. Possible solutions are public concessions that consider energy efficiency investments, or green leases versus a regular lease by the private sector.

IMPACT

- ✓ ***Sports centre:*** *51% of heating and 12% of electricity savings*
- ✓ ***Hotel:*** *58% of heating, 23% of cooling & 29% of electricity savings*
- ✓ ***Educative centre:*** *6% of electrical demand from PVs*


Active energy retrofitting solutions in tertiary buildings have proven short payback periods for ESCo clients

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

The proposed passive and active measures were technically feasible. The main obstacle was related to the definition of baseline in order to quantify savings, because of lack of energy performance data before the intervention.

ECONOMIC FEASIBILITY

Energy savings obtained by the implementation of active solutions in the 3 buildings have proven short payback periods for ESCo clients (attractive for private owners). Passive measures need longer paybacks, which are shortened by adding active solutions to the project.

REPLICATION POTENTIAL

Private tertiary buildings are very good candidates for the replicability of energy retrofitting by an ESCo. For buildings with public concessions, the sometimes incompatible contract duration from the public award should be addressed by the Public administration.

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Measure 1.1 Smart energy management in a private condominium in Stockholm

The implementation of trustful monitoring and control equipment in a multi-dwelling residential building to secure energy savings at the overall building level from different energy-consuming facilities.

What did GrowSmarter do? The service company L&T has installed different technologies and tools for smart energy management in the private condominium Brf Årstakrönet (56 dwellings). The technologies include: adaptive control system for heating; control of smart ventilation, indoor climate and energy quality; installation of Photovoltaics and storage.

Lessons learnt: The single installation of the smart technology equipment is not enough to guarantee the energy savings, but an on-going work involving people living in the building is required, together with the right maintenance and surveillance. Measure building energy performance prior to implementation to define realistic baseline and Energy Saving Targets.

Potential for upscaling and replication: The technology installed in this measure could provide larger energy savings if installed in older buildings (present building is not older than 8-10 years thus the margin for improvement of installation performance was relatively small). It is advantageous in terms of lowering costs and benefitting from existing knowledge that the contractor in charge of installing the equipment is the same one as the technical facility manager of the building.

IMPACT

- ✓ *11% of heating savings*
- ✓ *19% of electricity savings*
- ✓ *14% of total final energy savings*

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

The installation of the monitoring and control equipment is a well-established technology. In terms of data protection, the new General Data Protection Regulation (GDPR) required some technical changes on the monitoring of individual indoor temperature as each piece of information had to become anonymous.

ECONOMIC FEASIBILITY

The initial investment is low compared to building retrofitting actions. The installation of these smart technologies is self-financed with heating and electricity costs reduction for tenants.

Active energy surveillance and realistic energy consumption baseline are key to succeed with smart control tools

REPLICATION POTENTIAL

To replicate the measure in the private residential sector, it is recommended to have a really good communication with the Board of tenants of the condominium (through e.g. information meetings) and make them responsible for the contact with the rest of tenants/owners in the building. It proves to be easier to reach a good communication/acceptance with the Board compared to dealing with all the tenants in the building.

Measure 1.1 Energy efficient refurbishment of public housing area in Stockholm

Integration of energy retrofitting into a full-scale renovation of residential buildings owned by a public housing company. The scope of the energy retrofitting is very broad and is an outcome of the combination of passive and active technologies. The tenants get apartments with higher standards and better indoor comfort after renovation, while the property owner benefits from lower energy and maintenance costs.

What did GrowSmarter do? Skanska AB (project development and construction group) has implemented energy efficiency measures in six buildings with total 323 rental apartments (owned by the public housing company Stockholmshem) in the area of Valla Torg in Stockholm. The refurbishment involved the upgrade of thermal envelope and a combination of DH, geothermal heat pumps, exhaust air heat pumps, PV cells and heat recovery from waste water. A smart building management systems and indoor temperature sensors were installed.

Lessons learnt: Energy monitoring helps to increase the impact of energy renovation. Monitoring at the building level instead of dwelling level is a good alternative to avoid barriers with tenants' engagement and/or data privacy. In this way, energy savings can be more easily quantified for the building owner. Information campaigns on being a climate-active-tenant also helped to get acceptance. The main obstacle in this retrofitting was the tight schedule set for the project by both building owners and project managers. This is due to the fact that unforeseen obstacles (e.g. moisture, mould) often occur in large retrofitting projects.

Potential for upscaling and replication: In terms of replication, energy savings of 60% are a very ambitious target (the last 10-15% of energy savings are very costly). Interventions with the shortest possible evacuation of tenants should be pursued to enhance replication.

IMPACT

- ✓ *76% of total energy savings in buildings with geothermal heat pump*
- ✓ *60-62% of total energy savings in buildings without geothermal heat pump*
- ✓ *Up to 78% of heating energy savings*

Reaching high energy savings in residential buildings is possible with a deep renovation. This may require tenants' evacuation, which should be very well planned

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

The combination of active and passive technologies chosen for the deep renovation of Valla Torg did lead to the ambitious goal of lowering the overall buildings' energy demand by 60%.

ECONOMIC FEASIBILITY

The project is financially sustainable, although the sum of all energy saving measures has a long payback time. The value of the assets increased after retrofitting, which improves the financial analysis.

REPLICATION POTENTIAL

If the goal of a renovation is to reduce energy consumption and CO2 emissions, Valla Torg is a good example. However, social approval has not been easy in this retrofit project. In cases where the tenants must be evacuated, significant efforts are required for good communication between the housing company and the tenants.

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Measure 1.1 Energy efficient refurbishment of public tertiary buildings (offices and cultural centre) in Stockholm

The City of Stockholm has implemented policies to preserve the city's industrial built heritage while introducing energy efficiency criteria and local energy generation in an old industrial building (in a former industrial city area currently under transformation). Also, a set of energy efficient measures was applied to a publicly-owned commercial office building.

What did GrowSmarter do? The City of Stockholm has implemented a full renovation of the heritage brick building Slakthus 8 (now used as a cultural centre) with energy efficiency criteria (adaptive control system for heating & ventilation, heat recovery in the ventilation system and water heating, integrated PV in the glass of the skylight, LED lighting). In the offices building Kylhuset, the energy retrofitting intervention included the installation of a heat pump for waste heat recovery from a nearby data centre via the District Heating network, new highly efficient air handling unit, improved thermal insulation of the roof, and PVs.

Lessons learnt: Urbanization plans of the Municipality affect the economic assessment of the measure, since the value of the building will increase when the city area becomes more popular after the transformation process. It is advisable to analyse each building as part of its surroundings to look for energy exchange possibilities that can allow for efficient solutions.

Potential for upscaling and replication: For the data centre heat recovery action, the contractual conditions that will determine the economic feasibility of the heat pump installation are the agreed price of the recovered heat sent to the DH network, and the cooling savings for the excess heat producer. Also, this measure is dependent on the existing DH network infrastructure.

IMPACT

- ✓ ***Kylhuset***: *32% of heating savings*
  18% of electricity savings
  28% of total final energy savings
- ✓ ***Slakthus 8***: *57% of heating savings*
  47% of total final energy savings

It is important to analyse each building as part of its surroundings to find possibilities for waste energy recovery

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

The integration of PVs in both buildings presented some issues in terms of obtaining the permits because of the Architectural Heritage Protection requirements of the Municipality, solved by decreasing the PV surface installation. The rest of measures are technically feasible.

ECONOMIC FEASIBILITY

For Slakthus case, full renovation investments in old heritage buildings are often justified by other values than energy savings, e.g. protection of the built heritage making it accessible to everybody, or the use of the building as a kind of showroom (for citizen education). As for Kylhuset, the model could reach its financial sustainability by marginally increasing rents to offices occupants, which has not been contemplated by the Municipality so far.

REPLICATION POTENTIAL

Due to the high initial investment, the replicability of energy retrofitting of publicly-owned heritage buildings is highly dependent on Municipality urban planning policies. The replication of heat recovery intervention in Kylhuset from a nearby building depends on DH infrastructure.

Measure 1.1 Energy efficient refurbishment of a residential neighbourhood in Cologne

Integration of energy retrofitting into the renovation of residential buildings owned by the public housing company. The scope of the energy retrofitting is very broad and results from the combination of passive and active technologies to reduce the net energy demand of the neighbourhood.

What did GrowSmarter do? Dewog (public housing company) has implemented an energy retrofitting action in 16 residential buildings (with an impact on 687 rented dwellings) in the neighbourhood named Stegerwaldsiedlung. The action involved the upgrade of the buildings thermal envelope through insulation and efficient windows. Within the project, the energy company RheinEnergie was in charge of connecting the buildings to the District Heating network, installing Photovoltaic panels, air/water heat pumps and monitoring equipment.

Lessons learnt: In case the rents are raised in order to finance the measure, working for a fluent communication with tenants is very important. Tenants may not appreciate the energy efficiency measures implemented in their homes until they see a considerable reduction of their energy bills. Together with the City administration, several events were held for the tenants with the aim of informing about the impact of the energy retrofitting.

Potential for upscaling and replication: The replication potential is high for this intervention since public housing owners have the capacity to quickly reach a very large number of dwellings with a single action, as well as lower investment costs by contracting large projects.

IMPACT

- ✓ *Up to 59% of heating savings depending on the building*
- ✓ *Up to 61% of total final energy savings depending on the building*

If the retrofitting action leads to rents increase, information campaigns are advisable (explain all benefits)

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

The complexity of the measure has lain in the need for a nearly simultaneous recruitment of a very wide number of contractors. A careful planning is crucial to guarantee the minimum delay and impact on tenants' comfort (as they are not evacuated during works).

ECONOMIC FEASIBILITY

Energy savings are enough to pay off the investment (high heating savings in cold climate). However, the energy cost savings are captured by the tenants, whereas it is the building owner (public housing) who makes the investment. Rents were increased to a limited amount (restricted by Cologne law) but this does not reach the break-even.

REPLICATION POTENTIAL

An ESCo model could work to make the investment attractive for a private investor, as the tenants would be paying off the investment through a constant fee in their energy bills (with the ESCo model, the energy savings would be captured by the investor).

1.2 Measures on Home and Building Energy Management Systems (Smart Solutions 3 and 4)

Measure 3.1 Virtual Energy Advisor - Open city Home Energy Management System in Barcelona

The implementation of a municipal energy policy focused on citizen empowerment through the roll-out of an Open city Home Energy Management System (HEMS).

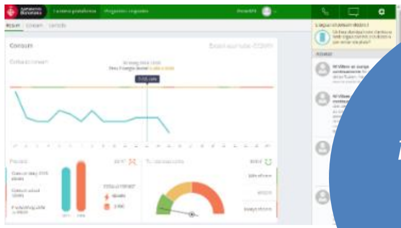
What did GrowSmarter do? Barcelona Municipality launched a campaign to encourage citizens to decrease their electricity consumption at home by providing a free electricity consumption visualization platform called 'Virtual Energy Advisor'. The tool, provided to more than 400 citizens, was in most cases fed by detailed electricity consumption data from an installed digital meter. The tool (managed by a web platform and mobile App) demonstrated several smart ways to advice tenants on how to optimize their behaviour in order to achieve maximum energy efficiency in their households.

Lessons learnt: The impact of the platform on household electrical consumption has shown an average 15% reduction. However, because of the first campaign normally captures "early adopters" (citizens with an interest in energy efficiency), the upscaling impact could be lower.

Potential for upscaling and replication: With this tool, the Municipality is able to gather detailed information on the residential electricity consumption profiles of the city based on district, building typology, etc. This feature can be the reason for Municipalities to upscale and replicate the measure, as they can use the information to foster suitable energy policies.

IMPACT

- ✓ *Over 400 users signed up*
- ✓ *15% of annual electricity savings per household on average*



City platforms should be designed following simplicity, low-maintenance and user-friendly interface to increase their acceptance

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

The basis to succeed with this measure is the effective collection of individual energy data, compiling it for the tenants. For its technical feasibility, it is important to clearly specify the O&M services required in the public tendering process to avoid to the maximum extent the relatively common connectivity issues experienced in this first pilot.

ECONOMIC FEASIBILITY

Based on a municipal policy, this measure has been completely financed with public funding, whereas citizens are the ones who capture the economic benefits. Based on this, the tool has proven a more beneficial Cost Benefit Analysis compared to some passive retrofitting actions implemented by the Public administration in public buildings. Scale economies would help to reduce the average costs of implementation.

REPLICATION POTENTIAL

In order to upscale the measure, it would be desirable to avoid the costs of electricity sub-metering equipment. Future implementations of this type could obtain the consumption data directly from the digital meters operated by the DSO.

Measure 3.1 HEMS - Private Home Energy Management System in Barcelona

The installation of a smart home solution to lower the energy demand in the residential sector through the visualization of customized individual energy data, real-time prices alerts of consumption, personalized recommendations on appliance level and control of specific appliances and indoor temperature. The solution includes a number of devices communicating to a central hub that sends data via WiFi to the corporate platform. The end user controls and sees those devices on an App. Devices include a thermostat, smart plugs and current clamps to disaggregate consumption.

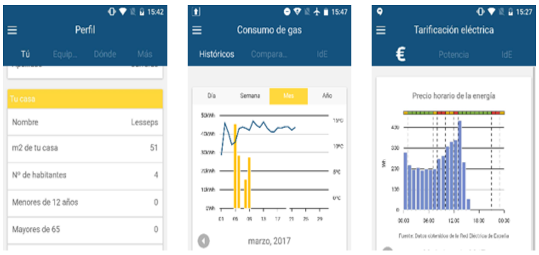
What did GrowSmarter do? The energy company Naturgy has developed a prototype of a HEMS for its clients in order to test the business model for smart services at home. Naturgy installed prototypes in 200 dwellings. The tool is managed by a tablet or smartphone, and also includes the visualization of electricity self-generation via PVs if available.

Lessons learnt: Work on reinforcing the communication chain to avoid connectivity issues is essential to guarantee the correct technical operation of the measure. User engagement activities are crucial: the impact of the measure is negligible if tenants are not active.

Potential for upscaling and replication: The fact that the company providing the smart home system is an energy utility and retailer increases the potential for upscaling due to the existing easier access to consumer data (and right to use it). In order to scale up, it can be interesting to partner with construction companies to incorporate smart home equipment into new construction.

IMPACT

✓ *Between 18 and 27% of electricity savings per household (although the measure was combined with energy retrofitting)*



HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

The optimization of battery duration based on communication protocols of devices would improve the technical feasibility. Radiofrequency protocols may not need as much power as WiFi-enabled devices and might ease the operation for the end user. Interoperability of final devices and gateways could be standardized.

ECONOMIC FEASIBILITY

The open home net is seen as an opportunity to improve the economic feasibility since it can offer shared sensors and actuators. By sharing the sensors needed to provide different services in apartments, it is possible to add services to a lower cost and facilitate the upscaling.

REPLICATION POTENTIAL

The upscaling of smart home solutions is based on market demand of home monitoring and control services that will significantly increase in the coming years. Demand-response and flexibility services will also have a direct positive impact.

Personalize smart home solutions and use gamification to effectively reach behavioral change

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Measure 3.1 Active House - Private Home Energy Management System in Stockholm

The installation of a smart home energy visualization application to lower the environmental impact of the energy demand in the residential sector by influencing tenants' behaviour with individual dwelling energy data. The tool is linked to smart plugs and thermostats that allow the user to control lighting and radiators remotely, besides monitoring energy consumption (electricity, hot water, space heating) in real-time.

What did GrowSmarter do? A start-up within the Swedish utility Fortum has developed the Active House application (a Smart Home solution) and installed it in 54 apartments in Valla Torg. The tool is managed by a tablet and presents customized individual energy data, hourly carbon dioxide emissions, etc.

Lessons learnt: Teaching the tenants on how to use the Active House solution and the associated costs of these information campaigns are an essential activity in the implementation of this measure. The basis for energy reduction is raising users' awareness and will to become more environmentally friendly.

Potential for upscaling and replication: Fortum intends to sell this solution by integrating it with other services for households in order to make the solution economically feasible.

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

In solutions that involve the use of so many sensors, improving battery life presents a challenge, as batteries normally need to be changed by the tenants or the building managers, thus the longer they last the more convenient for its technical feasibility.

ECONOMIC FEASIBILITY

With a relatively low price of energy and a low emission factor in Sweden (compared to those in Germany and in Spain), this measure is not economically feasible if it is done only to save energy. If a bigger picture is taken with e.g. the future lack of power in urban grids, the potential economic benefits of this kind of tool are broadened.

REPLICATION POTENTIAL

The more people that uses the solution, the easier to scale up (potential clients learn the benefits from friends/relatives). Using the tool for demand-response at the overall building level (by installing it in all apartments of a building) is seen as a promising service to enhance replication potential. The benefits of the system grow with scale.

The tool may help to teach tenants how to live eco-friendlier, but we need to transfer the responsibility and power to them in order to reach behavioral change

Measure 3.1 Smart Home System – Private Home Energy Management System in Cologne

Installation of a smart home system focused on automation/control of domestic appliances. The system includes heating thermostats, sensors for the state of windows (open/closed), smart plugs, indoor temperature and humidity sensors. It also offers the possibility of programming on/off status of devices from the App. The ultimate goal is to improve tenants' quality of life, as the decrease in energy consumption is not the main target and cannot be steered with encouraging behavioural change.

What did GrowSmarter do? The German energy company RheinEnergie has developed a prototype of a Smart Home System for its residential clients. The evaluation process lead to a Smart Home system which supports multiple radio protocols and open API to integrate the data into AGT's smart plugs system (Measure 5.3 in GrowSmarter). The technology was offered to all households in the Stegerwaldsiedlung neighbourhood and was finally installed in 5 dwellings.

Lessons learnt: The qualitative follow-up (via surveys) of the new technology performance is a good tool to evaluate how the Smart Home system improves clients' quality of life. Very good communication with potential clients is essential for success. In terms of data collection, a contract must be drawn up which gives the user a clear and comprehensible understanding of which data are collected and for which purpose.

Potential for upscaling and replication: The solution was built to be flexible. Components from different vendors (e.g smart plugs, thermostats) were connected to the gateway without any modifications on the backend side and analytics. Also, the change to a different gateway is possible as long as there are ways for the backend to access the data. Hence, the designed solution is scalable, flexible and transferable to other scenarios.

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

The installation of the Smart Home System was technically easy. Only in the case of intelligent heating thermostats, it is necessary to check whether an additional adapter is required for the installation.

ECONOMIC FEASIBILITY

Expanding the functionalities of the Smart Home system by including information on disaggregated and real-time electricity consumption data would raise the potential for economic savings. This is dependent on the National law. According to the economic analysis, with the automation of thermostats the measure seems to need a minimum mass of 189 users to be financially sustainable through energy savings.

REPLICATION POTENTIAL

Considering the experience in GrowSmarter, an intensive market study to investigate the interests of target residents is crucial. Citizens are in general not familiar with the technology. Information and engagement campaigns to raise awareness about the benefits of Smart Home systems will contribute to the upscale of the solution.

An intensive market study to investigate the interests of target residents is crucial

Measure 3.1 Energy Saving Center - Building Energy Management System in Stockholm

An Internet of Things (IoT) platform to be used as a Building Energy Management System (BEMS). The platform improves building energy performance by helping the decision-making process related to the application of energy efficient measures in both tertiary and residential buildings. The tool offers a proactive surveillance of the customers' installations with the regular analysis of building energy consumption data for its optimal use, and includes an adaptive heating control system.

What did GrowSmarter do? The service company L&T has developed the BEMS called 'Energy Saving Center' and installed it in the residential buildings Brf Årstakrönet and Valla Torg, as well as in Kylhuset offices building and the cultural centre Slakthus 8. The BEMS is fed by data from the automatic collection from a series of meters and sensors installed in the buildings.

Lessons learnt: Depending on the type of building owner (e.g. corporative, public administration buildings), the collection of measurement data may present some challenges due the need for development of a communication chain that works through different networks (firewalls). This should be considered in implementation planning phase. The tool has proven to enable an increased proactivity and fast reaction as well as less losses when detecting unwanted energy uses.

Potential for upscaling and replication: Including the energy surveillance tool in packages with other building services will reinforce the replication potential. The monitoring and decision-support software tool for the operation and maintenance of energy installations can also be sold together with other computer-based systems used to monitor and control building services such as lifts, fire safety, ICT networks, or security systems.

HOW DID THE MEASURE WORK?

Energy surveillance tools enable increased proactivity and fast reaction against energy losses

TECHNICAL FEASIBILITY

IT communication among all smart equipment is technically feasible but resource-intensive to deploy. There is no unique normalized standard communication protocol, making communication challenging.

ECONOMIC FEASIBILITY

The tool brings proven savings for the building owner, i.e. reduction of heat, electricity and water costs during building operation. In the residential sector, the focus is the building owner, as tenants may not capture the savings because it is common in Sweden that heating costs are included as a fixed fee in the rent.

REPLICATION POTENTIAL

Working with data on a building level brings less privacy concerns compared to working at dwelling level (compared to the installation of HEMS). Developing the business model from B2C (Business-to-Consumer) to B2B (Business-to-Business) is seen as a good opportunity to upscale and replicate the solution.

Measure 4.2 Resource Advisor - Energy performance evaluation platform in Barcelona

An Internet of Things (IoT) platform that aims at aggregating multiple types of data from every facility in a building in order to centralize information. This cloud-based software allows seeing KPIs that should help to identify outliers/opportunities to increase energy efficiency in the building.

What did GrowSmarter do? Schneider Electric has used its platform called 'Resource Advisor' to centralize the monitored data from some of the retrofitted buildings in Barcelona within the project. The tool shows KPIs based on the gathered data for the evaluation of the impact of energy retrofitting works in the building.

Lessons learnt: Automatic data gathering should start well before the retrofitting works to ease the creation and follow-up of the baseline, and also to avoid the strong dependence of monitoring systems operation with the finalization of retrofitting works. Also, clarity on who is responsible and accountable for Data Quality across the data transmission chain is necessary. Privacy as well as any Information technology (IT) security concerns should be tackled at the beginning of the project. The EU General Data Protection Regulation (GDPR) required additional security measures, software development and legal considerations, which make an increased development cost and therefore selling prices – even for industrial-based applications such as this one. The GDPR became an obstacle while sharing data among parties involved in the project, given the confidentiality agreements the partners had with the tenants of the buildings.

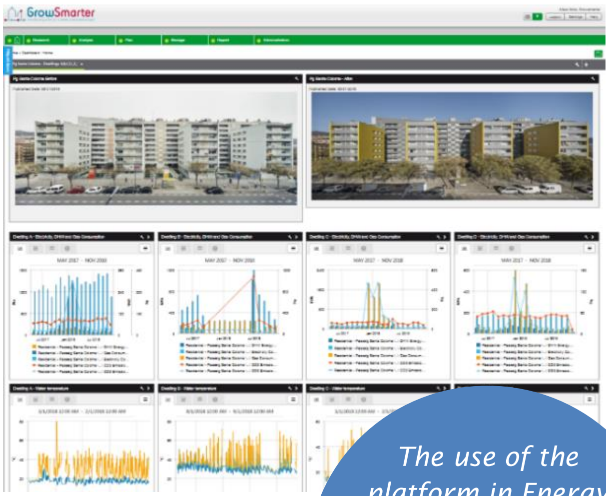
Potential for upscaling and replication: The integration of this type of monitoring platforms in Energy Performance Contracts (EPC) is regarded as a promising option to increase replication potential. The setup, use and maintenance of the software are subject to a contractual agreement.

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY
The measure is feasible, however the standardization of communication protocols with metering devices would significantly facilitate the feasibility.

ECONOMIC FEASIBILITY
For its economic feasibility, the platform is usually financed within a recurring services contract, as part of self-financed energy efficiency measures.

REPLICATION POTENTIAL
Improved and adequate regulatory frameworks for the energy monitoring and management industry (in terms of standards and protocols) would enhance the replication potential.



IMPACT
5% final energy savings in monitored tertiary buildings (estimated)

The use of the platform in Energy Performance Contracts increases replication potential

1.3 Measures on Building-integrated local energy generation and Smart control (Smart Solutions 4 and 6)

Measure 4.1 EnergyHUB - Smart management of photovoltaics and energy storage in Stockholm

Installation of Photovoltaic units and electrical storage controlled by a smart energy management software in both tertiary and residential buildings. The management software gathers relevant electricity consumption and generation information and optimizes the energy flow among the solar panels, energy storage and the grid to maximize battery usage and perform peak shaving strategies.

What did GrowSmarter do? The service company L&T has installed PVs, electrical storage and an inverter under the control of the so-called EnergyHUB management software in both tertiary buildings retrofitted by the City of Stockholm (Slakthus 8 and Kylhuset) and in the residential building Brf Årstakrönet.

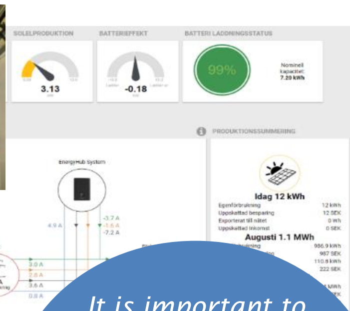
Lessons learnt: The installation of the management software in different types of buildings (residential and tertiary) allows observing how the electrical power is used over time and finding possibilities for power equalization between different types of buildings.

Potential for upscaling and replication: One of the main goals of the energy optimization in this measure is peak shaving, which is considered to be a major topic in the near future due to the forecasted congestion of the electrical grids in cities. In this sense, it is expected that the measure has a high potential for upscaling and replication.

IMPACT

Annual share of electricity consumption of building supplied by the PV+storage system:

- ✓ ***Brf Årstakrönet:*** *17%*
- ✓ ***Slakthus 8:*** *5%*
- ✓ ***Kylhuset:*** *9%*



It is important to study the possibilities for power equalization among different types of buildings

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

Less variations in communication protocols between battery and inverters for each manufacturer increase the technical feasibility.

ECONOMIC FEASIBILITY

The measure is self-financed as the hardware is paid with monthly fees that users pay for the PV, battery and energy management service. The government support available in many countries for battery purchase should also be considered.

REPLICATION POTENTIAL

The smart management of on-site energy generation offers a new approach to integrate buildings in local energy communities and maximize the investment in solar power. The future exploitation of the flexibility of buildings will require smart energy management systems.

Measure 4.1 Siedlungsmanagement - Energy management system at neighborhood level in Cologne

This software is an intelligent energy management system at neighbourhood level and aims to optimise the electricity consumption and heat generation of the heat pumps in the settlement, as well as the use of the battery storages in order to maximize the self-sufficiency of the settlement. The management system controls both internal (PV, air/water heat pumps, battery storage) and external (district heating) energy producers in the neighbourhood.

What did GrowSmarter do? The energy company RheinEnergie has integrated the Siedlungsmanagement software with the energy systems in the Stegerwaldsiedlung neighbourhood (16 buildings). The software receives data from the performance of 41 heat pumps (492 kW_{th}), 6126 m² of Photovoltaics (1084 kWp), district heating connection (1743 kW), and 16 batteries (210 kW), as well as estimated building energy demand. The software is prepared to run optimization algorithms and send set points to the energy generation units.

Lessons learnt: Controlling the devices as planned in the energy management system definition may be challenging. With such complex control, it is good to allocate a time period to monitor and test the devices behaviour.

Potential for upscaling and replication: Neighbourhood energy management systems are a relevant tool to approach low energy districts, controlling the energy consumption either by reducing it or shifting it during the day to flat the demand shape. The future trend towards the creation of local energy communities makes this system have a great potential for replication, even more in neighbourhoods where buildings have a single owner. Nevertheless, data transmission and connection of energy systems are technical issues to be overcome.

IMPACT

- ✓ *6000 Data points monitored*
- ✓ *36h Energy forecast*
- ✓ *73 Energy systems are controlled*

Common manufacturers lack the experience and disclosure of interfaces for external systems. Test periods are required before system operation

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

The electricity consumption forecast module of the smart energy management system will not provide very accurate results due to the impossibility of monitoring electricity consumption at dwelling level (smart meters could legally not be used). If they were able to be used, the results would be much more accurate.

ECONOMIC FEASIBILITY

The target groups are e.g. housing agencies and other energy providers. The software can be run based on minimizing energy costs for the neighbourhood, which is e.g. beneficial for the manager in case a fixed fee is charged to its tenants.

REPLICATION POTENTIAL

Single ownership of the buildings in the neighbourhood facilitates replication. Technically speaking, most of the manufacturers do not expect their devices to be part of such a complex energy management system. Intense discussions are required on how their devices can be externally controlled. This should be accounted when replicating.

Measure 4.2 Smart management of PVs and energy storage in Barcelona

Installation of Photovoltaic units and electrical storage with smart energy management software in both tertiary and residential buildings, including different innovative PV cells (i.e. half-cell) and different urban integrations (i.e. PV pergola). The management software gathers relevant information and optimizes the energy flows based on the real-time operation and the forecasts of building consumption, weather and grid electricity prices.

What did GrowSmarter do? The energy company Naturgy is testing the viability of the business model as an ESCo that offers electricity self-consumption installations to building owners. The research centre IREC developed the smart management system that controls the battery to optimize the performance of the system (based on usage of RE, emissions, costs, etc.). The local electricity generation units were installed in a residential building (Sibelius), a youth day-care service centre (Valldonzella), and at Naturgy's headquarters in Barcelona.

Lessons learnt: The accurate monitoring of smartly controlled self-consumption systems leads to a collection of large amounts of data. Database maintenance is very important in order to have consistent data. Depending on the battery inverter manufacturer, the integration of energy management systems may be technically challenging.

Potential for upscaling and replication: Having a regulation that facilitates the installation of distributed energy generation units is key for its replicability. It is only recently that the Spanish Government approved a law that allows various consumers to own the same energy generation unit and are able to sell the surplus electricity to the grid with remuneration. This new situation reduces the payback and makes the technology very suitable for a group of buildings with complementary load curves.

IMPACT

- ✓ ***Sibelius:*** *PV+storage power cover 65% of building's communal space electricity consumption (annually)*
- ✓ ***Valldonzella:*** *PV+storage power cover 20% of building's electricity consumption (annually)*

Distributed smart storage can bring energy flexibility in a community by reducing average peak load and increasing PV self-consumption

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

Controlling the devices as planned in the energy management system definition may be challenging, thus partnering with battery inverter manufacturers can be a good option to explore to overcome technical challenges for battery external control.

ECONOMIC FEASIBILITY

Tax exemptions applied by Municipalities for PV installation shortens the payback periods and improves the ROI. For its economic feasibility, the acquisition of batteries by small/medium customers requires incentives from Public Institutions.

REPLICATION POTENTIAL

To reach the full replication potential of the solution, the two main drivers are a favourable regulation for urban integration of PVs and reduction of battery costs (e.g. via public incentives).

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Measure 6.1 OpenDH - Feed-in of waste heat into District heating network in Stockholm

A business model that aims to recover surplus heat into existing District Heating networks to meet local heating energy demands by citizens in urban environment. This is done by the installation of plug and play heat pumps in the waste heat producer facilities to recover the energy into the DH network.

What did GrowSmarter do? The DH utility company Stockholm Exergi has developed this innovative business model called Open District Heating (OpenDH). Within GrowSmarter, Stockholm Exergi has delivered two heat recovery projects, one in a supermarket and one in a data centre, and injects the waste heat from the projects into the existing DH network of the area by the installation of heat pumps.

Lessons learnt: Robustness of the measured data collection is crucial and much more important than the periodicity of measurements. In cases of data losses, mean values for invoicing must be created and, in areas with higher proportion of recovered heat, the delivery temperature to the district heating customer must be ensured. Furthermore, since the heat pump operation responsibility is on the waste heat supplier, the O&M governance needs to be ensured for a successful project.

Potential for upscaling and replication: This measure is applicable to any city where there is a district heating system nearby into which the waste heat can be fed. The DSO (Distribution System Operator) needs to enable, allow and pay for third-party production into the network. Therefore, the upscaling possibility of this measure is good where there is an infrastructure to consume waste heat or collaborations with parties to start in small scale.

IMPACT

Recovered heat:

- ✓ ***Data centre**: 4.7 GWh/year (heating for 500 apartments)*
- ✓ ***Supermarket:** 0.5 GWh/year (heating for 40 apartments)*

The amount of excess heat produced by the building determines the feasibility of the business model

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

Since the waste heat from supermarket and data centre is at a level of 25-40°C, the energy can be consumed on the return line of the district heating network or (as the case for the GrowSmarter project) on the forward line of the district heating network after the temperature has been increased via heat pumps to a level of 68 °C.

ECONOMIC FEASIBILITY

The OpenDH business model for a District Heating utility is based on the balance between heat pump investment, revenues from waste heat sales and the increased electricity usage for heat pump (compared to standard cooling machines). In Stockholm this has shown to be economically feasible for both the DH utility and the excess heat suppliers.

REPLICATION POTENTIAL

If the District Heating infrastructure is in place, focusing on the data centre segment (a growing worldwide business where the cooling demand is the same throughout the year) is seen as a promising replication area. The solution provides an interesting case for Public-Private Partnerships (PPP) in energy supply.

Measure 6.3 Local energy generation towards nZEB in Barcelona

The implementation of technologies based on local energy generation to support reaching a nearly-Zero Energy Building (nZEB) status: (1) the connection of a building to an energy efficient District Heating and Cooling (DHC) network and (2) the installation of local electricity generation through Photovoltaics.

What did GrowSmarter do? Barcelona Municipality has promoted the use of local energy in the design of the full retrofitting action for Ca l'Alier building in order to transform it into a nZEB. A 68kWp photovoltaic plant was installed on the building rooftop. The new R&D centre was also connected to the local DHC network named "Districlima", whose heating and cooling is generated in a nearby plant based on thermal energy recovery (via the incineration of municipal solid waste from the city and use of sea water for cooling).

Lessons learnt: Even if nZEB criteria is applied in the building design and associated investment (with the connection of the building to local energy sources and investing in high thermal performance), it is essential to contract O&M services aimed at reaching the nZEB status and perform a thorough follow-up of building energy behaviour.

Potential for upscaling and replication: In mild climates, the DHC infrastructure is less spread than in cold climates. Notwithstanding, local regulation encourages the connection of large consumers (such as public tertiary buildings) to the existing networks, which fosters the potential for upscaling and replication of this measure.

IMPACT

- ✓ *PV able to cover 20% of building's electricity consumption*
- ✓ *100% local thermal energy supply*

A favourable Municipal legislation is crucial for the massive roll-out of on-site RES and connection to DHC networks

HOW DID THE MEASURE WORK?

TECHNICAL FEASIBILITY

The connection of the building to the local DHC network is technically feasible, partly due to the proximity of the building to the existing network and the favourable expansion plans of the utility in the area. The connection of the building to the local DHC network allows using the available local waste energy resources to supply its energy demand, which is not possible for individual thermal systems. This helps to upgrade the energy rating of the building.

ECONOMIC FEASIBILITY

In moderate climates, the economic feasibility of the connection of a building to a DHC network is strongly dependent on the proximity of the building to the existing network(s), the building energy needs, and the planned expansion plans of the network. In this case, the Municipality decided to re-build the industrial site to a nearly-Zero Energy Building (to be used as a showcase), thus the economic feasibility of the PV installation and the connection to DHC was not put at the forefront of the decision-making process. Even if the operation costs of the building are lower, the economic feasibility has not been evaluated yet.

REPLICATION POTENTIAL

The existence of large waste heat sources in the urban environment represents an opportunity for the deployment of DHC infrastructure, which (accompanied by favourable local regulation) ensures a replicable business case. The combination of local energy sources (i.e. DHC, PV) enabled to achieve the nZEB certification.

2 LESSONS LEARNED AND RECOMMENDATIONS FROM THE GROWSMARTER LOW ENERGY DISTRICTS WORKPACKAGE

Table 2: Aggregated recommendations based on lessons learnt from GrowSmarter WP2

	Suggested course of action	GrowSmarter's recommendations	Actors
PLAN the transition to low energy buildings and communities	✓ combination of passive and active retrofitting solutions ✓ integration of local energy generation in buildings and smart control ✓ waste heat integration into DHC networks	Include in retrofitting projects the combination of short payback (e.g. HVAC replacement) and long payback interventions (e.g. upgrade of façade thermal insulation)	Local Private
		Engage in early dialogue with stakeholders to ensure various approaches are discussed and considered prior to selection of the ideal RE technologies and district networks for the city, based on the local context	Local
ENGAGE building owners and tenants	✓ awareness and engagement campaigns ✓ energy visualization tools as enablers for systemic change ✓ use of retrofitted public tertiary and residential buildings as showcases	Develop engagement campaigns in-house or sub-contract a specialized company to perform them early in the process	Local Private
		Customize HEMS tools by adapting interfaces to each target group. Add features to make people interested in energy usage and the "eco-trend"	Private
		Use municipal buildings as examples for low-energy building design to encourage private actors to undertake similar investments.	Local
GROW investments in public building retrofitting and in energy monitoring	✓ long-term funding for strategic public building stock retrofitting ✓ energy metering as enabler for smart management and local energy communities	Use social/public housing retrofitting as a quick path to upscale residential retrofitting	Local
		Public-Private Partnerships (PPP): participate in co-financing programmes for existing publicly promoted retrofitting projects as an opportunity to enter in energy retrofitting business	National EU
		Consolidate standards for communication protocols by defining a unique standard or delimiting those that have proven as efficient	Private
SHAPE business models and financing options	✓ non-traditional business models for energy retrofitting ✓ assessment of environmental and social externalities ✓ low interest rate financing mechanisms for the upscale of retrofitting	Include the collaboration of Energy Savings Expert in structural refurbishment projects	Local Private
		Add clauses for quality assurance/certification schemes in energy retrofitting contracts (include evaluation of the professional experience of subcontractors)	Local Private
		Consider the increased value of the property and the environmental and social externalities of energy retrofitting projects in the financial assessment	Local Private
ADJUST legal and regulatory requirements	✓ updated building codes and standards ✓ green leases for public tertiary buildings ✓ favourable regulatory framework for self-sufficient installations & demand-response	Establish the technical and quality conditions in which the transfer of data from official smart meters to a third party can be carried out in a systematic, simple and scalable way	National
		Adapt the concession contract conditions for private operators in public tertiary buildings to promote energy efficiency investments	Local Regional
		Facilitate local urban planning regulation to make PV installations in buildings easier and simpler; eliminate tolls to sell surplus electricity to the grid	Local National

2.1 Measures on Energy retrofitting of buildings

Recommendations to private companies

Plan automatic data gathering well before the retrofitting works to ease the creation of a baseline to measure the resulting change that is caused by an intervention

- ✓ **Avoid the strong dependence of the start of operation of monitoring systems with the finalization of retrofitting works.**

  Make sure that what you are measuring in the post baseline data is the same as what was measured in the baseline data collection process.

Adopt new business models and clauses in energy retrofitting contracts

- ✓ **In building energy retrofitting, bundling long payback measures with quick payback measures can make the combined rate of return more competitive and have a direct impact on property value.**

  Active solutions bring higher economic savings than passive actions and shorten the payback time. The combination of short payback (e.g. replacement of Heating, Ventilating and Air Conditioning (HVAC) equipment or lighting systems to more efficient) and long payback interventions (e.g. upgrade of façade thermal insulation) can compensate too long paybacks (especially in mild climates with low heating energy demand).

- ✓ **'Design + build' contracting system (where design and construction services are contracted by a single entity) can present cost- and time-saving benefits as it eases the coordination of the different subcontracts in large interventions with a wide variety of energy efficiency technologies.**

  Construction companies that have an in-house design capacity can simplify the construction process. In case of professional client/building owner, it is also recommendable that the client actively participates in the design phase. In general, there is a need for simplification of the relationship with subcontractors to optimize resources in large energy retrofitting projects.

- ✓ **In case active energy efficiency measures are installed (e.g. photovoltaics, central heating system) in multi-dwelling buildings, Design Build Operate (DBO) contracts present benefits in terms of process simplification for building owners and potential economic savings due to economies of scale.**

  Since the refurbishment process may be very complex for the condominium owners, a single company (e.g. an ESCo) that offers an integral service to the customers (design, funding request, works implementation, validation of the works' quality and operation of the solution) can facilitate and foster the replicability of the energy retrofitting of residential stock. In this way, the contractor's duties and responsibilities to the client do not end at final acceptance but continue through a defined operational term. Additionally, this company could help to reduce investment costs because it is able to access to benefits from economies of scale.

- ✓ **Include the evaluation of the professional experience of subcontractors in the procurement process to avoid low quality implementation.**

  In some cases, there is a lack of quality assurance through e.g. certification schemes and sometimes distrust in installers and products. Awareness and training campaigns aimed at contractors and installers in the subject of building energy efficiency can also be of help. Need *to include quality verifications on the tender process in order to ensure the quality of works from the contractor (e.g. thermal imaging, blower door test).*

- ✓ **Public-Private Partnerships (PPP): The participation in co-financing programmes for existing publicly promoted retrofitting projects for the residential sector can be an interesting path for private stakeholders to enter into the energy retrofitting business.**

  In one of the demonstrated cases, the ESCo partnered with the Public administration by participating in existing retrofitting programmes with the goal of reaching a higher energy efficiency for the retrofitted buildings through the co-financing approach.

- ✓ **The collaboration of Energy Savings Expert in structural refurbishment projects that are already planned is an opportunity to include energy efficiency measures that would otherwise be omitted.**

  This relationship gives the Energy Savings Expert (Energy Services Company or similar) the possibility to adapt the project and add energy efficient technologies in the structural refurbishment, as well as commit to guarantee a predefined energy savings target.

- ✓ **Economies of scale should be considered in the economic assessment of a new business model based on energy retrofitting.**

  The positive impact of the economies of scale should be assessed and might lead from e.g. the combination of energy and structural refurbishment or large-scale refurbishment (i.e. clustering several buildings in the same city area).

  - ✓ **In order to scale up energy retrofitting of buildings, there is a need of low interest rate financing options that may be coming from a financing entity. It is also important to achieve financing for the whole refurbishment cost, as the funding may be received once the works are finished (and for some of the owners it will be impossible to pay any upfront cost).**

  From a technical point of view, the refurbishment of whole buildings (instead of individual dwellings) is what makes more sense, while the financial entity may apply their bonds to specific individual dwellings.

Add revenue streams other than energy savings to break economic barriers

- ✓ **Consider the increased value of the property after retrofitting in the economic assessment of an energy efficiency project. This brings more favourable results compared to only quantifying the energy savings.**

  In order to overcome too long paybacks in energy retrofitting, externalities should be considered. Banks are progressively recognizing the proven lower probability of default in energy saving loans and the increased value of the assets after energy retrofitting.

- ✓ **It is possible in the future that potentially higher cost of energy affects the housing prices and energy efficiency becomes an important factor when choosing properties.**

  Nowadays, energy conservation of the residential sector is not stimulated through the price mechanism. The impact of energy certificates on housing prices can be considered rather irrelevant in today's housing market (common for many European countries). Nevertheless, assessing the decrease of the building's environmental impact (potential avoided emissions) would significantly contribute to make energy renovation a sustainable business model. The use of certificates to evaluate both the environmental and health impacts of buildings should become a tool to increase the value of the property. In fact, the "green value" generated by the energy *performance of buildings is progressively integrated in financial approaches as a result of rising regulations and energy prices (with more or less presence depending on the country).*

Work towards gaining social acceptance

- ✓ **Engagement campaigns aimed at private owners of multi-ownership residential buildings are a key tool to succeed in the replication of energy retrofitting projects in this sector.**

  Developing engagement campaigns in-house or sub-contracting a specialized company to perform them early in the process has proven to be helpful to get the required approval of all owners to start the works. Engagement campaigns help a multiple inhomogeneous group of decision-makers reaching an agreement.

- ✓ **Full renovation that requires tenants' evacuation may lead to less acceptance among the tenants unless well communicated. Tenants have to be kept very well informed about the planned phases of the project right from the beginning of the process.**

  Communication is crucial to foster tenants' acceptance in this type of interventions. Strong efforts on keeping tenants in retrofitted buildings fully informed – and involved – about the plans of the building owner (both public or private) are required. Give the tenants a chance to influence in areas where possible, e.g. colours of walls and other more esthetical features. It is important to highlight the raise of quality standard and indoor comfort of the apartments thanks to the retrofitting works.

- ✓ **Building end-users should be informed about the environmental benefits of energy efficiency solutions applied in buildings, and the importance of their behaviour.**

  Energy savings due to energy efficiency upgrade of buildings are coupled to the users' behaviour. The change of citizens' behaviour regarding the use of renovated buildings should also be targeted to guarantee a reduction of the energy consumption and raise energy efficiency awareness in our society.

- ✓ **Inform potential clients (building owners) about the impact that energy refurbishment has on indoor (thermal and noise) comfort.**

  Home-buying public is not always informed about the non-economic benefits of high energy performance buildings, i.e. increase of quality of life. This is significantly important in mild climates where the economic savings from an energy efficient intervention may not cover the respective initial investment (as real consumptions are generally low).

For heritage building retrofitting: work together with the Urban planning department of the Municipality from the design phase of the project

- ✓ **Private companies performing energy retrofitting of cultural or industrial heritage buildings should work together with the Urban planning department of the Municipality from the design phase of the project.**

  Before initiating any energy efficiency intervention in heritage buildings, it is essential to develop clearly articulated notions of their architectural and cultural values. Collaborating with the Urban planning department of the Municipality from the very beginning of the project will avoid potential time delays and several changes in project design.

Recommendations to local governments (Municipalities)

Act to reduce social barriers in the upscaling of private residential retrofitting

- ✓ **Information campaigns co-promoted by the Public administration generate more trust among private residential owners in front of fully privately promoted campaigns.**

  Public administration not only as a source of funding but also as a source of campaigns for citizens' awareness/engagement. Targeting the user behavioural change and raise of awareness is recommended to city municipalities.

- ✓ **In large-scale home renovation plans, involving the public sector (i.e. city municipalities) in a leadership role can help upscaling the intervention.**

  In large-scale home renovation plans, the role of the Administration can have a very positive impact as a trustful actor that encourages citizens to get on-board (through the generation of a confidence climate among citizens). The leadership role by the Administration can involve functions such as: leading the tender stage for the execution of the works, managing the grants, proposing the most appropriate financing for the owners, managing the payments and delays.

Use social/public housing retrofitting as a quick path to upscale residential retrofitting

- ✓ **Social and public housing owners in the Municipalities are key institutional actors 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.

- ✓ **It is crucial to include the evaluation of the efficiency and performance either in the energy retrofitting contracts or by in-house staff.**

  A clause in the contract can be applied through independent punctual measurements or through an ESCo contract with Measurement and Verification plans.

- ✓ **Avoid the "rebound effect" (the increase of energy consumption due to certain behavioural responses by tenants that offsets the benefits of the energy refurbishment) to effectively achieve energy savings through awareness campaigns.**

  Include genuine public participation; highlight and explain the added value 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.

- ✓ **Energy retrofitting is also a tool to reverse inequalities in vulnerable areas of the city through the improvement of the habitability and the access to basic services.**

  Furthermore, reducing tenants' energy bills is a way to secure the solvability of the formers, thus limiting the amount of unpaid rents in public housing.

Use retrofitted public heritage buildings as showcases: when social relevance prevails in front of economic feasibility

- ✓ **Apply adaptive reuse policies with high energy efficiency criteria to obtain new low-energy public facilities.**

  Used buildings remain preserved considerably better than unused. The re-use of old heritage buildings avoids new construction and saves the energy needed for construction of new buildings.

- ✓ **Avoid too many exceptions in the energy savings obligations for heritage building renovation. Enable the implementation of energy efficiency criteria and on-site renewable energy generation.**

  Making heritage buildings sustainable is just as important as preserving their history. There is undoubtedly scope to reduce energy use in the existing heritage building stock. However, heritage buildings are commonly excluded from the legislation intended to reduce energy use. Municipal regulations should enable the implementation of energy efficiency criteria and on-site renewable energy generation in heritage buildings, instead of restricting their technical feasibility. It is important to avoid too many exceptions in the energy savings obligations of building renovation.

Facilitate energy retrofitting of public commercial buildings operated by a private stakeholder

- ✓ **Adapt the concession contract conditions for private operators in public tertiary buildings to promote energy efficiency investments.**

  Implication of the Public Administration is critical in energy efficiency projects for public tertiary buildings that have private operators, since the benefits from retrofitting are not only for the building operator, but also for the building owner (the local Administration). The project design and feasibility strongly depends on concession contract timeframe, as the building operator needs to have enough time to recover the investment in improving the energy efficiency of the building.

Recommendations to regional and national governments

Quantify externalities in the development of National strategies to comply with European Union's building retrofitting goals and to size public subsidies/investments

- ✓ **The impacts in health and in job creation are to be considered as economic externalities from public subsidies/investments for energy efficiency measures.**

  The quantification of health benefits and job creation and the associated cost savings for the public healthcare and unemployment welfare systems, respectively, should be included in the development of National strategies to comply with EU's building retrofitting goals and to size the public subsidies/investments. Cost savings in healthcare can be of the same order as the savings in the energy bill for residential renovation.

- ✓ **Include non-economical KPIs (social benefits) in the assessment of the development of National strategies for the compliance with EU's building retrofitting goals.**

  District-scale energy renovation plans have several social benefits for citizens other than economic savings: increase of buildings' value, cultural preservation, production of attractive *neighbourhoods for youth, among others. Attention should be paid to avoid anti-displacement policies such as gentrification.*

- ✓ **Consider the potential new sources of tax revenues due to the improvements in energy efficiency of the National building stock.**

  Indirect taxation such as value-added tax (VAT) on construction and installation services provides tax revenues for every euro of public funds spent on National Refurbishment programmes. This should be included in the development of National strategies to comply with EU's building retrofitting goals and to size the public subsidies/investments.

Act as a source of subsidies to upscale energy retrofitting of the private residential sector to the district level

- ✓ **Subsidies from supra-municipal funds are needed to upscale energy retrofitting in the form of thermal envelope upgrade of the residential sector to the district level.**

  This has been mainly observed in the implementation of passive retrofitting actions aimed at reducing the heating consumption in mild climates, such as the Mediterranean one.

- ✓ **Existing subsidies for the residential sector should be better computed based on real demands (instead of theoretical demands) in mild climates.**

  It has been proven that heating demands for the residential buildings are sometimes overestimated in the calculation of energy retrofitting impact. Due to the absence of heating system use by dwellers, theoretical ratios do not represent the real energy consumption of most of the dwellings and, therefore, the impact of energy retrofitting works shows to be lower than estimated.

Adapt the law to pave the way for the implementation of neighbourhood-level energy retrofitting interventions

- ✓ **A legislation applied to horizontal ownership where major energy refurbishment interventions have to be approved by only one part of the owners (instead of all the owners) can contribute to ease the implementation of this kind of interventions.**

  One of the main social barriers in residential building retrofitting is the decision-making process, which can be long and complex especially in cases of multi-owner houses (condominiums). Adapting the regulation to facilitate the required agreements to start the intervention will help the upscale of energy retrofitting in cities. Other possibilities are targeting buildings with a unique ownership.

- ✓ **Adapt legislation to reduce the risk of investments in energy retrofitting projects for multi-owner residential buildings.**

  An adapted legislation could ensure recovering money in the event of non-payment through for instance tax collection by the Public Administration (e.g. in Spain there is currently no guarantee to recover the money in case of non-payment). This would generate confidence and facilitate getting soft loans at low interest rate.

- ✓ **Apply a favourable VAT value for energy retrofitting actions even in cases that the grant applicant is not the beneficiary end-user.**

  The VAT value depends on the actor who asks for the grant. For example, the Spanish legislation applies a special reduced VAT for retrofitting actions but only in case it is the beneficiary end-user who contracts the retrofitting works. In other cases, the common higher VAT value is applied. This rule is a barrier for the ESCo companies and the public administration that want *to invest in energy retrofitting projects in the residential sector. Therefore, this hinders the viability of having a single entity managing the whole refurbishment process which could simplify the process for the end-users.*

Recommendations to the European Commission

Act as a source of financial incentives and grants to upscale energy retrofitting of the residential and tertiary sectors to the district level

- ✓ **Access to financing mechanisms is crucial for the success of the renovation of the national stock of residential and commercial buildings, both public and private.**

  Financing mechanisms, both government and privately driven, are the key tools to replicate and upscale energy retrofitting of buildings. Given the often large upfront capital investment required and the lack of awareness and knowledge about the benefits of efficiency upgrades, public funding to support awareness and education, including financial literacy, can help move some investment decisions forward.

2.2 Measures on Home and Building Energy Management Systems

Recommendations to private companies

HEMS: Put user acceptance and engagement in the focus of action

- ✓ **Study the interests and skills of potential users and adapt the technology to effectively achieve a behavioural change.**

  Changing people's behaviour takes long time. Customize the tools and performances for the end users by adapting the functionalities and interfaces to different target groups. Add features that make people interested in energy usage to prepare and encourage them to be part of the "eco-trend".

- ✓ **Financial advantages of HEMS for the consumers are still quite low: offer other functionalities (e.g. competitive incentives).**

  Dynamic electricity pricing programs are only common in a few European Member States and, in any case, the margin for economic savings due to the use of HEMS is not very significant for dwellers. Other motivations must be sought. Focus on gamification and similar tools with the objective to keep users engaged and involved.

- ✓ **Target tech-savvy and environmentally-friendly people as well as "influencers" in the first roll-out of Smart Home technologies.**

  Technology alone is not enough to change the way people consume energy, but it provides a method for using energy in a deliberate and conscious way. Targeting clients with technological knowledge and people with the ability to reach a wide audience can be more effective for the first product scalability exercise.

- ✓ **Make partnerships with the Municipality or real estate agencies to deploy educative processes with open workshops/campaigns to foster the promotion of HEMS.**

Planning communication campaigns with tenants well on time to inform about the advantages of HEMS technology is strongly recommended. Face-to-face meetings with residents are eye-opening. As a complement to financing, awareness and pedagogy are crucial. Make an accompaniment to the citizen throughout the process, explain the benefits (not only the reduction of energy consumption, but the increased comfort).

Data analytics is the core business of the technology/solution provider

- ✓ **Prioritize data protection, privacy & security developments to comply with GDPR.**

  Being GDPR an obligation, it is crucial that all elements and processes (software, hardware, contractual process) in the design and implementation phases for HEMS and BEMS roll-out are compliant with the regulation. In terms of data collection, a contract must be drawn up which gives the user a clear and comprehensible understanding of which data are collected and for which purpose. In GrowSmarter, the GDPR became an obstacle while sharing data among parties involved in the project, given the confidentiality agreements the partners had with the tenants of the buildings. The implemented platforms had to adapt data visualization through a process of aggregation and/or anonymization of users.

- ✓ **Data management and data analytics are considered critical and very important for the deployment of Home and Building Energy Management Systems.**

  Managing large quantity of data, extracting information and providing value to the client/company is highly dependent on data analytics and, consequently, the solution provider has to manage it as the core business from an early stage.

Put significant resources to plan data communication

- ✓ **Pursue the use of open IoT platforms that can receive different kinds of signals for an easy and cost-effective data communication, storage and post-processing.**

  The market for automatic data collection is currently still quite fragmented. The use of standardized and open protocols and platforms allows for the deployment of a plug-and-play system able to facilitate the subsequent operation.

- ✓ **For Smart home technology providers developing an own IoT platform, seek an open platform capable of connecting to everything (mobiles, clouds, etc.).**

  An open IoT platform able to connect with other applications and services (not only related to energy) may increase the sustainability of the business model.

- ✓ **In case of sub-contracting the development of hardware-software systems for energy monitoring platforms, define all the details on data integration prior to implementation in order to avoid non-expected additional costs.**

  Data communication, storage, and post-processing are often challenging due to large amounts of data. Therefore, significant resources must be put in these stages.

Measuring electricity consumption at dwelling level or building level?

- ✓ **Including real-time or nearly-real-time visualization of electrical consumption at dwelling level in Smart Home systems increases the functionalities of these tools.**

  The collection of high-frequency electricity consumption data by the HEMS allows for the introduction of attractive functionalities which are able to increase the energy efficiency of the residents' behaviour. Examples are the application of incentives for residents in the form of cost-reflective prices (varying prices based on the time of consumption), and the possibility to apply demand-response services. Presently, in order to enable such functionalities, HEMS providers *need to install and pay for specific appropriate hardware, which hinders the economic feasibility of the solution and its upscale.*

- ✓ **For HEMS that do not aim at "real-time applications", making use of the data from the present official smart meters is one way to reduce hardware costs.**

  At the present stage of the official smart metering deployment in the EU Member States, functionalities based on real-time measurements (seconds) are not compatible with the official smart meters. Therefore, mainly HEMS actions/performances based on data with a few-minutes or 1-day delay are compatible.

- ✓ **Installing energy monitoring equipment at building level instead of dwelling level may be one solution in case of encountering data privacy or economic barriers in the residential sector.**

  The functionalities provided by the HEMS tool vary in case of installing metering equipment at building level or dwelling level. Notwithstanding, for cases where data privacy and/or economic barriers appear, estimations of the individual energy consumption can be done to provide tenants with single-dwelling data. Eventually, HEMS and building-level energy surveillance platforms (BEMS) can be combined in multi-dwelling buildings.

Look for synergies to integrate HEMS and BEMS or building performance evaluation platforms in different business models

- ✓ **As solution provider, better define the benefits and target groups of HEMS and BEMS to make them more understandable.**

  The public and potential clients should better understand the differences between HEMS and BEMS. HEMS platforms are more aimed at user engagement, since residents (as the target group) use the visualization platform and learns about the energetic behaviour and consequent environmental impact of their dwelling. In contrast, BEMS tools are mainly aimed at the optimization of a building energy management activity (in terms of finding the optimal parameters for the control of energy-consuming equipment). This functionality allows to facilitate O&M works to facility managers.

- ✓ **HEMS: it can be interesting to partner with construction companies to provide home automation services.**

  Partnerships with the retrofitting construction sector are an option to explore for replication and upscaling. This brings the possibility of transferring technical innovations and advances from research stage to an application & wide use stage. In this case, a new actor would enter in the retrofitting construction project, i.e. the ESCo. The growing popularity of time of use tariffs and smart, IoT connected devices offer opportunities for Energy Service Companies to provide energy management and cost savings for adaptable users, while meeting energy and CO2 reduction targets.

- ✓ **BEMS and building energy performance evaluation platforms: an option for solution providers is to look for synergies and include the platform as a necessary part of self-financed solutions of active energy efficiency measures (change the model from B2C to B2B).**

  As it is sometimes difficult to attribute savings to a monitoring platform, BEMS and building energy performance evaluation platforms are normally not intended to be self-financed as a standalone. Energy Performance Contracts (EPCs) can support the upscaling of the installation of these platforms, which can be used as the tools to measure savings. Building Energy Management Systems can be the tool for building owners or subcontractors to follow up and *evaluate the energy efficiency works implemented, which in turn determinates the amount to be paid or rewarded, respectively (mainly for active energy solutions).*

- ✓ **If National legislation is favourable, include demand-response services in HEMS and/or BEMS development.**

With no demand-response services, it is sometimes difficult to justify the investment and monetize the value/savings. Also, more expensive real-time electricity meters could be justified in case of demand-response business case (according to cost benefit analysis).

Recommendations to local, national and European governments

Promote demand-response services through National regulation

- ✓ **A favourable regulation on demand-response and microgeneration services increases the associated economic benefits from the use of energy monitoring and visualization platforms for the end users. This in turn boosts the scalability potential of smart monitoring services.**

In general, regulation is slower than technology development and, consequently, it creates a mismatch between the business case and the technology stage. In this case, the mismatch is preventing the deployment of the best technologies related to HEMS. In fact, the monetization of the added value of HEMS would be easily justified by the participation in the demand-response electricity market. Time of Use tariffs allow engaged and empowered users to gain substantial cost savings over fixed rate energy tariffs by intelligently shifting their consumption to advantageous times.

Create or reinforce easy standards for data communication protocols

- ✓ **The consolidation of standard communication protocols would significantly facilitate the technical feasibility of building energy monitoring and management.**

IT communication among all smart equipment is feasible but resource-intensive. There is no unique normalized standard communication protocol, making the development of communication challenging. The consolidation of standards for communication protocols is necessary by defining a unique standard or delimiting those that have proven as efficient.

Leverage access to data from smart metering technology to support energy efficiency at the individual household level

- ✓ **A non-discriminatory access to data measured by the official smart-metering electricity and gas systems to the HEMS solution provider would avoid the duplication of devices for the detailed monitoring of household energy consumption at dwelling level.**

The upscaling of HEMS solutions is dependent on the reduction of metering equipment costs at individual household level. The EU Energy Efficiency Directive establishes the obligation of EU Member States to ensure that the "objectives of energy efficiency and benefits for final household consumers are fully taken into account when establishing the minimum functionalities of the meters and the obligations imposed on market participants", as well as "If final customers request it, metering data on their electricity input and off-take must be made available to them or to a third party acting on behalf of the final customer (e.g. an energy services company or energy aggregator) in an easily understandable format that they can use to compare deals on a like-for-like basis". However, many EU Member States deploying electricity smart meters still need to legally establish or otherwise ensure that these obligations are complied.

2.3 Measures on Building-integrated local energy generation and Smart control

Recommendations to private companies

Use smart control to find possibilities for power equalization among different types of buildings

✓ **The installation of smart energy management software in different types of buildings (residential and tertiary) allows identifying how the electrical and thermal power is used over time and looking for opportunities to develop local Smart local energy communities in the near future.**

Buildings of different uses, e.g. residential and commercial, could have mutually beneficial demand profiles and could therefore be better managed in a "microgrid" setting. This does encourage the development of district-level controllers to optimally manage the energy flows of energy consumption and generation in buildings. Clusters of buildings also have more chance to collectively participate in grid demand-response events.

Partner with equipment manufacturers to facilitate external and smart control

✓ **Controlling the devices as planned in the energy management system definition may be challenging.**

Most of the manufacturers do not expect their devices to be part of such a complex energy management system. Intense discussions are required with the manufacturers on how their devices can be externally controlled. This should be accounted for replication purposes.

Define a database maintenance procedure

✓ **For solution providers that own the data generated by local energy generation systems, it is recommended to put significant resources for database maintenance.**

The required accurate monitoring of smartly controlled distributed energy resources (DER) leads to a collection of very large amounts of data. The required database maintenance and treatment should be considered in the business plan definition.

If necessary, initiate discussions with expert lawyers to identify critical points to comply with legislation regarding the interaction with the grid operator

✓ **Due to the relatively new scenario that local energy generation in buildings presents in some countries when scaled up to neighbourhood or district level, the legislation regarding the measurement of energy flows may still be uncertain.**

Discussions with expert lawyers to identify critical points to comply with the new legislation in terms of the interaction between the buildings with microgeneration and the grid operator are recommended. The outcome of these discussions will be very useful for replication.

Recommendations to local, national and European governments

Harmonize regulatory frameworks to create local energy communities

✓ **Provide a legislation framework that brings legal security to foster the creation of local energy communities.**

Based on the country, the current lack of flexibility to trade with energy - and the sometimes unpredictable change of laws - build a state of no legal security for industrial partners to scale up distributed renewable electricity generation at community level. This claims for a political change. The regulatory framework in Europe for demand-response is progressing, but further regulatory improvements are needed. In order for building-integrated local energy generation to be self-financing, different models of local energy ownership are still to be tested. A regulation–free zone to prove hypotheses for smart local renewable energy generation in the urban environment would also contribute.

- ✓ **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 EU that allows the scalability of products and services associated to the use of detailed electricity consumption data from smart meters. This depends on the regulatory frame and the available IT infrastructure in each country. In Spain, although the installation of smart meters is mandatory for small consumers, the regulatory and normative framework is to some extent unconnected to the promotion and deployment of digital smart metering, as the use of smart meter data from third parties is not well defined. In Sweden, a massive digital meter deployment was done well before it was in other European countries, and data can be accessed by third parties. However, a significant amount of the installed digital meters has the ability to measure with monthly precision only. Sweden is currently considering a second wave smart meter roll-out in order to get a new metering infrastructure able to provide more advanced functionalities. In Germany, only a very small number of residential households have certified smart metering in their homes.

- ✓ **Provide a common and standard technical and safety regulation for batteries to be used in buildings.**

Product compliance with well-established international standards validate that the safety protection is adapted to the intended use at building level.

Promote economic and regulatory incentives for the acquisition of photovoltaic modules and batteries

- ✓ **Facilitate the local urban planning regulation (related to façades and roofs) to make the installation of PVs in buildings easier and simpler.**

Urban planning regulation should be an instrument to promote new PV installations. New ordinances by Municipalities that promote the use of rooftops for renewable energy generation have demonstrated to be of good help.

- ✓ **Establish a favourable regulatory framework for the promotion of self-consumption of renewable electricity in buildings through photovoltaic installations.**

It is necessary to establish a stable regulatory framework which would empower renewables self-consumers to generate, consume, store, and sell electricity without facing disproportionate burdens and tolls. This should apply to both individual renewables self-consumers and jointly acting renewables self-consumers (i.e. various consumers that own the same energy generation unit and are able to sell the surplus electricity to the grid with remuneration).

- ✓ **The incentives lead by Public Institutions to help medium/small customers in the initial investment for the acquisition of batteries can foster the creation of local energy communities.**

Early adopters of renewable energy technology are keen to apply for incentives and buy batteries which will broaden the applications of local energy generation in their buildings.

Table 3: Overview of key regulations affecting the implementation of GrowSmarter measures in WP2

Scope of Smart Solution	Measure	City	Example(s) – presence or absence of key rule or regulation?	Scope of regulation	Positive or negative impact	Recommendations / Solutions
Energy retrofitting of the existing building stock	1.1	BCN STO	Presence of Plans for the Protection for Architectural Heritage Buildings	National & Municipal	Negative. Difficult to obtain the required energy retrofitting permits (for thermal envelope upgrade and/or PVs installation) due to aesthetics requirements by the Urban Planning department	Be aware of all the constraints for listed buildings and adapt the project design for the implementation of energy efficiency measures and photovoltaics installation
Home and Building Energy Management Systems	3.1	All	EU General Data Protection Regulation (GDPR)	EU	Neutral (mandatory). The needed tenant consent requires early implementation in the project	Consider the time frame required to get tenant consent in your project schedule. Use engagement campaigns
	3.1	BCN	Absence of regulation that establishes the technical and quality conditions in which the transfer of data from official smart meters to a third party can be carried out in a systematic, simple, scalable and real-time way (after consumer permission)	National	Negative. Consumers in Spain are theoretically allowed to give access to data collected by digital meters to third parties. One has to currently use an FTP to access the data, as it is done by the consumer's retailer. However, the process is still too manual and the assignment of permits is not well established/regulated. The energy supplier is not obliged to send smart meter data in real time but only every 4 days. This impacts on the quality of information that can be shown to the customer	Install non-official digital sub-metering for high-frequency electricity consumption measurements

	3.1	COL	Presence of regulation that prohibits the installation of an additional meter on the customer side of the utility meter to obtain data about dwelling end use	National	Negative. There are no digital smart meters in the dwellings that participated in this measure, thus the only path to collect consumption data was the installation of sub-metering	The functionalities of the Smart home system were reformulated so the platform provides other services than energy consumption visualization
Building-integrated local energy generation and Smart control	4.1	COL	Absence of regulations and/or law interpretation for new concepts of local distributed energy generation systems at community level and their interaction with the grid	National	Negative. Innovative systems need new regulations	Deeply study all the requirements of your innovative system together with expert lawyers if required, and look for collaboration with policy-makers
	4.2	BCN	Presence of non-favourable legislation for energy self-consumption. No legal security due to unpredictable law changes	National	Negative. Difficult to reach economic feasibility of self-consumption installations	A change of Government lead to the introduction of more favourable rules to regulate self-consumption and to the cancellation of tolls (from April 2019 onwards)
	4.2	BCN	Presence of regulations that oblige new and retrofitted buildings to put minimum PV power installed	National & Municipal	Positive	
	6.3	BCN	Presence of favourable City regulation and permits that enable the use and/or expansion of the existing DHC infrastructure	Municipal	Positive	

3 EXPLOITATION OF RESULTS

As presented above, most of the measures implemented in GrowSmarter have potential for immediate replication and upscaling. Some solutions are already replicated in follower cities – for example, the city of Cork has established a GHG emissions reduction goal that involves a medium-depth retrofitting project applied to all social houses by 2040. This is funding-dependent and Cork City Council is taking a phased approach to this target. For partners as well as Municipalities, some results are of extra interest to exploit and develop further, including:

- In cities with existing district heating network infrastructure in place, the **feed-in of waste heat into District Heating networks** has shown a high potential for replicability. In Stockholm, the new business model of Open District Heating tested by Stockholm Exergi (partially owned by the Municipality) has shown promising results and will probably be up scaled in the city. For the case in Stockholm with Open District Heating, the core of the model is based on heat recovery at the location where the excess heat source is located and utilization through the existing vast district heating infrastructure. The coming development of the model in Stockholm is to establish prepared clusters / parks favourable for both data centre operation and waste heat recovery as source for the district heating supply. By this establishment, the data centre business becomes more energy efficient and financially favourable since the waste heat has a value. In addition, it is possible that in the future the administrative procurement processes for specific buildings (e.g. data centres) implement specific requirements for taking care of the excess heat generated by the servers. This can enhance the incentive and realization of the recovering of excess heat even more.

- The old districts of Barcelona have developed Plans for the protection of the architectural heritage of **industrial buildings** with the aim of preserving them and enabling new uses for abandoned buildings. In these plans, the District administration presents an inventory that allows establishing the priorities of action according to the deterioration of the existing building stock. Recently, industrial heritage buildings of Barcelona (e.g. libraries, civic centres, universities, housing, or corporate buildings) have been retroffitted to incorporate different uses (both public and private). In GrowSmarter, the participation of Library Les Corts and Ca l'Alier are examples of the application of such policies including **high energy efficiency criteria**. The funding model behind the retrofitting investment by the Municipality has been different for the two buildings (completely public vs. Public-Private partnership), which provides interesting results for further developments. In the specific case of the public-private facility Ca l'Alier, the low-energy building is expected to be used as a **showcase for good practices in energy retrofitting**, as the building was reborn into an Urban innovation centre that aims to be a reference for Smart city solutions. This is done by mainly two channels: (1) "City Workshops", aimed to be a space for the exchange of knowledge between cities, organizations and institutions that share the same challenges as Barcelona, and (2) the iLab, a platform where the ecosystem of urban innovation in Barcelona is revitalised, a kind of test laboratory where new products and services aimed at improving the quality of life of citizens are tested. Some examples of replication are the on-going building retrofitting actions of the industrial buildings L'Escocesa and Can Batlló, carried out by the Municipality.

- In Barcelona metropolitan region, current figures show that 50% of the publicly-owned existing libraries are between 10 and 20 years old while 25% of libraries are over 20 years old. In this context, the public institution 'Biblioteques de Barcelona' is consequently putting the focus on the **retrofitting of existing libraries** to improve and expand them. In terms of energy efficiency upgrade, the retrofitting action in Library Les Corts will be used as an inspiring example of good impact practice.

- In Stockholm, the **deep retrofitting action** implemented in a group of **residential buildings** by Skanska reached the target of 60% energy use reduction. To reach this ambitious goal, a concept with several new and existing products was applied in the pilot project. Results are already being exploited to copy parts or the whole concept to retrofit similar residential buildings, as they prove a functioning energy saving concept with a documented good energy performance. For replication in large renovation projects for public housing, targeting slightly lower energy savings is foreseen to shorten payback periods and make the project more economically viable.

- In Cologne, the climate protection coordination office developed an action program in April 2019, KölnKlimaAktiv 2022, including many measures that further develop outcomes of GrowSmarter on a city-wide scale. The city will develop and make mandatory consideration of a **guideline for climate protection for retrofitting** and new construction projects. In addition to promote the reduction of heat requirements, an **electricity saving initiative** for households and tertiary buildings has been created. To this end, a comprehensive campaign will be launched. This includes a specific Internet presence with information on advisory services, checks, energy-saving tips and campaigns such as a premium model to save electricity. Information and advisory services for citizens are also planned for the installation of **photovoltaics on rooftop**, intended to help with knowledge transfer. Finally, within the topic of urban development/urban planning, the aim of the City of Cologne is to plan climate-friendly energy supply solutions at an early stage within the framework of development projects.

- The **ESCo business model** through a private/private contract tested by the new business line of Naturgy will continue exploring opportunities to participate in **commercial or tertiary building refurbishment projects** in order to implement energy retrofitting actions. Private commercial buildings have shown to be very good candidates for the replicability of energy retrofitting by an ESCo as this type of buildings normally invest in building retrofitting works more often than other type of buildings, e.g. compared to private residential sector. The ESCo provides a turnkey solution and performs the investment in exchange for an annual fee based on energy savings. In this type of actions, the ESCo can also act as co-promoter, since the works can be executed simultaneously with other refurbishment works managed by the building owner or operator, lowering in many cases the implementation costs for both stakeholders.

- The **Smart Home system** developed by Fortum SmartLiving (a start-up within Fortum Markets) installed in the dwellings of one of the retrofitted buildings in Stockholm will be used after the project for further development and validation with the end-user. During the course of GrowSmarter, the system was upgraded to a complete new one due to GDPR new regulation. The project partner is already exploiting the results from the solution implemented in Stockholm in order to upgrade it so it can be commercialized with a new user interface adapted to different types of users. One of the greatest findings that has strengthened during the project is the need to make tenants involved over time (transferring the responsibility and power to make behavioural change a reality). In order to go commercial, the next step is to set up contracts for hardware sales, software sales and service agreements. Smart Home systems belong to a market that is constantly moving at high pace, requiring a high capacity to adapt, change, develop and sell at the same time.

4 CONCLUSIONS

The demonstration of a variety of energy efficient solutions aiming at lowering the environmental impact of district energy systems (by putting the focus on the existing building stock) has led to several learnings and recommendations for the future.

It is well known that a modernization of the existing building stock in European countries is required. Indeed, the European construction sector faces a major challenge to reduce the emissions of buildings by almost 90% by 2050. This demands new innovative solutions and services to be rapidly implemented in the sector's market. Based on this, it is expected that National building retrofitting strategies to come around Europe will not only aim to address the renovation of building structure but also the improvement of energy performance in order to advance to *Low Energy Districts*. In GrowSmarter, several demonstrative retrofitting projects (having an effect on an overall building surface of more than 120,000 m2) spread in the three European cities serve as prototypes for application, evaluation and monitoring of a set of energy retrofitting actions including both passive and active technologies. Undertaking the energy retrofit of a building has proven to bring both tangible and intangible benefits to the owner, the tenants/end-users, and society. Some of those benefits are: saving energy, money and emissions; increasing property value; creating jobs in the building sector; and improving the building's indoor environment quality (and the related economic savings for the healthcare system).

Innovative technologies to retrofit buildings are out there

The technology for **building energy retrofitting** is generally well established. However, there is still a lack of quality assurance (through e.g. certification schemes) and sometimes distrust in installers. Awareness and training campaigns aimed at contractors and installers in the subject of building energy efficiency are recommended by the three Lighthouse cities. As stipulated in some of the GrowSmarter demonstrators, it is recommended to include quality verifications on the tender process in order to ensure the quality of works by the contractor (e.g. with thermal imaging, blower door test). The project has demonstrated that an energy saving of 60% after refurbishment is possible, if a sufficient number of measures are implemented. This goal has been met in one set of residential buildings retrofitted in Stockholm, where several means of energy savings have been combined. In other buildings, only selected measures have been implemented and high energy savings cannot be expected. In these cases, the results are highly interesting and relevant as well, because the effect of only one or few measures can be evaluated more in detail.

The **climate is naturally determining** when considering the implementation of energy saving measures in a building, and this has been observed in GrowSmarter with commonly higher final energy savings in the cities with colder climates.

- In Stockholm, the ambitious achievement of an overall annual 64% reduction of the purchased final energy by the group of 6 buildings in the residential neighbourhood of Valla torg has been achieved. This translates to a reduction of 70% of the carbon dioxide emitted by this group of buildings.
- In Cologne, the large retrofitting project implemented in Stegerwaldsiedlung has reduced the total final energy purchased by the neighbourhood by 37% on an annual basis, meaning a 57% of CO_2 emission savings.

- In the milder climate of Barcelona, a total reduction of 30% of the annually purchased final energy has been obtained as the overall figure when adding up the impact in the 5 retrofitting projects that included extensive building thermal envelope upgrade (both residential and commercial buildings). The associated overall CO2 emission savings for this group of buildings in Barcelona has been close to 28% on an annual basis. In the Mediterranean city, the impact of retrofitting interventions in the residential buildings' energy consumption has shown to be lower compared to the impact in commercial buildings (which normally have a much higher energy demand).

In terms of absolute figures, it is worth mentioning that the retrofitting actions have avoided the emission of 741 tons of CO2 on an annual basis in Cologne, 396 tons of CO2 in Barcelona (accounting for the retrofitting projects that included building thermal envelope upgrade), and 251 tons of CO2 in the 6 buildings in Valla torg, Stockholm. When assessing the results per unit of retrofitted surface (conditioned floor area), Cologne presents an annual reduction of 21 kg CO2 per square meter, Barcelona presents a reduction of 13 kg CO2 per square meter, and Stockholm shows 8 kg CO2 per square meter.

- In Cologne, the switch from gas supply to district heating combined with PV and heat pumps for the new heating systems in the 16 buildings significantly affected the carbon footprint of the retrofitting intervention, since the CO2 emission factor of the district heating system is 3 times lower than the factor for gas consumption in the city.
- In Barcelona, the carbon footprint of buildings is quite high in general compared to the footprint in Stockholm. Therefore, a lower proportion of purchased energy savings in Barcelona has led in any case to a quite higher reduction of CO2 emissions in specific values.
- In Stockholm, district heating and electricity are produced mainly without using fossil fuels, therefore the possible saving of CO2 emissions is quite low from the start.

It should however be considered that there may be other factors than purely technical which may prohibit high energy savings to be reached. In the project, technical problems with energy retrofitting mainly arose for the compliance with **heritage preservation regulation**, which claimed an adaptation of the original designs (e.g. upgrade of external façade thermal envelope) or the dimensions of local energy generation units (mainly Photovoltaics). Nevertheless, making heritage buildings sustainable is just as important as preserving their history, and there is undoubtedly scope to reduce energy use in the existing European heritage building stock. This brings up the need for development of technological solutions which do not influence the visual appearance of buildings. Nonetheless, heritage buildings are commonly excluded from the legislation intended to reduce energy use. It is recommended that Municipal regulations should enable the implementation of energy efficiency criteria and on-site renewable energy generation in heritage buildings, instead of restricting their technical feasibility.

Going beyond traditional business models

In order to scale up energy retrofitting of buildings to district level, there is a need for low interest rate **financing options**. Both the economies of scale and the possible synergies between structural and energy refurbishment improve the economic feasibility of projects for building energy efficiency upgrade. Nevertheless, the uptake of **non-traditional business models** (such as innovative energy service contracts) in the retrofit sector is highly recommended. Traditional retrofitting contracts have for long been equal to no-guaranteed energy savings contracts. In contrast, other types of business models are able to bring the expertise in energy efficiency and the follow-up required to guarantee real energy savings.

ESCo's have so far not been very common in the residential sector because the occupant behaviour is in fact hardly controllable and brings difficulty to guarantee on energy/cost savings. In this line, it has been observed that in mild climates bundling long payback measures (e.g. thermal envelope upgrade) with quick payback measures (e.g. HVAC equipment replacement) make the combined rate of return more competitive. In GrowSmarter, the participation of private stakeholders as the energy experts in co-financing programmes for building energy retrofitting was successfully tested. Both Public-Private Partnerships (PPP) and private-private agreements were used to insert energy efficiency solutions in structural refurbishment projects that were already planned (both for tertiary and residential buildings). Also, the **landlord-tenant split incentive issue** was identified for both tertiary and residential buildings as a barrier that hinders the uptake of energy efficiency investments. Possible solutions are public concessions that consider energy efficiency investments, and the inclusion of the increased value of the property in the economic assessment of an energy efficiency investment for private owners.

Involvement of building users and social relevance

The energy performance is obviously not only dependent on the technical solutions implemented in the building, the **occupancy use** of the building does have an additional impact on the achieved energy performance. In some cases, the measured savings may be less than expected beforehand. The causes may be problems with the quality of the refurbishment or the components used, but also that the tenants living in, or using, the buildings do not behave as expected. The "rebound effect" (the increase of energy consumption due to certain behavioural responses by tenants that offsets the benefits of the energy refurbishment) should be tackled to effectively achieve energy savings. It is therefore advisable to make an accompaniment throughout all the process and educate on good practices and the importance of the impact that user behaviour has on building performance.

In terms of replicability, significant efforts towards gaining **social acceptance** and energy efficiency awareness among building users/residents are required to make the upscale of energy retrofitting projects a reality. Building owners should be better informed about the environmental benefits of the energy efficiency solutions to be applied in the building. Mainly in multi-owner buildings, developing engagement campaigns in-house or sub-contracting a specialized company to perform them early in the process has proven to be helpful to get the required approval of all the owners to start the works.

In some cases, social relevance shows to prevail in front of economic feasibility. In GrowSmarter, public heritage buildings were fully renovated with high energy efficiency criteria. Using municipal buildings as showcases for low-energy building design is seen as a useful tool to encourage private actors to undertake similar investments.

Technology that makes buildings talk

The impact that **user behavioural change** and **building energy management** has on building energy demand was evaluated in GrowSmarter through the roll-out of household energy visualization platforms (HEMS) in the three Lighthouse cities. Nowadays, the financial advantages of these tools for consumers are still quite low. Dynamic electricity pricing programs are only common in a few European Member States and, in any case, the margin for economic savings has proven not very significant with the current tariffs and HEMS functionalities. Therefore, other motivations must be sought. Changing people's behaviour takes long time. Solution providers need to study the interests and skills of potential users and adapt the technology to effectively achieve a behavioural change. Functionalities such as competitive incentives and gamification tools have proven to help on keeping users engaged and involved to prepare and encourage them to be part of the “eco-trend”. In terms of economic feasibility, making use of the data collected by **official smart meters** is seen as a promising option to reduce hardware costs and increase replication potential. In accordance with the EU Energy Efficiency Directive, “new-generation smart meters should be able to directly supply measurements to the final customer through the usage of different display devices, with the goal of enabling real-time services in the domains of energy awareness, home automation, load shifting, and demand response”. Based on the respective national legislation, this may bring a new possibility in some countries in which official smart meters will be able to send the metering data to customer devices in nearly-real-time conditions. As a consequence, time of use or real time energy pricing tariffs are likely to become more available and popular among consumers. However, we cannot expect the average consumer to constantly monitor or understand energy price fluctuations and manually reset many of their devices. This leads to opportunities for the upscaling of smart home solutions, based on an expected increasing market demand of home monitoring and control services in the coming years. Demand-response and flexibility services will also have a direct impact on the replication/upscaling potential of HEMS. When looking at energy management and visualization services at building level (normally aimed at operation and maintenance staff), BEMS solutions have proven to bring less data privacy concerns than HEMS. In addition, BEMS are also able to play an important role in the participation in demand-response and flexibility services in the coming years. Nevertheless, improved and adequate regulatory frameworks for the energy management industry (in terms of standards and protocols) are required to enhance the replication potential.

Local renewable energy technologies and smart management

The **decentralization of electricity generation** allows to take advantage of the local renewable energy sources in the urban environment. To achieve this, one of the main paths is through the use of the building stock to locate small/medium energy generation units. Towards this goal, *Low Energy Districts* in GrowSmarter has demonstrated the integration of local renewable energy generation in buildings in the three Lighthouse cities. In fact, the retrofitted buildings with the highest energy savings in the project have included the use of renewable energy sources as part of the solution. In GrowSmarter, local energy sources have been mainly integrated through the use of solar energy collected by **solar photovoltaic** (PV) panels and energy from the ambient collected by the use of **heat pumps**. In several demonstrators, Smart solutions have involved the installation of PV modules coupled to **batteries** controlled by smart energy management systems. In some cases of Barcelona and Stockholm, the current local urban planning regulation for PV installations in buildings decreased the proposed scope of the measure due to aesthetics requirements. In general, it is observed that current National legislations should provide more drivers/incentives to encourage the use of decentralized solar energy initiatives in urban planning policies. In turn, Municipalities are also able to have an orchestrating, but not restricting, role to promote the integration of local renewable energy systems with the urban building stock.

The experience with the installation of advanced **smart management of energy generation** has proven some technical challenges, further work is required to reach a state of technology that allows a smooth external control of commercial equipment. Nonetheless, the smart control of energy generation and storage in single buildings has proven as technically feasible with the different tested management systems in GrowSmarter. This is the first step towards the development of district-level control systems that will allow the origination of **'local energy communities'**. Managing energy resources at a wider district level rather than building level can provide greater energy and cost savings to all users. Distributed smart storage can bring energy flexibility in a community by reducing average peak load and increasing PV self-consumption. Furthermore, buildings of different uses, e.g. residential and commercial, present mutually beneficial demand profiles (complementary) and could therefore be better managed in a "local energy community" setting. However, in general the current regulation in the EU Member States still presents lack of flexibility to trade with energy. A clear and harmonized regulation according to the current state of technology is required in order to fully deploy (at commercial level) the generation of districts made up of 'prosumers' (buildings that both produce and consume energy) under advanced smart control strategies.

The integration of local thermal energy sources in the urban building stock has also been demonstrated in GrowSmarter through the connection of buildings to existing **District Heating** (DH) and **District Heating and Cooling** (DHC) networks. DH and DHC systems are gaining popularity partly due to their improved efficiencies in front of individual systems and to the possibilities they offer for waste heat integration. It is in fact the capability **for waste heat integration** in networks what that has been explored in the project as a promising opportunity to recover local energy sources otherwise wasted. In this line, a city with a solid DH infrastructure such as Stockholm has demonstrated an innovative business model that recovers waste heat from medium excess heat suppliers such as a supermarket and a data centre. Focusing on the data centre segment (a growing worldwide business where the cooling demand is the same throughout the year) has been found as a promising replication area for cities where the District Heating infrastructure is in place. Going back to the topic of building energy retrofitting, the connection of a building to the local DH or DHC network has shown to contribute to the upgrade of **building energy rating** and (depending on the energy source type of the thermal network) to achieve nearly-Zero Energy Building status.

GrowSmarter as an inspiration for Low energy districts development

We have gone past the point where going 'green' is an option. It has now become an absolute necessity. We hope, through the experiences of GrowSmarter, to inspire all stakeholders in the industry and the administration to make a significant effort to improve the performance of our buildings in every sense and ensure a better built environment for our future cities. Building-integrated local renewable energy generation and waste heat recovery are proven technologies, while smart energy management systems play a crucial role in the equation to reduce electricity consumption and in the transition towards 'local energy communities'. The demonstrated Smart solutions in the GrowSmarter project have demonstrated that citizens should be put at the centre of all the action. Communication, information and user engagement campaigns are crucial to build trust. Educating citizens is nearly as important as guaranteeing the correct implementation and operation of the implemented energy efficiency measures. We need the acceptance and awareness of building users to make *Low Energy Districts* the preferred path in the upcoming urban development of European cities.

5 MEASURES AND CONTACT INFORMATION

Table 4: Overview of the Smart Solutions, measures, cities and partners involved in WP2, along with the page number on which each measure is presented in this report

Solution	Measure	City	Partner(s)	Contact person
SS1. Efficient and smart climate shell refurbishment	M1.1 Energy efficient refurbishment of social housing	Barcelona	Barcelona Municipality, IREC	Manel Sanmartí (msanmarti@irec.cat)
	M1.1 Energy efficient refurbishment of public tertiary buildings	Barcelona	Barcelona Municipality, IREC	Manel Sanmartí (msanmarti@irec.cat)
	M1.1 Energy efficient refurbishment of private residential buildings	Barcelona	Naturgy	Milagros Rey (mreyp@naturgy.com)
	M1.1 Energy efficient refurbishment of private tertiary buildings (hotel, sports centre, educative centre)	Barcelona	Naturgy	Milagros Rey (mreyp@naturgy.com)
	M1.1 Smart energy management in a private condominium	Stockholm	L&T	Peter Andersson (peter.andersson@l-t.se)
	M1.1 Energy efficient refurbishment of public housing area	Stockholm	Skanska, Stockholmshem	Harry Matero (harry.matero@skanska.se)
	M1.1 Energy efficient refurbishment of public tertiary buildings (offices and cultural centre)	Stockholm	City of Stockholm	Mika Hakosalo (mika.hakosalo@stockholm.se)
	M1.1 Energy efficient refurbishment of a residential neighbourhood	Cologne	Dewog, RheinEnergie	Christian Remacly (c.remacly@rheinenergie.com)
SS3. Smart, energy saving tenants	M3.1 Virtual Energy Advisor - Open city Home Energy Management System	Barcelona	Barcelona Municipality, IREC	Manel Sanmartí (msanmarti@irec.cat)
	M3.1 HEMS - Private Home Energy Management System	Barcelona	Naturgy	Milagros Rey (mreyp@naturgy.com)
	M3.1 Energy Saving Center - Building Energy Management System	Stockholm	L&T	Peter Andersson (peter.andersson@l-t.se)
	M3.1 Active House - Private Home Energy Management System	Stockholm	Fortum	Larz Pohl (larz.pohl@fortum.com)
	M3.1 Smart Home System – Private Home Energy Management System	Cologne	RheinEnergie	Christian Remacly (c.remacly@rheinenergie.com)
SS4. Local Renewable energy	4.1 EnergyHUB - Smart management of	Stockholm	L&T	Peter Andersson (peter.andersson@l-t.se)

production and integration with buildings and grid	photovoltaics and energy storage			
	4.1 Siedlungsmanagement - Energy management system at neighborhood level	Cologne	RheinEnergie	Christian Remacly (c.remacly@rheinenergie.com)
	4.2 Smart management of PVs and energy storage	Barcelona	IREC, Naturgy	Manel Sanmartí (msanmarti@irec.cat)
	4.2 Resource Advisor - Energy performance evaluation platform	Barcelona	Schneider Electric	Adrià Casas (adria.casas@schneider-electric.com)
SS6. New business models for district heating and cooling	6.1 OpenDH - Feed-in of waste heat into District heating network	Stockholm	Stockholm Exergi	Martin Brolin (martin.brolin@stockholmexergi.com)
	6.3 Local energy generation towards nZEB	Barcelona	Barcelona Municipality, IREC	Manel Sanmartí (msanmarti@irec.cat)

GrowSmarter
Transforming cities for a smart, sustainable Europe

6 SOURCES / REFERENCES

List of key GrowSmarter project documents		
Name of document	**Link**	**Finalised**
Fact sheets	http://www.grow-smarter.eu/solutions/	2016-2018
Technical and management reports, D1.3, D1.4, D1.5, D1.6	http://www.grow-smarter.eu/inform/reports/	Feb 2016, June 2017, Dec 2018, Dec 2019
Implementation reports D2.3, 3.3, 4.3	http://www.grow-smarter.eu/inform/reports/	Feb. 2018
Draft concluding reports D2.4, 3.4, 4.4	http://www.grow-smarter.eu/inform/reports/	Feb. 2019
Lighthouse cities market introduction, D6.2 Economic validation and assessments, D6.3 Smart city market introduction, D6.4	http://www.grow-smarter.eu/inform/reports/	Feb 2018 Jan 2019 Oct 2019
Reports on results of technical, economic and social validation, D5.3, D5.4	http://www.grow-smarter.eu/inform/reports/	Dec 2018 Oct 2019
Data management plan, D1.2	http://www.grow-smarter.eu/inform/reports/	First version 2015
Recommendations for policy makers and practitioners, D1.7	http://www.grow-smarter.eu/inform/reports/	Nov 2019
Project brochure, D8.3 Project result Brochure, D8.10	http://www.grow-smarter.eu/inform/press-corner/	Update 2017, Nov 2019

About GrowSmarter

GrowSmarter (www.grow-smarter.eu) brings together cities and industry to integrate, demonstrate and stimulate the uptake of '12 smart city solutions' in energy, infrastructure and transport, to provide other European cities with insights and create a ready market to support the transition to a smart, sustainable Europe.

GrowSmarter project partners

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