SHARINGCITIES

Deep energy retrofits for buildings

A SHARING CITIES PLAYBOOK

2020 V.1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691895

CONTENTS

Click on the buttons to navigate through this document

Introduction
How to use this playbook and introduction

Challenge & Solution

Insights

Benefits

Implementation Toolkit

This playbook is produced by Sharing Cities, a major international smart cities project. It addresses some of the most pressing urban challenges cities face today across ten replicable solutions.

WHAT IS THIS PLAYBOOK?

This guide gives an overview of how Sharing Cities rolled out building retrofit schemes in its three 'lighthouse cities' – Lisbon, London and Milan. The aim was to address challenges in each city context and share the experience so other cities can learn from it.

This playbook will:

- Help you understand what solutions were tested in the Sharing Cities lighthouse cities and what urban challenges they address.
- Help you understand the value proposition of the solution, in economic, social, environmental, and financial terms.
- Offer practical guidance so city officers have all the information they need to rollout out the solutions in their city, including:
  - Strategic and technical design.
  - Ownership structures.
  - Business models.
  - Financing options and routes to market.
  - Stakeholder engagement and communications.
  - How to safeguard citizen interests.
- Answer common questions and concerns you may have about these solutions.
- Sum up the key challenges, recommendations, and lessons learned from testing these solutions. Other cities can then use these insights to guide their own schemes.

TOOLS & RESOURCES

The playbook also includes references to a range of tools to support your development and delivery plans. If you'd like the source files for these tools, email: Sharing Cities **pmo@sharingcities.eu** or tweet us **@CitiesSharing**

Sharing Cities tested a range of technologies across various sectors, including mobility, data platforms, infrastructure, and energy systems. Many of these technologies complement each other. Some even directly work together to produce better results. This table shows how different Sharing Cities technologies relate. You may find it useful to cross reference materials in other playbooks.

RELATED TECHNOLOGIES TESTED IN SHARING CITIES

	e-bikes sharing schemes	e-Car Sharing	e-Vehicle Chargers	e-Logistics	Smart Parking	Digital Social Market	Building Retrofit	Sustainable Energy Management Systems	Smart Lampposts
e-bikes sharing schemes	✗		✓			✓			
e-Car Sharing		✗	✓			✓	✓		✓
e-Vehicle Chargers	✓	✓	✗	✓	✓		✓	✓	✓
e-Logistics			✓	✗	✓				
Smart Parking		✓	✓		✗				
Digital Social Market	✓	✓				✗	✓	✓	
Building Retrofit		✓	✓			✓	✗	✓	
Sustainable Energy Management Systems			✓				✓	✗	
Smart Lampposts		✓	✓						✗

WHO IS THIS GUIDE FOR?

We created this guide with two key audiences in mind:

1

City officers, governments and public authorities who are considering or are in the early stages of implementing building retrofit programmes.

2

Lighthouse and fellow city members of Sharing Cities looking for a way to scale their building retrofit efforts.

LIGHTHOUSE CITIES

LISBON

LONDON

MILAN

SHARING CITIES:
A TESTING GROUND FOR INNOVATION

Sharing Cities aims to change forever how we think about the role of digital technology in our cities. We want to clarify how we all can benefit from and contribute to this transformation process.

Led by the Greater London Authority, we have run 10 smart city projects in each of our lighthouse cities of Lisbon, Milan, and London (together with the Royal Borough of Greenwich). Our aim is to test how innovative technological solutions can address some of the most pressing urban challenges cities face. These include in mobility, energy efficiency, data management, and citizen engagement.

Our vision is of a more agile and more collaborative smart cities market. This would dramatically increase both the speed and scale at which we can rollout smart solutions across European cities. We wish to engage citizens in new ways too, so they can play an active role in transforming their communities. We want to share solutions, practices, experiences and results, and improve the way we manage city data and infrastructure. By doing so, we will co-create a better living environment and reduce our energy costs.

About Sharing Cities

The Sharing Cities 'lighthouse' project is a testbed for finding better, common approaches to making smart cities a reality. By fostering international collaboration between industry and cities, it will develop affordable, integrated, commercial-scale smart city solutions with high market potential. Project partners also work closely with the European Innovation Partnership on Smart Cities and Communities (EIP SCC01 – Lighthouse Projects).

In addition, Sharing Cities offers a framework for citizen engagement and collaboration at a local level. This strengthens trust between cities and communities. The project draws on €24m in EU funding. It aims to trigger €500m in investment and have a long-term impact on the smart cities' marketplace.

Part of the European Horizon 2020 programme, Sharing Cities includes 34 European partners from across the private, public and academic sectors. Together the group works to deliver near-to-market solutions, such as:

- **Smart lampposts** – integrated smart lighting with other smart service infrastructures (electric vehicle (EV) charging; smart parking; traffic sensing; flow data; wifi etc).
- **Shared e-mobility** – a portfolio of linked initiatives supporting the shift to low carbon shared mobility solutions. Specifically: EV car-sharing; e-bikes; EV charging; smart parking; e-logistics.
- **Integrated energy management system** – rollout system to integrate and optimise energy from all sources in areas of cities (and interface with the city-wide system). This includes demand response measures.
- **Urban sharing platform (USP)** – a way to manage data from a wide range of sources including both sensors and traditional statistics. The platform uses common principles, open technologies and standards.

- **Digital social market (DSM)** – an approach to encourage citizens to engage with and use sustainable smart city services. The aim is to shift perceptions and change behaviours through rewards in exchange for continued and improved citizen engagement.
- **Building retrofit** – install energy efficient measures in existing public, social, and private building stock. This will link to other solutions like the integrated energy management system to optimise energy performance.

Packaging tested smart city solutions across Europe

Sharing Cities has captured the experiences from deploying these solutions and lessons learned along the way in a series of playbooks. Our programme partners and other cities can use this research to reduce barriers, speed up processes and ensure a consistent approach.

We want to provide a set of 'packaged' mobility solutions and document the replicable parts of a smart city solution. This will help cities and suppliers better navigate the challenges of delivering fresh, cross-sectoral solutions to improve the urban environment. Making these solutions both cheaper and quicker to come to market will boost the confidence of buyers and investors alike.

Our playbooks use the EU Smart Cities Cluster's emerging 'packaging concept'. This captures (i) societal needs (ii) technical components (iii) business models and financing options. This one is concerned with building retrofits. To find out more about the EU Smart Cities Clusters projects, visit EU Smart Cities Information System (SCIS).

1. Deep energy retrofit: Enhancing energy efficiency in the built environment

The challenge

Cities and urban areas face major challenges to meet the rising needs of their populations. At the same time, they must maintain a healthy living environment and increase quality of life for all their citizens. Today more than half of the world's population live in urban areas. This is set to increase significantly over the next decades, with strong implications for urban management and governance.

Climate change is another growing concern. Urban areas not only produce a considerable portion of human-made greenhouse gas (GHG) emissions, they're also particularly vulnerable to its effects. Both local decision-making and strategic approaches have a part to play in finding opportunities and pursuing more sustainable pathways.

The energy sector has a critical role both within a climate change mitigation and an urban planning framework. However, integrating a larger amount of renewable energy sources in energy systems is a major challenge for electricity supply. In this respect, various factors are shaping how cities deal with energy demand and supply. Cities account for about 65 per cent of global energy demand and 70 per cent of energy-related carbon dioxide emissions.[1] This will only increase as their populations continue to grow.

Recently, there's been much effort to speed up development and deployment of energy efficiency and low-carbon technologies in urban contexts. However, many low-carbon energy technologies still lack maturity – particularly when compared to traditional ones. This means public support schemes are needed for deployment and attracting the necessary increases in investment in technologies and infrastructure.

Energy efficiency is one of the main priorities supporting urban areas in this crucial transition. The rationale is clear and focuses on making the use of energy more efficient. In other words, decreasing the overall energy demand will result in lower GHG emissions. However, this goal has broader benefits beyond energy supply and demand. If done well, it also supports economic growth, enhances social development, advances environmental sustainability, ensures energy-system security and helps build prosperity.

Despite the significance of these benefits, they're still being left out of most policy and programme evaluations for various reasons. These include a lack of relevant data and evaluation methods, estimation challenges and perceived credibility risk. In the urban environment, buildings present the largest potential for savings. They are responsible for 40 per cent of energy consumption and 36 per cent of CO_2 emissions in the EU.[2] Alongside improving the health and wellbeing of occupants, energy efficiency measures in buildings also save money. These include by reducing energy use for heating and/or cooling, electricity for lighting, and lowering building maintenance requirements.

The emphasis is on integrating these two concepts. That means aiming to promote adequate urban planning practices so there are opportunities to reduce energy consumption. It also means supporting the integration of renewable energy systems (RES) and smart grid technologies in an urban context. Cities play a crucial role in driving global energy demands, this is a big challenge within a Smart Cities context. It is however key to ensuring a safe, reliable, affordable and sustainable energy system.

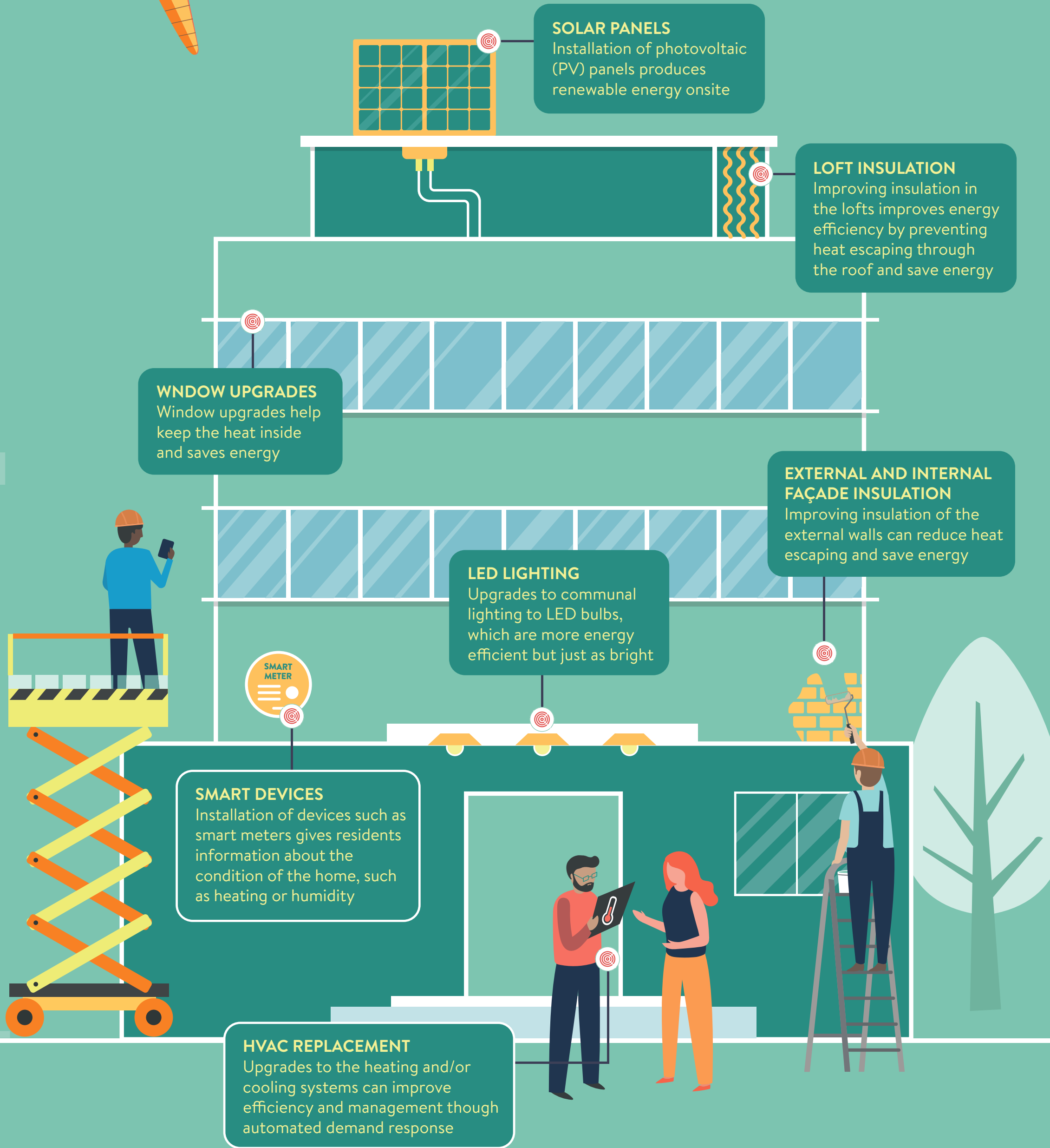
The vital parts of a deep energy retrofit scheme

BROAD BENEFITS

ENERGY
- ✓ Lower energy bills
- ✓ Increased property value
- ✓ Substantial energy use reductions especially in extreme climates

SOCIAL
- ✓ Lower energy bills lead to greater individual savings
- ✓ Improved thermal comfort and residents' wellbeing
- ✓ Reduce health issues due to poor indoor air quality and thermal environment

ENVIRONMENTAL
- ✓ Improved air quality
- ✓ Reduced carbon emissions
- ✓ Supports wider climate change mitigation efforts



Deep energy retrofits – What is it and how does it differ from regular building retrofit?

Most new buildings are now built to be energy efficient. However, most building stock in our cities is old. Through Sharing Cities, we've explored how to retrofit older buildings in the three lighthouse cities with energy efficiency measures and smart controls. The aim is to reduce energy consumption by 50 per cent through tailored energy measure packages in public and private housing. In the first months of 2019, simulations showed that Sharing Cities' building retrofits had reduced energy consumption by around 40 per cent. The figures pointed to an overall reduction of about 26 per cent.

In total, 15 buildings (of various types) were retrofitted across the three cities. This playbook summarises the lessons learned from these projects:

LISBON	• Two public housing neighbourhoods, originally built in the 1960s and 1940s • Three private residential buildings with historical significance, built in 1933, 1840, and 1943 • Two public service buildings – the historic Lisbon City Hall completed in 1880, and an elementary school, built in 1961
LONDON	• Two public housing estates in the Royal Borough of Greenwich, built in 1937 and 1938
MILAN	• One public housing building, built in the 1980s • Six privately-owned multi-property residential buildings

Of course, building retrofits are not a new idea. However, there are three major differences in the Sharing Cities approach:

1. **Carrying out deep retrofit works by combining the installation of renewable generation with the latest energy management control technologies.** This is on top of standard retrofit measures to boost energy efficiency. Combining these technologies has enabled greater efficiencies. For example, through connected monitoring and control, the Internet of Things (IoT), and sustainable energy management systems (SEMS) together. The impact of such an approach shows how smart cities can benefit communities, over and above standard building retrofit works.
2. **A co-design approach developed by partners TEICOS and Future Cities Catapult.** Housing residents were actively engaged and contributed to the design and choice of interventions. This engagement carried on once works finished to ensure continued support, that upgrades were effectively used and to improve wellbeing.
3. **Most building stock in our cities, especially in major European cities like Lisbon, Milan, and London, is old**. Many are significant in terms of cultural and heritage terms. As such, they are protected by regulation. This can make retrofit hard especially for things like renewable generation as they don't often fit with the historical building aesthetic. However, Sharing Cities has shown how this can be done effectively.

This playbook features the following retrofits and showcases what's different about our approach

1. Deep energy renovations in multi-property residential buildings

In Milan, six residential buildings were retrofitted – a total of 24,670 sqm. The successful creation and rollout of the co-design process is already being scaled-up in other multi-property buildings in the city. Technical design and co-design meetings with owners, means each intervention is tailor-made. These include insulation of external walls, renewable energy sources and updating heating and lighting systems to more energy efficient technologies.

MILAN / Multi-property residential buildings

- Milan privately owned buildings, showcasing a unique co-design process and profitable business model.
- A fresh approach to co-design was created that is already being scaled-up in other multi-property buildings across the city. Thanks to the technical design and the co-design meetings with owners, each intervention is tailor-made. These include insulation of external walls, renewable energy sources and changing heating and lighting systems to more efficient technologies.

Photovoltaic panels (deductible at 50%)

Type: semi-integrated photovoltaic system (6kWp)
Position: on the facing south roof
Performance: high efficiency (30% of the energy needs)

Stairwell window-frames (deductible at 50%)

Technology: aluminium window-frames with double glass
Performance: window-frames installation contributes to reduce thermal dispersion of the stairwell

Internal walls insulation (deductible at 50%)

Material: EPS panels with graphite
Thickness: 12 cm
Finish: plastic plaster
Performance: high thermic insulation, thermal bridge resolution

Thermoregulation with thermostatic radiator valves (deductible at 50%)

LED lights (deductible at 50%)

Façade external insulation (deductible at 70%)

Material: EPS panels with graphite
Thickness: 12 cm
Finish: plastic plaster
Performance: high thermic insulation, thermal bridge resolution

Roof insulation (deductible at 70%)

Material: XPS panels
Thickness: 12 cm
Finish: gravel and synthetic sheath
Performance: high thermic and acoustic insulation, long-lasting

Pilotis floor plan insulation (deductible at 50%)

Material: fiberglass panels
Thickness: 14 cm
Finish: gypsum fibreboard modular countertop
Performance: high thermic insulation

Heat system tele-management (deductible at 50%)

2. Integrated low carbon technologies in public housing

In the Royal Borough of Greenwich, London, two social housing estates, Ernest Dence and Flamsteed, underwent a deep retrofit.

Ernest Dence was a chance to test out Solar PV generation and a retrofitted renewable heating system on an estate in a conservation area. The communal gas boilers are being replaced by a water source heat pump, using boreholes drawing water from the Thames basin. This will provide heating and hot water to the building. A sustainable energy management system (SEMS) connects the energy asset. This allows for dynamic energy management. Generating further carbon and cost savings also helped improve the performance of the heat pump (see the SEMS and Digital Social Market Playbooks to find out more).

In addition, deep retrofit in Greenwich included ambitious energy efficiency fabric improvements. These include loft and external wall insulation, window refurbishment as well as upgrades to communal lighting and individual gas boilers. The project also trialled Internet of Things (IoT) technologies like smart thermostats, temperature and humidity sensors, boiler sensors and connected smoke alarms. These can help reduce energy use and save residents money on their energy bills and alert to environmental conditions such as damp/mould. They can also be used to monitor impact of the retrofit and provide an improved and proactive maintenance service.

Introduction
Challenge & Solution
Deep retrofit: Enhancing energy efficiency
Insights
Benefits
Implementation Toolkit

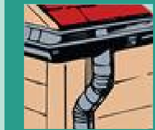
LONDON

Building retrofit in London focused on two large social housing estates in Greenwich's Peninsula ward both built between the war period. They consist of 267 flats of varying sizes and provide social housing for local residents.

The borough's Asset Management department identified both estates as requiring works before the Sharing Cities programme.

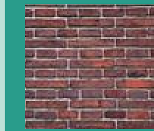
Almost 10 per cent of Greenwich households are in fuel poverty. This is affected by the energy efficiency of a property, the cost of energy and household income. In the ward where the estates are located, the figure is 11.1 per cent – higher than the London average of 10.6 per cent.

The retrofit activities for Ernest Dence Estate are pictured here.



Guttering
Repairs to the guttering.

Windows
Upgrades to windows, to help keep the heat in.



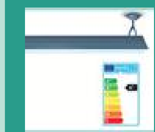
Building repairs
Repairs to brick and concrete work, including the roof and chimney stacks, as well as the drains where needed, to improve the condition of the building.

Loft insulation
Improving insulation in the lofts, so that less heat escapes through the roof.

Smart devices
Installing devices which give you more information on conditions in the home, such as heating or humidity.

Heating
Upgrades to the heating system, which will make homes warmer and make the system more efficient and less polluting.

Balconies and walkways
Repairs and new waterproofing to balconies and walkways, to improve their condition.



Lighting
Upgrades to communal lighting to LED bulbs, which are more energy efficient but just as bright.

Redecoration
Communal areas such as staircases and entrances will be redecorated, to clean up after the works.

3. Deep energy renovations in public cultural heritage buildings

Lisbon's City Hall is an iconic historic building. It posed some interesting regulatory challenges and limitations in terms of how to implement retrofit. It is a 'living' example of how a working public service building can improve its energy behaviour and still maintain its architectural features. It also provides a model for other cities with similar historic buildings and challenges.

As a result of the retrofit, City Hall's energy bills have fallen by around 40 per cent.

Scale of impact: As one of the municipality's five least energy efficient buildings, reducing consumption was a financial priority.

Service buildings are around 40 per cent more energy intensive than residential buildings. Across the EU, this represents an average energy consumption of about 200 and 300 kWh per m^2, compared to an average of 180kWh/m^2 in residential buildings.[3]

LISBON / Deep energy renovations in cultural heritage buildings and installation of solar PV

Lisbon's City Hall building is heritage protected due to its architectural and artistic value. This iconic building reflects the image of Lisbon, and of liberal, regenerating and republican Portugal. It is home to the Mayor's office and is used for city council meetings. It's also used for events including high-level receptions for national and international delegations from cities and companies around the world.

The chosen solutions were constrained both by current regulations and the technology equipped to handle historical buildings. For instance, it wasn't possible to improve existing building insulation for these characteristics and artistic features on the exterior facades and interior walls. The complex nature of these works meant that procurement was a challenge. This is because very few companies can carry out such work. In addition, works had to be approved by the Directorate General for Cultural Heritage.

This diagram shows the other solutions put in place in the building. To understand the real impacts of the interventions, a building energy management system (BEMS) was also rolled out.

The aim was to: (i) monitor the energy consumption and needs of the building and its equipment, and (ii) contribute to creating mechanisms leading to increased efficiency, particularly by changing behaviours.

Windows refurbishment
Upgrade windows to reduce thermal leaks and improve comfort.

HVAC replacement
Improve efficiency and management through automated demand response.

Smart meters
The installation of energy smart meters to provide more information.

LED lighting
Improve energy efficiency of communal lighting by installing LED bulbs.

Photovoltaic panels
The installation of a photovoltaic system to produce renewable energy.

Energy management
Integrating the different energy vectors, optimising operation and energy use.

Installing the PV system was also difficult due to the building's historical nature. Both the number of panels and solutions also had first to be approved by the National Directorate General for Cultural Heritage. The main limitation was around the potential impact on panoramic views because of the many belvederes around the city. The directorate was strongly opposed to this. After a long and complex licensing process with several changes to the initial plans, a solution was arrived which everyone agreed on.

2. How to navigate the challenges of conducting building retrofits: insights from Sharing Cities

Deep energy retrofit isn't just about energy savings. It's also about how best to meet the objectives of stakeholders. These include building users or residents, owners and building energy managers. The municipality may also need to meet or set energy or climate related targets. Every project is different and requires specific interventions.

Sharing Cities' works went way beyond standard retrofit and repairs. We set highly ambitious targets through rolling out new low-carbon technology which challenged the status quo. As we navigated new waters, we also had to learn and improve along the way. Sharing Cities collected the following insights as a result of that process:

Project design and management considerations

Consider pairing retrofit works with other smart city technologies so that energy efficiency improvements have more impact. Conducting a building retrofit is also a good time to integrate smart energy management systems (*see the SEMS playbook*). This increases the potential impact of the energy efficiency works even more. You should consider what the appropriate solutions are based on your aims. This is in terms of both energy efficiency fabric improvements and additions of low carbon energy supply and storage. It is useful to analyse what solutions are suitable, compared with how much energy can be saved or generated. Using new technology and working with multiple inputs from different fields, makes the design and specification process more complex. However, this is valuable and can further increase the impact of the measures.

Unforeseen challenges can sometimes spur innovation. To understand projected energy consumption, a team at Imperial College London developed a simulation of the building, also known as a 'digital twin'. This showed how the sustainable energy management system (SEMS) might be able to optimise energy use once the retrofit measures were completed. The digital twin developed has far reaching applications beyond just this housing block. In addition, real-time field-data was integrated into the London Datastore. This is being fed into to the digital twin, alongside external data sets such as weather and pricing. The results from SEMS so far are impressive showing a 10 per cent energy reduction on top of the building retrofit action.

A strong monitoring framework and good data collection is vital to show impact and achieve success. Data collection gives project partners the information needed to understand the impact of the interventions. It helps them to see how effective these are and offers a basis for continued learning and improvement. The goal is to assess and evaluate the impact, not only of retrofit on physical building performance, but also on occupant behaviours. To achieve results, it is not only necessary to measure energy efficiency improvements and other factors such as indoor air quality. You must offer accessible ways to consult the data and easy 'instructions' for non-technical users, alongside an information campaign. It's vital to get the baseline information right from the start as it's much harder to get the data later.

Ambitious energy efficiency improvements of publicly-owned buildings require the use of skilled, experienced and reliable suppliers. Our works went way beyond standard retrofit and repairs. Sharing Cities set hugely ambitious targets and challenged the status quo using new, low-carbon tech. The process relied more heavily on a wide range stakeholders and experts and additional specialist work. In some cases, the supply side of procurement and construction was also complex. Throughout this project, it was hard to find vendors with the right skillsets to perform highly specific and technically challenging retrofit works. There weren't many companies operating in the construction market when we started (2015) – and this sector is still relatively traditional. A proper dialogue between the private construction and public administration sectors could help tackle most of the capacity and operational problems of such projects.

Building retrofit projects are complex. External factors can create knock-on effects and exacerbate delays. Some building retrofit works were delayed due to unforeseen circumstances. These types of complex projects typically span months to years and involve a wide range of stakeholders. As such, they are vulnerable to external factors and disruptions, such as political cycles, challenges from residents, and economic downturns. In London the Grenfell Tower fire caused unanticipated delays to construction in the ensuing investigations and regulation changes. More recently the arrival of COVID-19 caused construction work to stop while social distancing measures were put in place to control the virus' spread.

Design restrictions must be considered when carrying out retrofit works for historical buildings. For example, in London, certain areas of Greenwich have restrictions to preserve character and heritage in the social housing buildings. These influenced whether measures such as external wall insulation and Solar PV could be applied. In Lisbon City Hall, regulations stopped Solar PV from being installed anywhere onsite that was visible from any vantage point from the city. The plaza on which City Hall is located sits at sea level surrounded by hills. This severely limited the total surface area and locations in which the PV panels could be installed.

Political and regulatory environment

Be aware of regulatory constraints and changes that may determine future rules on low carbon buildings. This is highly relevant to the energy efficiency sector, which is something relatively new for public administration. Legislation can change rapidly in this area and can heavily influence processes. At the same time, it is a core part of climate actions and the movement towards a low-carbon economy. Cities may not always have the freedom to rollout actions that can help achieve ambitious energy efficiency goals. However, by understanding how policy directions may be shaped in the future, cities can get ahead of the game. That way, they'll be ready to roll-out these types of deep energy retrofits at scale.

Political engagement is essential and plans to mitigate risks should be made with political changes in mind. Political will is the starting point, that must be followed by the setting of clear goals. Equally important is to ensure continuity in the political interest and in the management of these projects from one administration and another. Elections and changes at senior political level in cities have big impacts. This can cause delays and lead to lengthy project reviews and adaptation, or in some cases, with projects being cancelled altogether. In London, a new Mayor was elected in 2016. This meant that plans for a Combined Heat and Power (CHP) plant in Greenwich were scrapped to improve local air quality. Plans to use the plant as a low carbon heat solution had to be changed accordingly. Greenwich instead now plans to install a water-sourced heat pump as a comparable, low carbon alternative.

Cultural and social considerations

Engagement with residents is critical and must start before work begins and continue post-retrofit. The people affected must be involved from the start, in order to collect information about their needs and to co-design solutions. Milan's co-design process in multi-owner buildings is a great example of pre-retrofit engagement and how this can lead to innovative results.

The co-design process in multi-owner, residential buildings has shown to be key to success. Every building is different, distinguished by its architecture, conditions, use, population (for housing) and context. To make sure this works, you need your residents to be supportive. That means including them from the design stage and throughout the process.

Changing the habits of residents and how they use energy is critical to the long-term success of a building retrofit. Post-retrofit, it is even more important to engage people. Both the private and public sector need to communicate better with citizens about the importance of post-retrofit actions. The three cities have devised different ways and means to promote take-up of energy efficiency behaviours, by raising people's awareness.

3. What is the value of a deep retrofit?

The deployment of deep energy renovation is a complex task that requires the coordination, sharing and action of several actors. One challenge is the lack of coordination and differing objectives between those stakeholders who manage/benefit from financial aspects and the socio-technical ones. Local authorities want to preserve the economic and social value of property, citizens' wellbeing, conserve cultural heritage, and make energy and economic savings. However, they often lack the financial tools and structural organisation to do so.

Cities such as London, Lisbon, and Milan have a large amount of old building stock with inefficient heating and cooling systems. This wastes energy and money. Deep energy renovations could make a huge difference. They could also yield important benefits on the urban air quality, especially large and polluted cities like Milan. There buildings' heating systems are responsible for about 50 per cent of the city's emissions (SOx, NOx and PM).

Deep energy renovation projects have a clear environmental benefit in **reducing energy use** and **carbon emissions**. They can also lead to consistent **economic savings**, both for tenants and for the municipality (according to the costs accounting scheme in public housing).

If all the public housing stock in Lisbon were retrofitted, the city could reduce its CO_2 emissions by 17,304 tons annually. In Milan, the city could save 259,262 tons of CO_2 annually from being emitted.

It should be noted that building performance is hugely influenced by the behaviour of occupants. This is not under the control of design. In particular, this is true of energy consumption for heating / cooling and for lighting, which are subject to how people use systems and windows. That is why Sharing Cities focuses a lot of attention on monitoring energy and environmental performance. We try to assess the impact of occupants' behaviour on the final consumption, eventually supporting them to improve it. The energy savings may lead to financial savings because of the decrease in the energy delivered to the buildings for space heating. However, some of the benefits will not be realised, as often people don't heat or cool their homes to the necessary comfort levels.

Public and social housing present one of the toughest environments to promote building renovation. This is mainly due to split-incentives issues. Sometimes, it can also be a difficult relationship between the property owner (municipality) and tenants who may not be proactive. This can make renovation works harder in buildings that are occupied by tenants. Nonetheless, building energy retrofits may have different benefits from an economic, social and environmental perspective. These will depend on the actions taken, the time scale considered, and the stakeholders involved. The following text comes from a publication by Monteiro et al. It summarises some of Sharing Cities' work which is valid for most European cities, including Lisbon, London, and Milan.

Energy benefits

A deep energy retrofit strategy focuses on substantially reducing the building's energy needs, while also providing adequate thermal comfort conditions for occupants. The building envelope is therefore the core object of the retrofit.

For Sharing Cities' public housing projects, simulation results show huge potential for energy saving, both in Lisbon, and especially Milan, which has cold winters.

This table shows the primary energy demand for heating, cooling, hot water, lighting and ventilation, for baseline (pre-retrofit) and retrofit scenarios. The heating values represent the demand to maintain thermal comfort conditions in the housing units (20°C). These are based on simulations and reference weather data sets, which may differ from the actual operational consumption of the building. The same consideration is valid for the cooling values, where a constant temperature of 26°C is assumed as a proxy for comfort in Lisbon's public housing. Cooling was not simulated in Milan as no cooling system exists in the pre-retrofit and it is not included in the retrofit.

Primary energy for baseline and retrofit of public housing estates in Sharing Cities[4]

PRIMARY ENERGY	MILAN – BASELINE	MILAN – RETROFIT	LISBON – BASELINE	LISBON – RETROFIT
Heating (kWh/m^2 yr)	214	17	95	59
Cooling (kWh/m^2 yr)	-	-	4	4
DHW (kWh/m^2 yr)	21	12	37	37
Lighting (kWh/m^2 yr)	15	10	12	10
Ventilation (fans) (kWh/m^2 yr)	-	17	-	-
Total (kWh/m^2 yr)	250	56	148	110

MILAN / Energy savings in residential buildings

The distribution of savings across the residents is a crucial issue. It is being discussed in Milan, where ground floor apartments could experience a lower reduction of energy use. This is because the insulation layer applied to the floor slab can have only a limited thickness. The current Italian legislation requires energy metering at the apartment level in any building with a centralised heating system so that bills reflect consumption. However, in *San Bernardo* buildings the energy costs are reallocated to the tenants. This follows a standardised method according to the regional law LR 27/2009, provided by DGR X-3965, art. 10 comma 12.

Environmental benefits

Environmental benefits around climate change may be evaluated by means of yearly equivalent carbon dioxide savings. Long term benefits may be estimated using standard emission values. These are based on an assumption that the entire public housing stock in Milan and Lisbon is retrofitted. The potential savings are summarised in the table below. The conversion factors assumed from energy to CO_2 emissions in Lisbon are 0.144 $kgCO_2/kWh$ for electricity and 0.170 $kgCO_2/kWh$ for gas. In Milan, they are 0.4332 $kgCO_2/kWh$ for electricity, 0.1998 $kgCO_2/kWh$ for natural gas and 0.2642 $kgCO_2/kWh$ for fuel oil.

Estimated yearly carbon savings in Milan and Lisbon when applying the proposed energy retrofit to the entire public housing stock

	MILAN	LISBON
CO_2 savings (tons)	259,262	17,304

Comfort benefits

The main benefit for tenants of public housing is the potential improvement of indoor thermal comfort and indoor air quality (IAQ). Many public housing residents experience low levels of thermal comfort. This is due mostly to an inadequate mean radiant temperature. In other words, the temperatures of surrounding walls are too low, coupled with cold air draughts. Improving the building envelope and making it more airtight are the best way to address these complaints. Mechanical ventilation and education on how best to operate windows can also help guarantee adequate levels of IAQ. Better thermal comfort can improve the quality of life of occupants, physiologically and psychologically. In the long run, this may help to reduce health issues related to a poor thermal environment.

Social benefits

If the retrofit approach proves economically feasible and can be scaled up across public housing stock, the social benefits will be scaled up too.

These environmental and economic benefits include:

- reduction of air pollution
- carbon savings
- waste reduction from avoidance of demolition and construction
- new business opportunities
- job creation
- increase of GDP
- positive impacts on public finance
- reduction of energy import dependency
- improved social welfare.

It is hard to estimate and evaluate most of these societal benefits, so they are often neglected in technical reports. However, they might represent, in the long run, one of the most important effects of energy retrofits. Qualitative feedback from residents in the Milan and Greenwich retrofit projects showed they'd enjoyed being involved. It had also helped them develop stronger links and build community cohesion.

The table on the following page summarises the direct benefits and wider impacts of deep energy retrofit works.

BENEFITS	DIRECT IMPACT	WIDER IMPACTS	SHARING CITIES EXPERIENCE
Energy	Substantial energy use reductions especially in extreme (hot or cold) climates. Lower energy bills.	Reduction/ avoidance of demolition and reconstruction by retrofitting instead. Increased property value.	In Lisbon, the private building retrofits enabled property developers to sell retrofitted units at higher prices.
Environmental	Improved air quality. Reduced carbon emissions.	Supports wider climate change mitigation efforts.	In Milan, buildings' heating systems are responsible for about 50% of the emissions in the urban area (SOx, NOx and PM).
Improved thermal comfort levels	Improved residents' wellbeing.	Improve overall quality of life – including physical and mental health. Reduce health issues due to poor indoor air quality and thermal environment.	Many public housing residents experience low levels of thermal comfort. This is due to poorly insulated walls and draughts from windows and doors. Retrofit actions reduce this as well as teaching residents to use new building features like thermal controls and window ventilation.
Social	Lower energy bills lead to greater individual savings.	Improved social welfare, reduction of energy poverty.	


Before


After

Introduction
Challenge & Solution
Insights
Benefits
What is the value of a deep retrofit?
Implementation Toolkit

4. How to rollout a deep retrofit scheme

Sharing Cities carried out deep retrofits in Lisbon, London (Greenwich), and Milan on a range of buildings. These included both public buildings such as municipal buildings and social housing, and private developments. The purpose was to show how these retrofits can be replicated for other similar buildings. Rolling out the retrofit schemes in the lighthouse cities followed this general process. This section covers some of these **tools and processes** from examples in Lisbon, London and Milan.

Exploring opportunity

- **Conduct demand analysis**
- Define goals with key stakeholders
- Establish baselines through data collection and surveys
- Develop use cases

Audience engagement

- **Establish and maintain stakeholder engagement**
- **Engage in co-design with residents**

Technical design

- **Understand the characteristics of your building**
- **Assess technical options and select package of retrofit solutions**
- **Develop technical specifications**

Finance and implementation

- **Develop business model and financing plans**
- **Start procurement**
- Implement retrofit

Monitoring and sharing

- **Create monitoring system and link with sustainable energy management system (SEMS)**
- **Develop metrics and key performance indicators**
- Carry out continuous performance monitoring

Note that building retrofits are highly context-specific. That means the process and solutions can vary depending on the building type and location. As such, not all parts of this process will be relevant to your project. It might also mean you will need to carry out activities not described here. Sharing Cities has collected a lot of data detailing how the process was rolled out in each set of buildings in the three cities.

Introduction
Challenge & Solution
Insights
Benefits
Implementation Toolkit
How to rollout a deep retrofit
Stage 1 Exploring opportunity
Stage 2 Audience engagement
Stage 3 Technical design
Stage 4 Finance and implementation
Stage 5 Monitoring and sharing

Exploring opportunity

Demand analysis

The need to understand the problem and its 'size'

A holistic view of the city's building stock is required (if not crucial...) to characterise the landscape and understand its performance. Basically, different approaches should be rolled out depending whether the problem has an overall influence. Alternatively, it may be more significant for a specific type of buildings (public or private, residential or tertiary, etc). For this reason, you must understand what problems the city needs to target as well as the priorities.

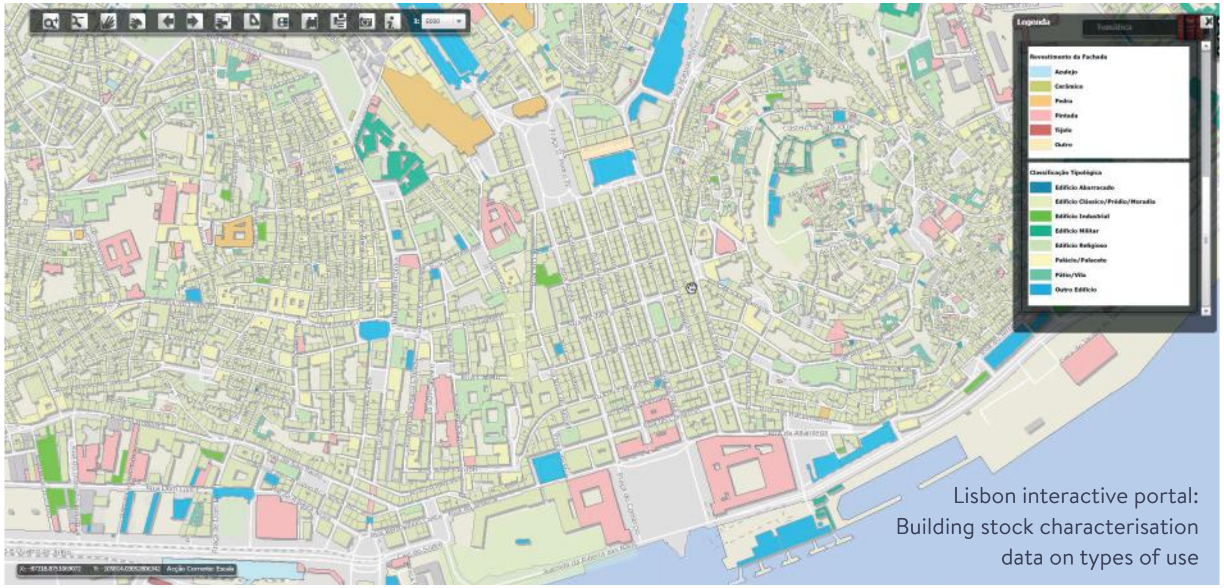
You can use several approaches, forms and tools, with different configurations to support cities for this purpose. However, in truth, much will depend on the availability of building stock data for the city.

Urban building asset database (UBAD)

Data contained in UBAD can be used to provide useful information to decision makers. Decision support tools (DST) or Decision support systems (DSS) include all tools necessary to data analysis and scenarios generation. They may start from simple statistical elaborations useful to generate baselines, benchmarks and best practices, but they can also extend to clustering activities and policies simulation.

Almost all Europe cities have databases which include some of the necessary information. However, these are often incomplete, not digitised and/or owned by stakeholders who should be involved in the activities. Sometimes databases do not exist and must be created from scratch. This was the case with building operational energy use in Sharing Cities. This has been created by deploying a monitoring plan and using an integrated data platform and sustainable energy management system (SEMS).

You can then add specific information to this local data, on the energy performance of the estates involved in the programme. This includes real time electricity and heat consumption, thermal imaging, heat demand profiling and techno-economic and feasibility studies.



Lisbon interactive portal: Building stock characterisation data on types of use

Demand analysis – Decision support tools (DSTs)

Buildings are a major use of energy and land, especially in cities. To reduce their impact, we must design and manage energy-efficient buildings and better plan energy supply systems. Decision-makers and urban planners need to evaluate scenarios and establish the best alternative to decrease overall energy consumption. These tools should be set up to consider the city as a system composed of different but related components.

For instance, not all the buildings within a city or district may become zero energy after a retrofit. There are many reasons for this including final use, safety and security, orientation, heritage constraints etc. Nevertheless, if seen as a complex interconnected system, the network of buildings within a district may become net-zero altogether. In retrofit campaigns there are always limitations due to building types or the urban form. That's why you need a balance of buildings to achieve good results.

DSTs differ from one another because they are often developed for different aims. However, in the case of deep energy retrofit, a DST should always provide detailed analyses of energy use. You may also want to assess solar potential, consider mutual shading among buildings, evaluate GHG emissions, outdoor and indoor comfort and cost-benefits. Integration with district heating and cooling, other energy networks, alongside transport and mobility may provide a complete understanding of urban performance.

Set a baseline and quantifiable targets to understand performance

You need a stringent monitoring framework and good data collection to show impact and achieve success. Data collection gives project partners the information they need to understand the interventions' impact and effectiveness. This also provides the basis for continued learning and improvement. The goal is to assess and evaluate the impact, not only of retrofit action to physical building performance, but also of occupant behaviours.

Building Energy Specification (BES) tables

A Building Energy Specification (BES) table details the building's characteristics and the retrofit specification. We completed such tables for each building that underwent retrofit works to establish a baseline and measure the savings in energy following the works (please see the following page).

Here is an example from Greenwich:

Building Energy Specification Table (BEST)
(to be completed for every diffrent type/category of proposed building)

Community / site: Greenwich | BEST no. 1

1,1 **Building Category** [1] | total area / category / BEST sheet [2]: 7.320 m²
description: Ernest Dence: Built 1937, medium rise block, solid brick

1,2 **Local Climate**
Climatic Zone (national definition): Temperate

January average outside temperature	°C	4,2
August average outside temperature	°C	16,2
Average global horizontal radiation	kWh/m² yr	
Annual heating degree days [3]	°Cd/yr	1774

1,3 **Maximum requirements of building fabric**

			Existing building [5]	National regulation for new built [6]	National regulation for refurbished buildings or normal practice (6a)	suggested specification [7]	Reduction %
Façade/wall	U	W/ m2K	2,1	0,18	0,55	0,3	45%
Roof	U	W/ m2K	2,3	0,13	0,18	0,16	11%
Ground floor	U	W/ m2K	n/a	n/a	n/a	n/a	#VALORE!
Glazing	U_g	W/ m2K	3,1	1,40	1,6	1,5	6%
Average U-value	U_w	W/ m2K	#VALORE!	#VALORE!	#VALORE!	#VALORE!	#VALORE!
Glazing	g	total solar energy transmittance of glazing [%]	0,76	0,63			0%
Shading	Fs	Shading correction factor					0%
Ventilation rate [4]		air changes/hr		5			0%

2 **Building Energy Performance**

2,1 **Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses**

energy carrier existing building	suggested energy carrier		specify energy efficiency measures	Existing building [5]	National regulation for new built [6]	National regulation for refurbished buildings or normal practice (6a)	suggested specification [7]	Reduction
Heating + ventilation								
Gas	District Heat Network	kWh/m²yr	1.) Fabric/insulation measures: + roof insulation + new windows (30%) 2.) Replacing pipework and insulating, radiators, TRVs, HIUs (8%)	139,2	39	139,2	89,6448	35,6%
Cooling + ventilation								
Natural	Natural	kWh/m²yr		0	0	0	0	0,0%
Ventilation (if separate from heating/cooling)								
Natural	Natural	kWh/m²yr		0	0	0	0	0,0%
Lighting								
	electricity	kWh/m²yr	LED in communal areas	7	5,7	7	3,5	50,0%
Domestic Hot Water (DHW)								
Gas	District Heat Network	kWh/m²yr	HIUs instantaneous hot water	92,8	30	92,8	85,376	8,0%
Other energy demand								
		kWh/m²yr		n/a	n/a	n/a	n/a	#VALORE!
		kWh/m²yr	Subtotal sum of energy demand	239	74,7	239	178,5208	25,3%
Appliances (please indicate, but costs are not eligible)								
	electricity	kWh/m²yr						

2,2 **RES contribution per m2 of total used conditioned area (kWh / m2 yr)**

total production kWh/yr	m² installed	kW installed	specify RES measures	Existing building [5]	National regulation for new built [6]	National regulation for refurbished buildings or normal	suggested specification [7]	RES increased contribution [%]
								-
1.281.152	n/a	250	Heat pump - To supply 100% heat demand	0	0	0	175	-
								-
								-
								-
		kWh/m²yr	Subtotal sum of RES contribution	0	0	0	175,02	-

3 **Building Energy Use** per m² of total conditioned/heated floor area (kWh/m2 yr)

		Existing building [5]	National regulation for new built [6]	National regulation for refurbished buildings or normal practice (6a)	suggested specification [7]	improvement from regulation for refurbished/normal practice
kWh/m²yr	Subtotal sum of energy demand	239	74,7	239	178,5208	-60,4792
kWh/m²yr	Subtotal sum of RES contribution	0	0	0	175,02	-175,02
kWh/m²yr	Total Building Energy Use	239	74,7	239	3,50	-235,50

SUPPORT per m² of this building type	235,5 €	TOTAL SUPPORT per m² of this building type	1.723.860 €

Monitoring and benchmarking, and management and operation, are both based on measurement and verification. They must initially inform the design process, providing real energy data that may integrate with the design team's energy audit. After the retrofit, they allow a chance to obtain real operational data. This includes for fault detection activities, in order to optimise building service systems performance. It also provides feedback for the building occupants, technical and political decision-makers.

All the other objectives and related actions are part of co-design and construction. As such, they should be followed step by step:

1. Monitoring and benchmarking energy and comfort performance of the existing building.
2. Reducing energy needs with action on the building envelope.
3. Reducing energy use by installing the most energy efficient building service systems.
4. Reducing delivered energy by exploiting renewable energy sources.
5. Allowing for building, district and city energy optimisation by connecting the construction to an energy management system and installing storage technologies connected to renewable energy systems.
6. Management and operation of the whole building, including interaction with and feedback from occupants.

LONDON

In London, the Royal Borough of Greenwich conducted surveys to collect data on:

- Background static data collection – for example from the council's asset and repairs software systems; early drawings and plans of the estates; past electricity and gas consumption readings and billing.
- Site inspections and surveys – site visits and observations by qualified officers from the Housing team; stock condition surveys as part of a wider council stock condition exercise.
- Tenancy team knowledge of the estates and resident and tenant and resident association feedback.
- Investment grade audits – deeper inspection and proposals for energy efficiency measures, which provide initial cost assessment.
- Planning information – such as conservation areas, allowable works and design restrictions or guidelines.
- Real time data collection – the above has been supplemented with info from real time data collection devices. This includes from electricity consumption on communal supplies and return and flow temperatures on existing communal heating networks. An example of real time data collection is given in the image below.
- Thermal imaging, both static and drone images.
- Specific to the water source heat pump:
    - Background info and data on the current energy system and network. For example, gas consumption, production and efficiency, experienced return and flow temp, current control, secondary set up.
    - BAU cost and price of current heating system and supply to residents.
    - Existing networks and infrastructure in the area, for example power lines, sewer systems, land ownership and other key loads.
    - Local and regional hydrological and geological data and information.
    - Heat demand profiling/energy demand modelling.

Real time electricity use in the Ernest Dence boiler room, for baselining purposes

Introduction
Challenge & Solution
Insights
Benefits
Implementation Toolkit
How to rollout a deep retrofit
Stage 1 Exploring opportunity
Stage 2 Audience engagement
Stage 3 Technical design
Stage 4 Finance and implementation
Stage 5 Monitoring and sharing

LISBON

We identified a set of data sources for analytics and assessments. These included:

- Energy consumption – through energy (electricity and gas) smart meters in the resident's apartments.
- Energy production – through monitoring the production of renewable energy resulting from the PV systems installations.
- Thermal performance of the building's envelope – by conducting thermography assessments during the different stages of retrofit works and rollout.
- Comfort assessment – through surveys of all residents during the different stages of retrofit works and rollout.
- Socio-economic characterisation – through surveys of residents participating in the group.

The aim of collecting these data is to help project partners understand the impact of the interventions at different scopes and levels. For example, technical performance, socio-economic impacts, attitudes and behaviours, institutional consequences and potential systemic changes. Generally, these include:

- Energy savings with heating, cooling, ventilation and lighting.
- Energy produced from renewable sources.
- Improvement of indoor thermal, visual and acoustic comfort.
- Improvement of indoor air quality.
- Building performance reliability.
- Energy supply reliability and grid stability.
- Financial benefits.
- User satisfaction.

Thus, beyond energy performance, the purpose was to ask how such interventions can help alleviate issues like energy poverty. In addition, there were meetings and interviews with the building operators and local stakeholders. These are also considered an important part of the post-retrofit activities.

The aim is to evaluate the perception and willingness of these local actors to replicate and/or scale-up the approach to similar city buildings. In this regard, given the positive experience of the whole process, the feedback received from these entities has been very positive. The outcomes were perfectly aligned with the housing policies and strategies defined for the city. This process has been replicated in several other projects being carried out in social housing districts, by both the municipality and GEBALIS, the municipal company that assures the management of all the housing districts of municipal construction.

Audience engagement

Establish and maintain stakeholder engagement

Regardless of the methodology used, any retrofit project should establish and then maintain stakeholder engagement throughout the project and even once work is over. This will ensure that the works are carried out and any challenges can be addressed appropriately. Depending on the building type, the management and intervention responsibilities falls on different departments and city authorities, at different parts of the retrofit process.

Before and during the retrofit

LONDON

In London, the Royal Borough of Greenwich was the sole owner and manager of the buildings. Most actors that participated in the design and delivery of retrofit in Greenwich are internal to the council. For example, council departments responsible for housing repairs and maintenance, capital projects and mechanical and electrical engineering. Within the council, the design and delivery process involved collaboration between various multidisciplinary actors. A cross departmental project management group was set up, led by the council's housing capital projects team. This worked to gather inputs and support for the design of the works programme.

The engagement strategy has sought to involve and inform residents throughout the process. This includes:

- Statutory consultation for leaseholders.
- A digital approach to communicating the retrofit works.
- Engagement both during and after the retrofit programme.
- A dedicated contractor resident liaison officer, and some opportunity for co-design, for example for the low-carbon heating system at Ernest Dence.

LISBON

In Lisbon, Lisbon municipality is the sole owner and general manager of the City Hall building. Therefore most of those involved in different stages of the process, from design to delivery, were internal. These include several council departments, such as those dealing with mechanical and electrical engineering, building repairs and maintenance or finance. Several external bodies were also involved, either by directly participating in managing the different building typologies, or through the process to assure compliance with current rules and regulations. In fact, the decision-making process is complex and quite fragmented in the municipality organisational structure.

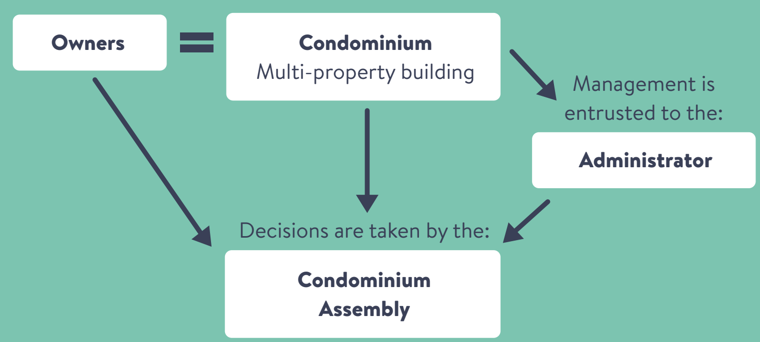
In Lisbon City Hall, the retrofit process was challenging and faced several constraints. These included central regulations, such as the protection of panoramic views and maintenance of original characteristics. These limited the measures that could be introduced, so alternative solutions had to be found. Additionally, as the next sections explain, the procurement process was challenging too. The utility company (and also a Sharing Cities partner) EDP Distribuição (EDP-D) was also involved in the process by ensuring the development of SEMS.

The Directorate General for Cultural Heritage (DGPC) – the national body responsible for managing interventions in classified buildings – played a key role too. The National Court of Auditors validated the financial and procurement aspects of most of the interventions.

MILAN

In Milan, the retrofits involved a multi-property development. This mean the stakeholder engagement process was complicated. Final decisions are dependent on the condominium assembly, a group which includes all the flat owners. The assembly is usually called to a meeting twice a year by the administrator. This is to approve the financial statement and talk about different issues such as building management, safety, cleaning and decorum etc.

At the start of the meeting, the administrator counts everyone present and calculates the thousandths of property they represent (each apartment, based on the commercial area in square meters associated with it, corresponds to a certain number of thousandths of ownership). At least 501 thousandths is required to validate the assembly. Then the majority must approve the project and, of course, the cost.

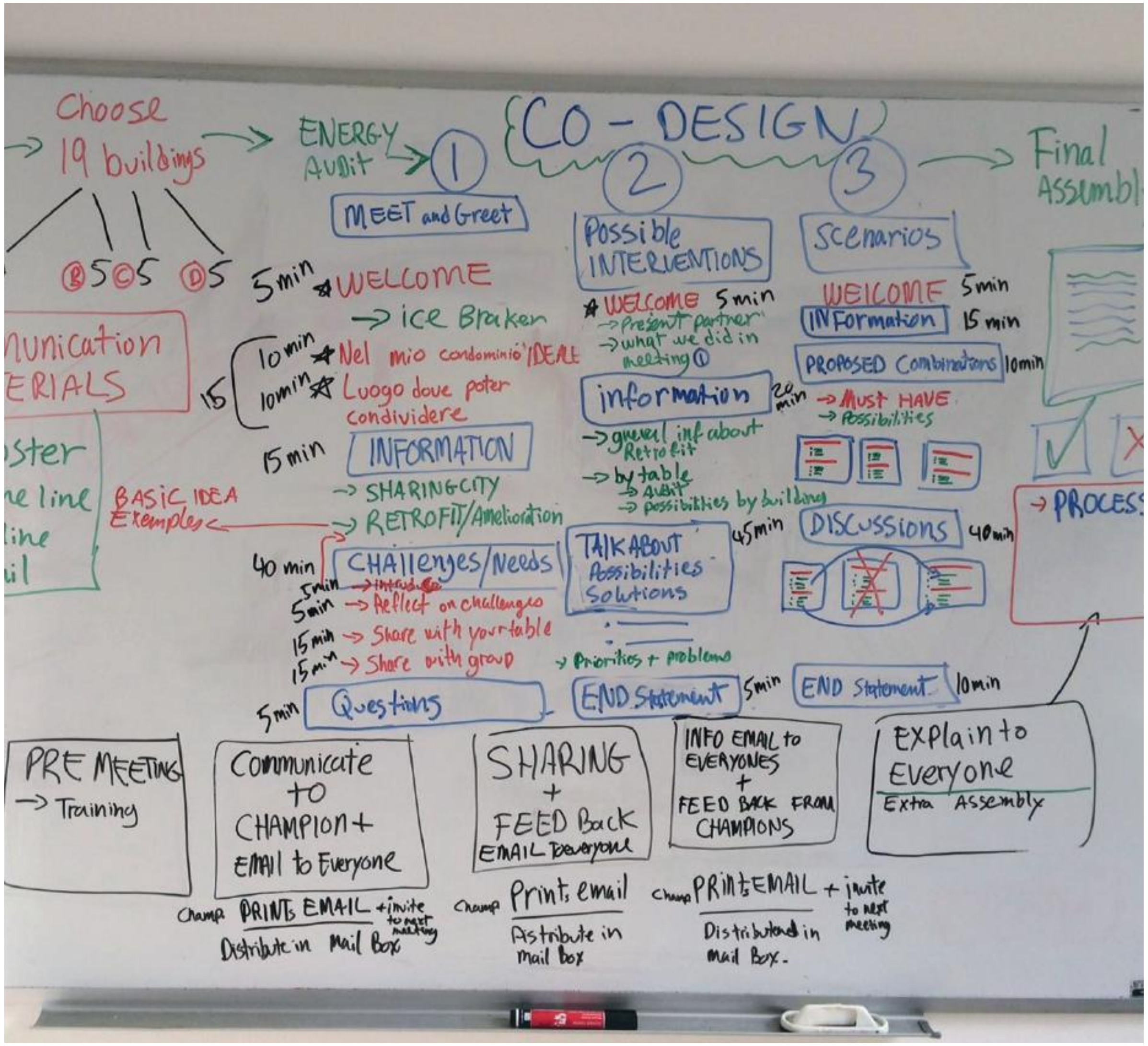


Introduction
Challenge & Solution
Insights
Benefits
Implementation Toolkit
How to rollout a deep retrofit
Stage 1 Exploring opportunity
Stage 2 Audience engagement
Stage 3 Technical design
Stage 4 Finance and implementation
Stage 5 Monitoring and sharing

Engage in co-design for residential type buildings

One unique outcome of our Sharing Cities' retrofit projects was a co-design process which better engaged residents in private dwellings. Co-design is based on cooperation between technicians – engineers and architects – and owners of multi-property buildings to create a shared solution. The objective is to minimise obstacles and barriers by clearly explaining the interventions, discussions, and presenting the results in a simple way. The aim is to create a positive and 'approval-oriented' mood inside the workgroup before the final assembly.

This type of approach can be very helpful in **residential properties**. It can ensure that residents affected by the building works are supportive throughout and understand how they'll benefit once work is over. It also helps ensure that residents use energy in an optimal manner once measures are in place. This co-design process was led by project partner TEICOS for private residential building retrofits in Milan, with local partners Politecnico di Milano-Dastu, Poliedra, Comune di Milano, supported by Future Cities Catapult (FCC) London.



Meetings with owners

The co-design process is divided into three main meetings and a further meeting with flat-owners of condominiums. The first three meetings took place in the local city hall, always at the same week, day and time to make it an easy habit for people. The additional meeting took place inside the condominiums.

In meeting one, we introduced the ideas of retrofit and co-design to residents. This included the importance of building energy efficiency in terms of reducing energy use, comfort and saving money. Participants were put in different groups so they could talk freely and find new visions together. They were asked to imagine their ideal house, the challenges of improving their own houses/ the entire building, and discuss specific needs.

Between meeting 1 and 2 there was an energy audit of the building. The results were summarised and presented in workshops in a simple way so everyone could understand.

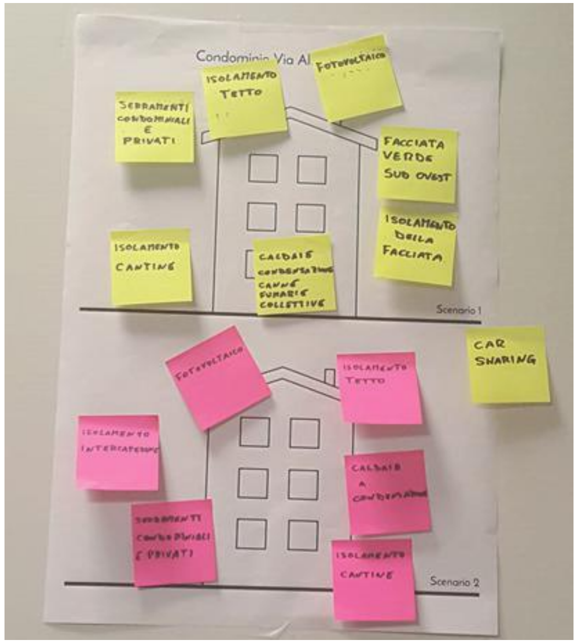
The main purpose of the second meeting was to develop energy retrofit scenarios for each intervention. This involved preparing a set of cards which described the interventions and technical solutions.

Each card describes the intervention and its advantages and disadvantages. It ranks each option in terms of energy performance, cost, time of realisation, invasiveness, maintenance and change of appearance. This allows people without technical knowledge to make an informed decision.

Interventions cards for building envelope (red), roof (green), energy system (blue)

Introduction
Challenge & Solution
Insights
Benefits
Implementation Toolkit
How to rollout a deep retrofit
Stage 1 Exploring opportunity
Stage 2 Audience engagement
Stage 3 Technical design
Stage 4 Finance and implementation
Stage 5 Monitoring and sharing

Below are intervention strategies for different parts of the building. For each intervention, you can apply different strategies and materials depending on cost, time and efficiency.



Scenarios poster produced in meeting 2

The third meeting aimed to bring everyone together on a shared project based on cost estimation and energy performance. Beforehand, the chosen two scenarios were analysed in detail. This included energy performance and cost assessment.

In the first part of the meeting, a poster of each scenario was shown with hidden cost and energy values. The aim was to ask:

1. How much would you be willing to pay?
2. In percentage terms, by how much do you think your condominium energy use could be reduced?

The real values were later revealed and discussed together. At the end, participants were asked to choose which scenario they preferred. Most chose a 'middle way'.

The final meeting took place in a common area of the condominium to encourage as many flat owners as possible to attend. We presented the chosen scenario in a poster with technical and economic information, and an emphasis on the environmental benefits of retrofitting.

After the retrofit

Planned post-retrofit actions

Experience shows that the energy renovation of a building should be accompanied by a 'renovation' of the inhabitants' behaviour. How occupants interact with the refurbished property can multiply the benefits of such interventions. That's why post-retrofit engagement is so important.

Post-retrofit engagement: Residents User Manual

To speed up behaviour change, we created a handbook to help residents better understand the interventions. It was drafted by our Sharing Cities partners Teicos and Legambiente, with technical support from acoustics, energy efficiency, fire and sustainable construction experts. drafted a manual: **Well living in an energy efficient home – a user manual for conscious inhabitants**. It has six chapters:

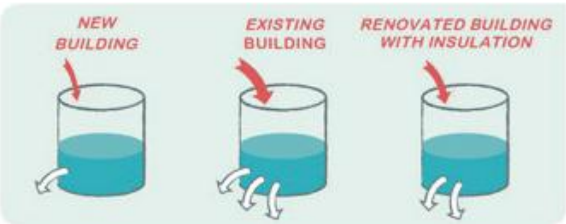
1. Why we produced a user manual.
2. Management of the dwelling.
3. Benefits of a thermal insulation intervention.

4. How to behave after the intervention.
5. Let's keep saving energy.
6. Q&A.

The three main objectives are to:

1. Inform the user about the correct management of a house, highlighting the main differences between before and now.
2. Describe general benefits of thermal insulation interventions.
3. Suggest the best way to enhance the intervention and avoid unnecessary consumption.

The manual uses simple illustrations to aid understanding of technical concepts. For instance, the building is represented by a jar. The newer and better insulated the building, the fewer losses. That means there is less need for energy to keep the comfort level constant (water level stands for comfort and/or internal temperature level).



New building: energy consumption is 'nearly zero'. Thermal insulation minimises losses; only a little energy is required to compensate for them.

Existing building (built before 2005): Not well insulated (or not insulated). It requires much energy.

Retrofitted building: Losses are reduced thanks to thermal insulation of the envelope.

The manual also gives practical examples. In paragraph 2.4, "Reducing humidity and pollution of indoor air", it shows a list of activities the steam production for each *(see table)*.

That helps in understanding terms (such as relative humidity) and shows 'what can you do' to best manage indoor air quality.

The manual provides simplified technical information and useful advice on managing the refurbished apartment. It aims to be a 'guide to change'. We consider it vital post-retrofit action.

TIPO DI AMBIENTE	ATTIVITÀ	VAPORE PRODOTTO
Soggiorno	Seduto in attività leggera	65 g/ora
Studio	Seduto in attività media	80 g/ora
Soggiorno	Guardare la televisione	45 g/ora
Cucina	Seduto a tavola	115 g/ora
Area fitness	Danza moderata	230 g/ora
Area fitness	Attività atletica	450 g/ora
Angolo cottura	Bollire 4 L acqua a fiamma viva e senza coperchio 30min	2800 g (da evaporazione) + 600 g (da combustione)
Angolo cottura	Bollire 4 L acqua a fiamma bassa con coperchio 30min	500 g (da evaporazione) + 240 g (da combustione)
Soggiorno	Lavare 20 mq pavimento	250 g
Soggiorno, piante in casa	5 vasi medi, piante verdi, stagione invernale	100 g/ora
Bagno	Asciugare all'aria un bucato di lavatrice, in inverno	200 g/ora (per 24 ore circa)
Bagno	Doccia, 10 min erogazione acqua calda	150 grammi

For co-design tools and templates, or more information on the Residents User Manual, email: **pmo@sharingcities.eu** or tweet us **@CitiesSharing**.

Technical design

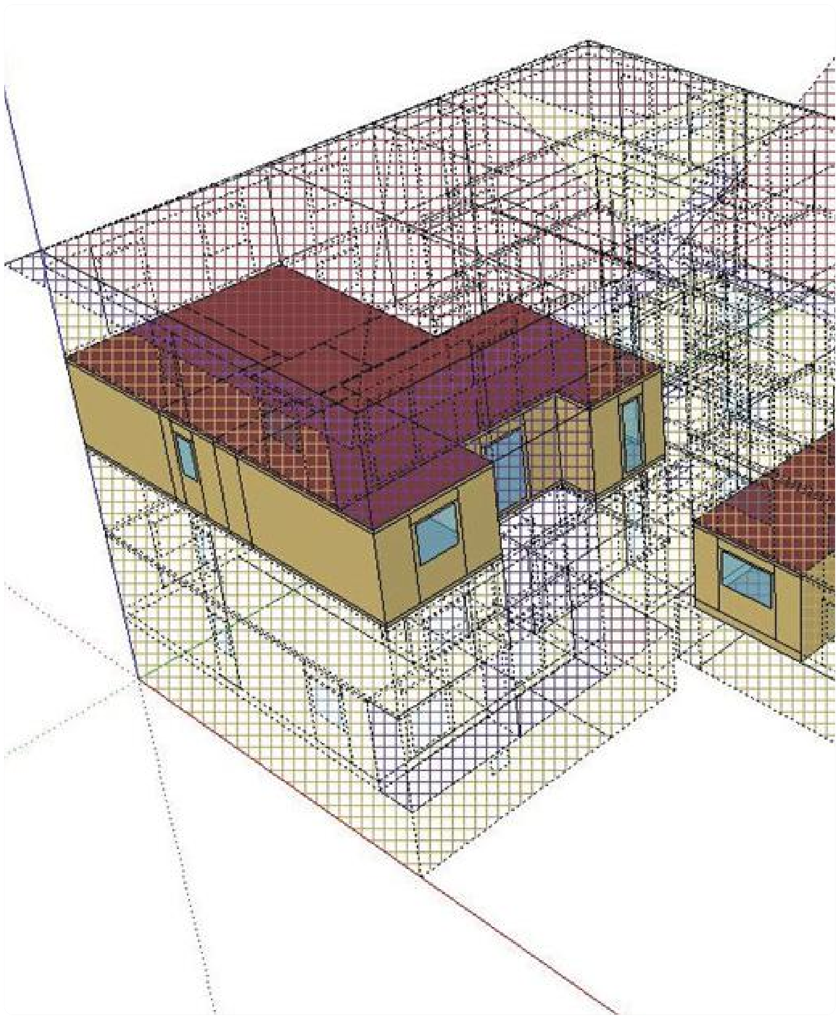
Assess technical options and choose a package of retrofit solutions

At this stage of the project, you need to first understand the baseline building characteristics. Then you can consider technical options to achieve your desired retrofit results.

Develop building energy model

Use the existing building plans and designs to create a 3D model of the building. You will need to think about the building's characteristics such as the materials used. You should also consider building use patterns, like the number of occupants and schedules for occupancy. Other factors include existing lighting systems, set point temperatures, and estimating equipment power and use, including heating and cooling systems. A building model can help you work out patterns of energy use. It allows you to run accurate audits to determine the building's initial state, as well as existing equipment and its influence on how energy is used.

Assess the potential impacts of different energy retrofit measures and solutions using these models and dynamic simulation software. Build scenarios which consider various combinations of different technologies, to help define the most suitable approach/package of solutions. This should be based on several criteria, including economic, financial and technical parameters. These must be assessed against potential impacts, considering any regulatory/legal limitations.



You can assess the impact of potential interventions once you understand the building's characteristics

LISBON

Lisbon employing Rhino (3D CAD modelling software), used this model alongside dynamic simulation software. It gave partners all the info they needed to determine the best approach/retrofit package and assess any potential impacts. The process was done by adding the building 3D model to an energy model developed in ArchSim. The complete models were then ran using EnergyPlusTM and a Lisbon weather simulation. The weather data came from LNEG, and accounted for weather variations throughout the year.

Lisbon City Hall 3D Model made with Rhino software

Develop technical specifications

Once the package of retrofit solutions has been chosen, you can start developing technical specifications for the works, procurement and rollout. Different types of building works may require input from specialists to help develop technical specifications.

Repairs works

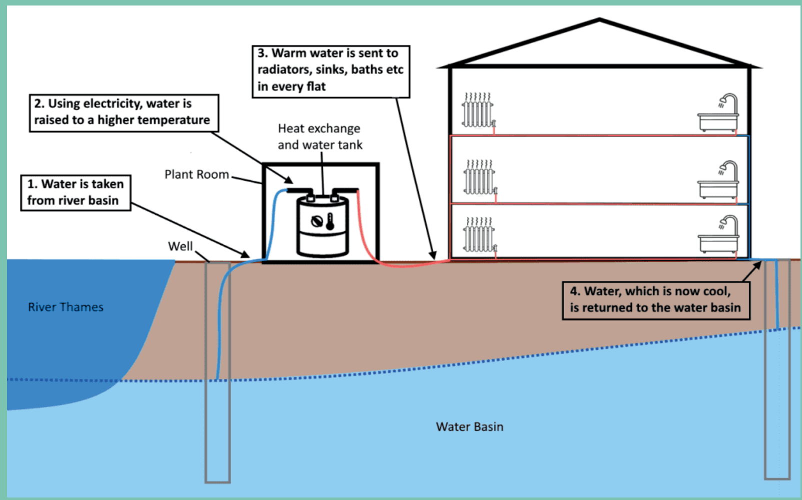
For repairs like façade brick work, concrete repairs, balcony coatings and redecoration, the technical design or determination of works may need to be made by a specialist. For example, a quantity surveyor or qualified officers in a city's housing department with experience in this area. This was the case in Greenwich for the social housing works.

Energy efficiency works and smart devices

Quantity surveyors can determine works to improve the energy efficiency, such as wall and roof insulation, windows, lighting, and more efficient individual boiler systems. Input will be needed from mechanical and electrical engineers to design the specification of devices including boilers, the electrical lateral and risers. This is also a chance to consider technical designs and specifications for new low carbon technologies that can be integrated into the buildings. In addition, this point is good time to consider introducing smart devices. These can monitor energy performance and impact, and help building owners and residents to manage and reduce their energy consumption.

LONDON / Water-sourced heat pump

For the Ernest Dence estate, integrating new tech involved an in-depth study of the feasibility of a zero carbon energy system. This led to the use of a water source heat pump. It draws water from boreholes which tap into the water source of the Thames gravels to provide heating and hot water for the estate. This option was chosen because of the area's hydro-geographical resource, suitability, potential carbon savings and economic reasons. Other options were discounted for several reasons including heat offtake no longer being available, and the tidal range of the Thames. This made it unfeasible to abstract water directly from the river itself.



Introduction
Challenge & Solution
Insights
Benefits
Implementation Toolkit
How to rollout a deep retrofit
Stage 1 Exploring opportunity
Stage 2 Audience engagement
Stage 3 Technical design
Stage 4 Finance and implementation
Stage 5 Monitoring and sharing

Finance and implementation

Develop business models and financing plans

Investment is always hard to secure, and it needs to be driven by the saving provided by the retrofit. The payback time of the investment, derived from the building's energy models, can help you understand costs and support for decision making. Despite these challenges, several funding mechanisms are available at EU level, mostly targeted at public authorities. In addition, most of the countries have national and local funding schemes targeting buildings energy efficiency and RES integration.

Several cities are also creating their own schemes. An example can be based on revolving funds and the creation of 'one stop shops' to ensure private owners are engaged.

Funding opportunities in EU countries include:

- European Structural and Investment Funds (cohesion funds in particular).
- European Investment Bank (EIB) loans.
- Green and/or social bonds.
- National and local grants.

Municipalities might have additional funding, if they are able to manage economic savings as further funding streams for deep energy:

- Savings due to Dutch auction (lowest unique bid auction).
- Savings in energy operational costs (especially if individual energy billing were made mandatory in public housing).
- Other revenue stream such as demand-response (participation in the flexibility market).
- Projects to leverage, divest and/or generate income from real estate holdings.

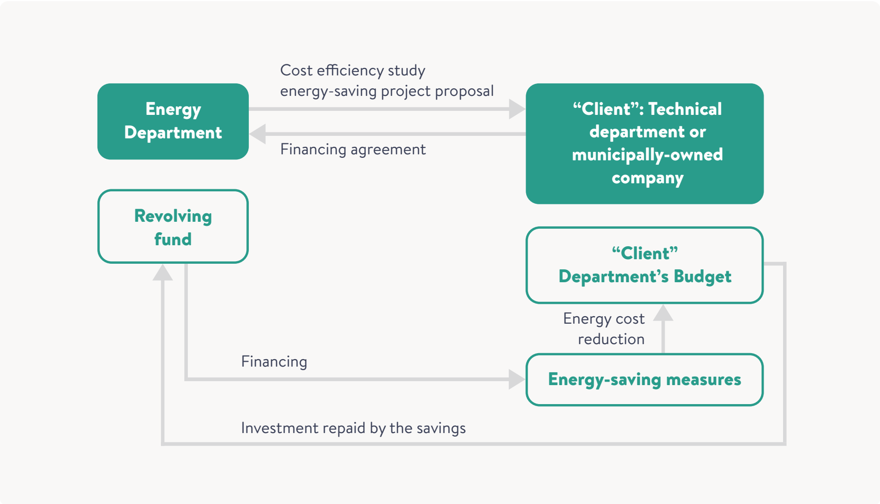
Revolving fund

Funding opportunities do exist at EU and national level, to foster deep energy renovation of public building stock. The limited use of it depends on the organisation of municipalities that typically do not have departments and trained personnel to pursue these opportunities. Moreover, city governments are typically unprepared to reuse the economic savings from energy retrofit as an additional revenue stream. Yet this can start a virtuous cycle to self-financing further energy renovation interventions.

A revolving fund is a financing scheme which allows a city to finance multiple investments aimed at energy savings without being bound to an external funder. This scheme, alongside internal contracting (intracting) schemes aims to increase energy efficiency and the use of renewable energy in public buildings, equipment and facilities.

The ‘intracting’ method is based on the idea of an energy performance contract (EPC) entirely operating within the city administration without involving external stakeholders. For example, an energy service company (ESCO). Different departments in the same municipality cooperate so that one may serve as the contractor for another lacking its own investment funds.

Contracting is based on the following process: a technical department or a municipally-owned company (‘the client’) submits an energy-saving project. The project and its energy-saving potential are then examined by the energy department. If the payback period proves acceptable and the project cost-effective, the two departments sign an agreement together. The ‘client’ department starts repaying the investment the following year. These repayments are then used to finance other projects of the same type.[5]



A schematic of a Revolving fund scheme, which Milan and Lisbon municipalities are pursuing

Introduction
Challenge & Solution
Insights
Benefits
Implementation Toolkit
How to rollout a deep retrofit
Stage 1 Exploring opportunity
Stage 2 Audience engagement
Stage 3 Technical design
Stage 4 Finance and implementation
Stage 5 Monitoring and sharing

Start procurement

Procurement processes differ depending on local regulations and building types. Here we highlight some of the more unique aspects of procurement our projects went through.

City-owned buildings

Working with city-owned buildings – including public buildings like Lisbon's City hall, and social housing, meant using public procurement procedures.

LISBON / Public Service buildings – Lisbon City Hall

Lisbon's City Hall building had to stay open during the retrofit works as it hosts some of the municipality's most important activities and ceremonies. It is also where the president and many city councillors are based. Together, these factors place strong limits on which interventions could be planned and put in place. As a result, the interventions were phased over time. They also were divided into different areas of intervention. This created some constraints around procurement. Conversely, it made some procedures easier and allowed the use of different procurement frameworks. This helped to reduce the value of tenders.

LONDON / Specialist requirements to enable innovation

The council conducted procurement for the works in Greenwich according to its existing procedures. Once the nature of the works was determined through the technical design process, this was translated for each estate into a scope of works. This defines what works will take place, and provides more detailed technical information and specifications.

The scope of works forms the basis of the procurement documents. It is then reviewed by a quantity surveyor to provide bidders with an estimated cost/budget for the works. This alongside instructions to bidders and information on scoring is then put out for tender.

A separate procurement exercise was needed for the Ernest Dence heating system as the works are of a specialist nature. Exploring an innovative water source heat pump and shallow boreholes meant a more detailed specification was required. This increased the likelihood of a specialist contractor and supply chain being used. To get the best results, a separate procurement was needed. It would also need to consider the addition of SEMS. This is something unheard of in the market.

Privately owned buildings

Working with privately owned buildings, the procurement process is not necessarily defined by regulatory procedures, although regulations differ by country.

MILAN / Tender or direct negotiation – starting works in private buildings

Tender

The condominium assembly invites companies to participate in the tender, with their own offer. The metric calculation/ estimate which has been developed by TEICOS is provided to the companies which will give their listing. It is costed according to the price list of building works of Milan Chamber of Commerce.

The condominium then chooses the most profitable offer, usually by means of a commission, made up of a group of owners. The group is tasked with comparing the offers both on the economical and the technical compliance side. This is key: technical indications, such as materials, technologies, execution and results must be respected to achieve the required impact. These are described in the BES tables.

Direct negotiation

The condominium, after a positive vote from the assembly, can otherwise choose to assign works directly to a company. In this case the administrator and company representative will be involved in a direct negotiation. This will focus on the definition of details, both technical and financial.

Monitoring and sharing

A good monitoring framework put in place at the start of rollout will ensure the scheme continues to deliver value during operation. The methods you use to measure the impacts of the specific measure must be reliably understood, quantified and evaluated. These will inform performance and areas of improvements.

As the saying goes, 'if you cannot measure it, you cannot improve it'. This is particularly true following renovation work, if you want to establish a knowledge loop and assess the procedure.

There are several reasons to monitor energy and environmental performance. For example, building management and performance optimisation as well as construction work assessment. It can also help create an operational database to inform future projects and provide educational tools to designers and city planners.

Detailed monitoring may in addition provide the basis for an accurate cost accounting. If people are urged to pay what they really consume, they may become more aware of environmental issues. This may lead eventually to more proactive and wiser behaviours. Nevertheless, costs accounting is a complex task in public housing for a range of social, technical, administrative, and political reasons. Sharing Cities established a quite detailed monitoring plan which was able to provide an accurate description of the building performance. However, the topic of accounting remains an untapped resource that requires a complicated approach to solve.

Data monitoring system and integration with SEMS

Conducting a building retrofit is also a good time to integrate smart energy management systems (see the Playbook here). This can further increase the potential impact of the energy efficiency works. It is important to consider what the appropriate solutions are based on your overall goals. This includes both energy efficiency fabric improvements and additions of low carbon energy supply and storage. The Sharing Cities deep retrofit works were done to allow a sustainable energy management system (SEMS) to be overlaid. The following explains how the technologies work together and can support performance monitoring and evaluation.

LISBON

The City Hall building monitoring views the impact assessment of the retrofit interventions in several ways. It focuses on energy consumption and production data, and the impacts such interventions have on comfort and how they are perceived. As such, the monitoring plan for the Lisbon service building requires data to be collected from several sources. This includes installing equipment linked to the sustainable energy management system (SEMS), surveys and interviewing operators, the building manager, stakeholders, municipality workers. A SEMS was also installed in City Hall. This system will monitor the loads from the PVs, the HVAC, the DHW heaters and other smaller equipment. SEMS will enable the monitoring and optimisation of energy consumption, as well as producing and sharing renewable energy on site.

LONDON

The programme takes a staged approach to monitoring and evaluating the building retrofit. It uses the timing of interventions to evaluate and understand the impact of each measure in addition to the overall impact. Greenwich follows this approach. It seeks to evaluate physical measures on the estate like wall insulation and renewable energy generation. It also considers the impact of new energy efficiency devices, services and advice to estate residents.

Static data from surveys and thermal imaging has been collected. This is augmented by real time data from a number of smart or IoT devices deployed on both estates. The aim is to monitor communal and residents' energy use, and environmental indicators. In collecting this IoT data, there have been concerns around data protection and adherence to the General Data Protection Regulation.

A SEMS has been developed for the heating system at Ernest Dence Estate. This system will seek to optimise the running of its heating/energy system by taking in data from the different energy assets. These will then be combined with external factors such as weather and energy pricing, and algorithms and an advanced process control approach will be applied. To date, optimisation based on cost and carbon emissions has been modelled. In the process of creating the SEMS, a digital twin environment was built to simulate the estate and energy assets being introduced. The digital twin was also able to simulate the impact of the energy efficiency measures planned for the estate.

MILAN

For the private residential buildings, impacts will be monitored by collecting information from smart meters installed in residents' houses and the common area. In addition, meters have been installed to collect information on the renewable energy produced in site.

BEMS (building energy management systems) will also be installed, but this information will be confidential. Due to privacy issues, this process requires residents' consents, which will be collected shortly. The impacts of the retrofit measures on their satisfaction, comfort perception, needs, routines and behaviour changes will also be addressed.

Common monitoring framework

A common monitoring framework allows you to compare metrics with other similar schemes globally, and easily identify where performance can be improved. CITYKeys is a performance monitoring framework funded by the EU's HORIZON 2020 programme. It has worked with cities to create and validate key performance indicators and data collection procedures. By so doing, CITYKeys has enabled common and transparent monitoring and easy comparison of smart solutions across European cities. Read more at: **www.citykeys-project.eu/citykeys/project**

Sharing Cities also developed a common monitoring framework to evaluate performance of all our smart cities projects. As such, the building retrofit projects are measured in six ways: technical, economical, business, social and system. To perform this holistic evaluation, we monitor several metrics including:

- **Input metrics**: These are exogenous (system level or technical) characteristics that need to be controlled for order to assess the effective impact of the building retrofit interventions (for example: local weather, local events, national primary energy factor and population density).
- **Process metrics**: These are monitored to provide information on the practical viability of the specific building retrofit intervention from the technical, institutional and economic point of view (for example financial viability).
- **Output metrics**: these are the techno-socio-economic metrics measured to quantify the impacts of a building retrofit intervention. (For example, household energy bills, sensor data, infrastructure installed, technologies developed).
- **Outcome metrics and impact KPIs**: these quantify the effect of an intervention along the six perspectives shown above. For building retrofit interventions, these are:
    - Household and communal energy use, household indoor comfort, tenant housing satisfaction.
    - Participation of RES, operational reliability and grid stability/ peak load.
    - Greenhouse gas emissions and pollutant emissions.
    - Stakeholder satisfaction.
    - Solution replication.

Key metrics

The table on the following page provides an overview of the KPI Sharing Cities used to monitor and evaluate our building retrofit initiatives.

KPI	Stage	ShC CMEF lvl	Perspective	Aggregation	Reference	City
Household energy use	Outcome	Retrofit, SEMS, DSM, Smart City	Technical	Household, City	ETSI TS 103463, CITYkeys, ITU-T 1602, ISO37120, SCIS	Lon, Mil
Communal energy use	Outcome	Retrofit, Lamppost, Smart City	Technical	Building, City	ETSI TS 103463, CITYkeys, ISO37120, SCIS	Lon, Mil
Participation of RES	Outcome	Retrofit, SEMS, Lamppost, Smart City	Technical	Building, City	ETSI TS 103463, CITYkeys, ITU-T 1602, ISO37120, UN SDG11, SCIS	Lis, Lon, Mil
Household indoor comfort	Outcome	Retrofit, Smart City	Attitude	Citizen	CITYkeys	Lon, Mil
Tenant housing satisfaction	Outcome	Retrofit, Smart City	Attitude	Citizen	ESCR	Lis, Lon, Mil
Greenhouse gas emissions	Impact	Retrofit, Lamppost, Smart City	System	Building, City	ESCR, ETSI TS 103463, CITYkeys, ITU-T 1602, ISO37120, SCIS	Lis, Lon
Pollutant emissions	Impact	Retrofit, Lamppost, Smart City	System	Building, City	ESCR, SCr, ETSI TS 103463, CITYkeys, ITU-T 1602, ISO37120, UN SDG11	Lis, Lon, Mil
Operational reliability	Outcome	Retrofit, SEMS, Lamppost, Smart City	System	Household, Building, Local electricity substation	ITU-T 1602, ISO37120	Lis, Lon
Grid stability/Peak load	Outcome	Retrofit, SEMS, Smart City	System	Local electricity substation	ISO37120, SCIS	Lis, Lon
Stakeholder satisfaction	Impact	Retrofit, SEMS, Mobility, Lamppost, Smart City	Business	Household, Building, Scheme	CITYkeys	Lis, Lon

Introduction
Challenge & Solution
Insights
Benefits
Implementation Toolkit
How to rollout a deep retrofit
Stage 1 Exploring opportunity
Stage 2 Audience engagement
Stage 3 Technical design
Stage 4 Finance and implementation
Stage 5 Monitoring and sharing

KPI	Stage	ShC CMEF lvl	Perspective	Aggregation	Reference	City
Financial viability	Process	Retrofit, SEMS, Mobility, Lamppost, Smart City	Economic	Household, Building, Scheme	CITYkeys, SCIS	Lis, Lon, Mil
Local weather	Input	Retrofit, Mobility, SEMS, Lamppost, Smart City	System	City		Lis, Lon, Mil
Local events	Input	Retrofit, SEMS	Technical	Building, City		Lis, Lon, Mil
Primary energy factor	Input	Retrofit		National	National standards	Lis, Lon, Mil
Solution replication	Impact	SEMS, Mobility, Lamppost, Retrofit	Business	City, Global	CITYkeys	Lis, Lon, Mil
Household energy bill	Output	SEMS, Retrofit	Social	Household, Building, City	ETSI TS 103463, CITYkeys	Mil
Population density	Input	Retrofit, Mobility, Lamppost	Social	City		
Data produced/ transmitted	Output	Lamppost, Retrofit, SEMS, Mobility, Smart City	Technical	Scheme, City		Mil
Infrastructure installed	Output	Retrofit, SEMS, Mobility, Lamppost	Technical	Scheme		Lon, Mil
Technologies developed	Output	Retrofit, SEMS, Mobility, Lamppost	Technical	Scheme		Mil

Introduction
Challenge & Solution
Insights
Benefits
Implementation Toolkit
How to rollout a deep retrofit
Stage 1 Exploring opportunity
Stage 2 Audience engagement
Stage 3 Technical design
Stage 4 Finance and implementation
Stage 5 Monitoring and sharing

References

1 IEA (International Energy Agency), 2015: Energy and Climate Change, World Energy Outlook Special Report, OECD/IEA, Paris.

2 EC (European Commission), 2010: Directive 2010/31/EU of the European Parliament and of the Council, of 19 May 2010, on the energy performance of buildings.

3 Source: https://ec.europa.eu/energy/en/eu-buildings-factsheets-topics-tree/energy-use-buildings

4 C. Sousa Monteiro, F. Causone, S. Cunha, A. Pina, S. Erba, Addressing the challenges of public housing retrofits, Energy Procedia, Volume 134, 2017, pp 442–451

5 P. Schilken, J. Cicmanova, Cities and regions: Accelerate your energy transition thanks to innovative financing schemes!

Acknowledgements

This playbook is part of a series focusing on evidence and lessons learned from Sharing Cities, which is funded by the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 691895.

It was produced Sharing Cities partners indicated by the logos below.

Designed by: It's Like This Studio

Contributions from: Liam Dargan

Edited by: Helen Booth

Photography

Photos from Lisbon Case Study are credited: Lisbon Municipality

SUPPORTED BY

MAYOR OF LONDON