Sustainable Energy Management Systems

A SHARING CITIES PLAYBOOK

2020 V.1

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CONTENTS

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.

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WHAT IS THIS PLAYBOOK?

This guide gives an overview of how Sharing Cities rolled out sustainable energy management systems 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 our 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 leaders, governments and public authorities who are considering or are in the initial stages of rolling out a sustainable energy management system (SEMS) or similar service.

2

Lighthouse city members of Sharing Cities looking for a way to sustain their SEMS post-funding from Horizon 2020.

3

Follower cities in the Sharing Cities network who may be in the process of developing and rolling out SEMS.

4

Energy industry stakeholders, regulators, policymakers and end users that may gain useful insights into new ways of working and governance practices.

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 (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.
- **Sustainable energy management systems** – 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 sustainable energy management systems (SEMS). To find out more about the EU Smart Cities Clusters projects, visit EU Smart Cities Information System (SCIS).

1. Sustainable energy management systems: Optimising energy efficiency

The urban energy 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, governance and infrastructure.

Installing, upgrading or replacing urban infrastructure (such as energy, water, sanitation, waste, transportation and telecommunication) is hard. It requires significant investment and forward planning and accounting for a broad set of factors and activities. It also often has huge financial, environmental and social consequences. As such, a sustainable approach is needed, particularly considering the wider global challenge of climate breakdown.

Generally, the response of cities to the challenge of an increasing population has fallen into two broad categories:

i. **Renewable energy generation** – Increasing energy demand alongside public awareness of environmental issues has led to various government policies and commitments to expand and decarbonise local energy generation. However, many low-carbon energy technologies still lack maturity compared to traditional options. This means public schemes are still required to support deployment and attract the investment needed in technologies and infrastructure.

ii. **Energy efficiency** – The case for improving energy efficiency is clear and focuses on reducing demand – that means decreasing the overall energy requirements. However, there are a much broader range of benefits to energy efficiency being more widely adopted. It supports economic growth, enhances social development, advances environmental sustainability, ensures energy-system security and helps boost prosperity. However, these benefits are often left out of programme evaluations for various reasons. These include a lack of relevant data and evaluation methods, estimation challenges and perceived credibility risk.

Despite renewable generation and improved energy efficiency being part of the solution, energy management at a district or city scale is often overlooked. One reason is that energy management in cities is typically run by isolated digital and hardware solutions, leading to missed opportunities. A joined-up approach is needed to energy management and the promotion of adequate urban planning practices. This can create opportunities to reduce energy consumption and support the integration of renewable energy systems (RES) and smart grid technologies in cities.

Political, geographic, cultural and economic contexts can add to the challenge. But, they also offer cities the chance to customise their approach to managing their own energy ecosystem.

LISBON / City-wide energy management system

South-western Europe's geography means that Lisbon has different energy needs from other parts of the continent. Cooling is very much in demand, and natural gas is used mainly for cooking and producing domestic hot water (DHW) rather than heating.

The city's building stock is long overdue for renovation. This increases the costs of refurbishing existing buildings compared to new development outside the city centre. Buildings in the downtown area benefit from heritage status. However, this makes refurbishment and the adoption of renewable generation technologies complex.

In 2018, the Municipal Assembly approved the Sustainable Energy and Climate Action (SECAP) plan. This forms the city's environmental performance planning and monitoring tool towards 2030. It is based on a commitment to communication, information and education, by providing quantified and up-to-date information on different city indicators. These include energy, water, greenhouse gas (GHG) emissions and materials. This approach is delivered through the Lisbon Observatories initiative.

This has created the framework for a city-wide energy management system. Development has centred on the system's integration into the strategies and policies defined for the city, providing a broader vision for the tool. This integration has focused on aligning and connecting with other tools and methods being used and developed.

MILAN / Combines economic growth with sustainable innovation

Milan's specific challenge is to rollout sustainable innovation following a harsh and prolonged economic crisis. This requires radical changes in how people live, move, and work, and in the municipality's level of involvement and engagement with citizens.

Between 2012 and 2014, Milan's city leaders adopted a series of plans and strategic policy frameworks. These included around urban development; sustainable mobility; energy efficiency; the sharing economy; and smart cities. However, complex urban challenges linked to significant economic and population growth threaten these policies. Solutions must be shown to be scalable and transferable to accommodate this future uncertainty.

Launching a Smart Energy Management System is further challenged by the exponential increase in big and open data, and the complexity of digital infrastructure rollout. This includes issues around data privacy, security and ownership.

Milan municipality is also promoting SYNCHRONICITY. This project aims to create a universal approach to developing, procuring and deploying IoT- and AI-enabled services. It embodies the principle of integrating projects so there is a trackable and interoperable ecosystem. This will produce a range of co-benefits and will multiply the impact from individual projects.

LONDON / Growth borough Greenwich supports the city's energy transition

Greenwich is also an area of historical and cultural significance. This creates challenges associated with energy efficiency, building improvements and renewable installations. Other local concerns around air pollution and the climate emergency means action is vital. The borough is currently developing a zero carbon action plan. It acknowledges the need to invest in more policy changes and projects and sets ambitious targets including:

- Procuring 100% renewable energy.
- Buying more zero and ultra-low emissions vehicles.
- Making sure all our new buildings are energy efficient.
- Planning to install LED street lights which use less power.
- Creating safer routes for walking and cycling.
- Rolling out controlled parking zones to discourage car use.
- Installing electric vehicle charging points.
- Planting thousands of extra trees.
- Setting up a carbon offset fund to finance future energy-reducing measures.
- Creating a partnership of businesses and local organisations to help reduce emissions across the borough.

Ofgem, the UK's gas and electricity regulator, ran a consultation for the 2021 energy price control period, RIIO-2 (Revenue=Incentives + Innovation + Outputs). RIIO-2 places a greater emphasis on network companies to support innovation in the energy system. The aim is to support the transition to a decentralised, decarbonised and digitalised future for the network. In this regard, a system able to optimise energy assets across a district or city scale is an increasingly important feature of the energy system.

Sustainable energy management system (SEMS)

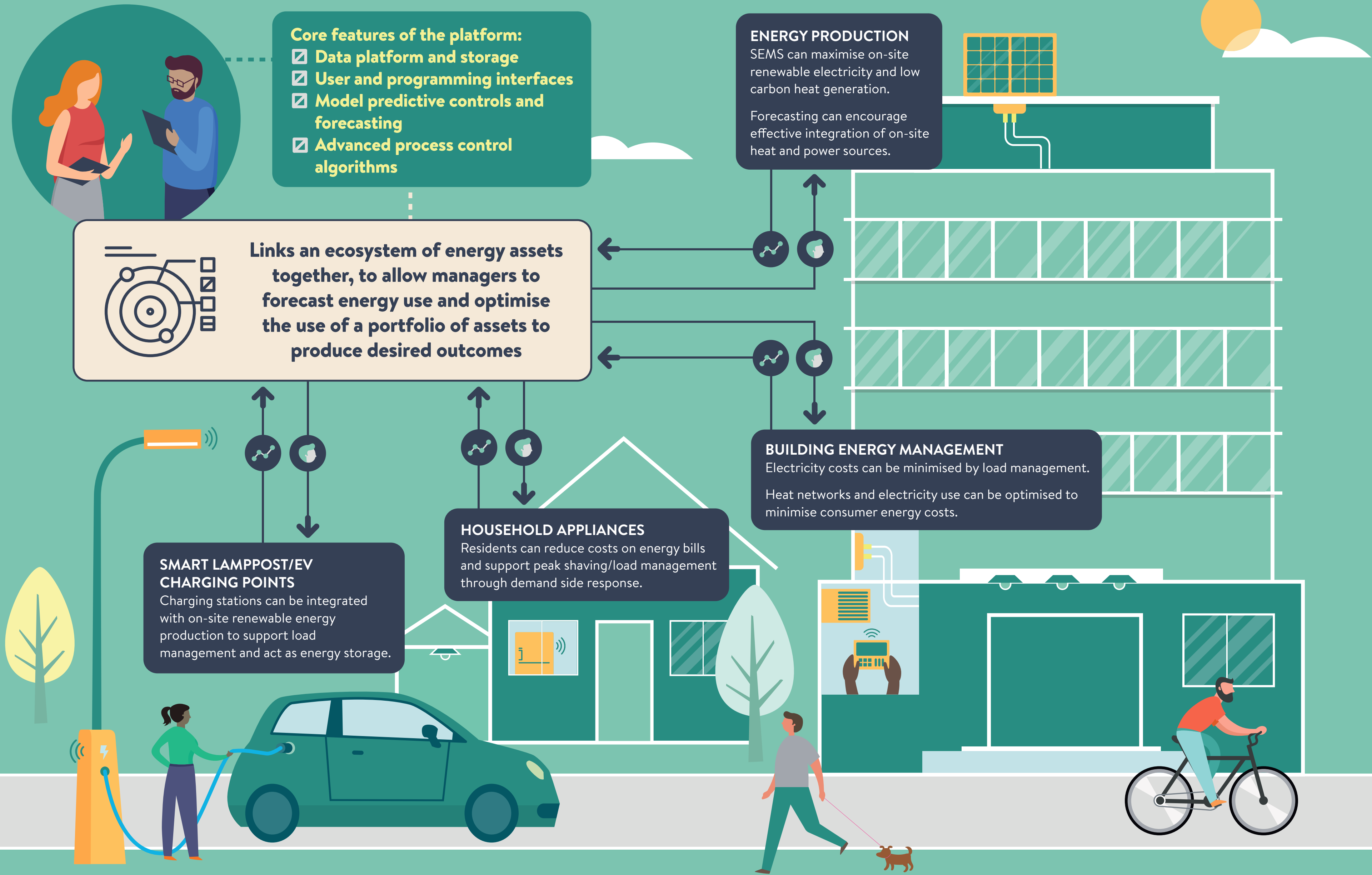
SEMS is an integrated energy management system that allows energy managers to control and optimise use. Energy assets can include:

- Energy producers like solar panels and heat pumps.
- Energy consumers like lampposts.
- Electric vehicle charging points.
- Household appliances like washing machines and dryers.

The SEMS works by linking all these energy assets together. It collects data from them and forecasts energy use. This helps energy managers to understand energy production and use patterns. These can be combined with external data such as weather to predict levels of demand or production. Equipped with this information, energy managers can use SEMS to control the way energy assets are operated across the network. The 'optimal' solution is different depending on your policy goal. So, if you wish to improve air quality, you'd set up the system to help energy managers use it to reduce local air pollutants. To reduce carbon emissions, you'd set it up so energy managers can maximise the use of renewable energy and energy storage. The system will achieve these goals by linking all the assets together and forecasting how energy managers can best use the energy assets.

Policy objective	How SEMS can help achieve policy objective
Improve air quality	Reduce energy consumption from combustible sources that release pollutants harmful to health.
Decrease carbon dioxide emissions	Operate energy assets and instruct consumers to operate appliances when renewable energy generation is highest.
Load balancing/peak shaving	SEMS can forecast when peaks in energy use occur and ask users to reduce electricity consumption at those times or use energy storage when available.
Optimise energy performance	Operate energy assets according to demand and ignore cost and environmental factors.
Low cost energy	Operate energy assets and instruct consumers (residents) to operate appliances when electricity costs are forecast to be low.
Revenue maximise	Operate the energy assets to maximise income from national and local revenue streams.

The key parts of a sustainable energy management system



2. Insights and recommendations for rolling out SEMS

We have applied the core common principles of SEMS consistently across the three lighthouse cities and over the lifetime of the project. However, the nature of cities and the limitations imposed by the financial, commercial, regulatory and technical barriers requires flexible and adaptable approach. The evolution has been a smooth process because of decisions made at the start of the project. For example, a modular approach to system architecture, using strong data communication methods, using an integrated data platform and deploying 'online' and 'offline' control.

SEMS is operating in a virtual or live environment in all three lighthouse city projects. This provides feedback for system calibration and refinement. By taking an iterative approach to refining these systems, we have developed the following recommendations:

- The **modular approach** to SEMS allows you to take advantage of existing city assets or integrate assets developed in future.
- Provide **flexibility for algorithm** additions or development to update SEMS as your energy system changes.
- Understand the limitations of control in a commercial setting and be realistic about the level of influence you can expect over proprietary assets and infrastructure. **Design your control strategies appropriately**.
- SEMS is well placed to take advantage of increasingly available data. Simplifying the secure **access to energy data** is a key enabler for this technology.
- **Cloud services provide scalability**, but the increase in energy consumption from computational requirements and data servers will need to be addressed.
- The **ownership model requires clarity**. SEMS as a city service or infrastructure supports the system's ambition and objectives, but current technical and financial resources sit with private organisations.
- For proprietary development of SEMs, the external social, environmental and financial **benefits should be internalised**. Clear price signals for energy flexibility, and emissions reductions would support this.

Key considerations

Each component of SEMS has several merits. There are also challenges and contextual considerations which can impact how viable and effective SEMS is to achieving your goals.

1. Location

SEMS is designed to be an entirely open and interoperable system, allowing any energy assets or management systems to be integrated. This means any location is a potential site for deploying SEMS.

However, when choosing districts or energy assets, consider the following:

Availability and access to data. SEMS is extremely data intensive. Therefore, energy vectors that you already have available data for, or can easily obtain data, will improve the system's performance and functionality.

Asset diversity. System integration and optimisation will have a greater impact if there is a diverse mix of generation, storage and consumption assets available. This will provide greater demand and generation diversity, offering SEMS a greater range of control strategies.

Scale. Assets that are more energy intensive could experience greater benefits from SEMS optimisation. Consequently, you could achieve greater impact, such as environmental savings, cost savings, renewable generation.

Significance or potential impact. For political or institutional reasons, you may choose to include 'statement' assets within the SEMS portfolio. This could be used to showcase what is possible and demonstrate leadership.

Demographics. SEMS is designed as a solution to the increasing demand and electrification of city systems. Therefore, choosing a geographical area that is energy constrained or is expected to be so in future, will maximise the benefits of SEMS.

Digital twin provides a virtual environment to test SEMS on future infrastructure

There are important considerations for the location of deployment in the real-world. However, the speed at which software solutions can be developed will often outstrip physical infrastructure installations and upgrades. That's why it's important to use a 'virtual simulation' to test the system before launch, or a **'digital twin'**. This can be in the form of a simple model, generating artificial data to calibrate and validate the algorithms. It can also be a fully modelled energy system using known specifications for future assets with virtual links shadowing data platforms and control simulators.

The form of simulation you choose will depend on the time and budget available. However, a more detailed simulation can eliminate uncertainty. It can be used as a support tool for validating energy infrastructure investment decisions and identify future constraint areas.

In London, the DataStore meant real-time data was available to a virtual simulation of the Greenwich SEMS before the physical infrastructure was deployed. Using known specifications of the energy assets to be used in Greenwich, experts from Sharing Cities' partner Imperial College London developed a 'Digital Twin'. This simulated the existing and proposed local energy system. It includes data transfer, modelled assets and forecasting and optimisation algorithms. This meant the city could simulate energy consumption to test different use scenarios, while construction on the retrofit works were still being done. Greenwich provided data on the local context and buildings and expected system constraints (like thermal comfort of residents). Greenwich also outlined their policy objectives, such as cost savings and CO_2 reduction. This ensured that the virtual environment was representative of the real world to allow for a smoother deployment of SEMS.

For a detailed overview of the Greenwich SEMS and digital twin architecture **see the paper** co-authored by researchers from Imperial College London, The Alan Turing Institute, and the Greater London Authority.

2. Delivery methods

The procurement process to determine the right solution providers will have a big impact on how the entities involved in the SEMS collaborate. SEMS is made up of several components; forecasting algorithms, predictive controls, human and programming interfaces, data storage and machine learning. You must decide whether to appoint a single 'turnkey' provider to deliver the whole system, or if you prefer a consortium.

The technical nature of the system components and the communication between them may be more reliable if the same entity developed the entire solution. A single solution provider may also provide the fix more quickly and cost efficiently than a consortium. This is because resources may be more readily available and internal working processes already established. However, the highly technical nature of the tender specification means that very few organisations (if any) can deliver all elements. Even if they claim to have the ability and capacity to provide all requirements, they may not be specialists in each area. That is why procuring highly skilled technical partners to form a collaborative consortium is a viable alternative. In this situation, skilled and significant project management resources are needed to ensure alignment and integration. However, it allows for a modular and non-proprietary system to be developed which can be amended and added to in future. It also reduces the risk of a single organisation withdrawing from a project or being unable to deliver.

Whatever the decision relating to a turnkey or consortium delivery method, the procurement process is vital. Identifying and pre-qualifying suitable organisations will save significant time in the procurement process. A well-structured and comprehensive brief ensures a good response. It also minimises the resource requirements of reviewing and evaluating multiple submissions.

3. System design

SEMS works best when designed to integrate with a data sharing platform, to avoid excessive data transfer, storage memory and processing power. In Sharing Cities, SEMS was designed to integrate with the Urban Sharing Platform developed for the project. This provided a horizontal mechanism for integration. At small scale, it is possible for SEMS to also collect data – making it a fully autonomous system which operates independently from a USP. This is a far cheaper and quicker solution and may suit if your budget and timescales are tight. However, this design limits the system's future scale-up and replicability.

As a minimum, SEMS should integrate with a data store. Other useful functions of the USP include a graphical interface and data reporting. The USP could also provide the interface between local energy assets and SEMS. However, this will require a long-term plan for operation and maintenance services (may be more complicated in a collaborative solution).

The system design must also consider whether licensed or open software is most appropriate. Licensed software often consists of more comprehensive functionality and dedicated support services. Yet it may not be able to interface with all existing or future data-sources. The use of an open source platform is cheaper and offers greater flexibility for future development. If it possesses enough functionality to your project's requirements, this will also prevent compatibility issues. However, open source systems may also require careful consideration of security and accessibility.

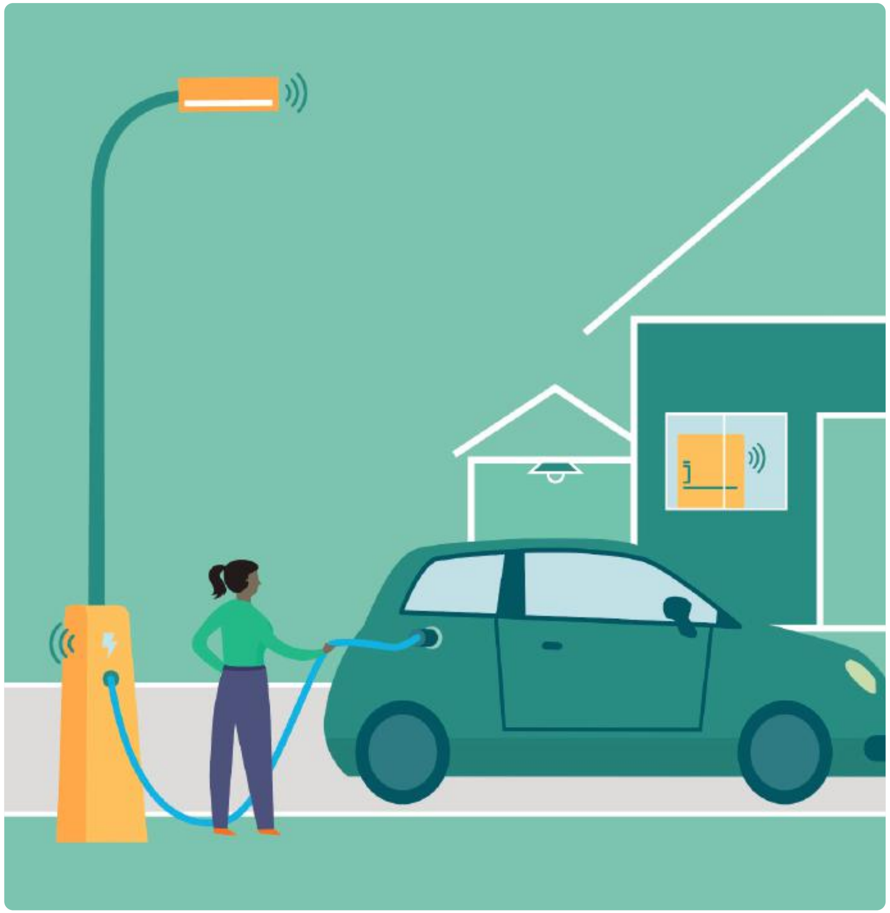
Eliminating the ability of SEMS to control management systems directly is one way to mitigate this issue. Ultimately, the system design you choose will be directed by your project aims and stakeholder objectives.

4. Functionality

SEMS could use a single algorithm in which all assets are handled in one optimisation. It could also adopt a more modular approach where different modules are managed by a coordination layer. There are several, diverse types of energy vectors and objectives to be managed by SEMS (in particular considering future scalability). As such a modular solution may be most practical. Taking a modular approach to deploying algorithms will require additional resources to develop the coordination layer. It will also allow new assets to be added separately and at different times. This means it is more robust and scalable. This prevents the risk of issues within a single algorithm causing a total system failure, as problems can be isolated.

An 'algorithm engine' uses tags and labels to identify the responsibilities of different modules and associate them with specific assets/groups of assets. This is an important part of a modular system. Such algorithms could also be supplemented with an asset template to define the information needed for use in new algorithms.

The design of the control functionality of SEMS is critical. The solution from the algorithms can be activated directly through SEMS or provided to local management systems as recommendations. A direct control strategy would provide more optimised performance and ensure the system operates in a fully integrated and coordinated way. However, there may be some assets which, for technical, commercial or legal reasons, cannot be directly controlled by SEMS. Direct control could also present a security risk as previously mentioned if the SEMs using open-source software. Therefore, your system may prefer to employ a local management system. This will limit its influence to sending recommendations for activation only if they are within pre-defined parameters of the local system.



Recommendations from the lighthouse cities' experience

By testing SEMS in Sharing Cities, we found that there are several barriers which limit the potential for city-scale energy management systems. These can be broadly categorised into four areas – technical, financial, regulatory, and commercial. Through our experience, we have developed a set of recommended actions that start to address certain aspects of these barriers.

Critical issues/ barriers	Recommended actions – What	Recommended actions – Why
Technical – Our energy system is in a period of transition. New technologies are being developed and deployed at a rapid pace. Developing a management system that can integrate existing and future technologies is difficult given the uncertainty.	Understand your existing energy assets, including the available data and control functionalities that they provide.	This will inform the scope and scale of SEMS. Older assets will have limited control functionality and may require new sensors and meters for enabling data connections. In some cases, assets may need to be replaced or upgraded. It is best to know this as soon as possible as this can take time.
	Using a modular system architecture allows you to add new features over time. Anticipating further innovation in the energy system and planning your solution will help future-proof SEMS.	SEMS is meant to free cities from technological lock-in. The modular nature allows new innovations to be introduced without making the existing system redundant, saving both time and money.
	Integrate your delivery plan with other planned activity in your city. The scope of this activity should align with your SEMS goals. This might include building upgrades and retrofit, e-mobility infrastructure and vehicle deployment, renewable energy installations.	Understanding planned activity will inform the scope of SEMS in your city. This will allow you to smoothly integrate new functionalities, assets and systems. Being aware of timescales for delivery will also improve project planning. This will enable you to anticipate key periods of rollout and allow for suitable resourcing.

Critical issues/barriers	Recommended actions – What	Recommended actions – Why
Financial – It is difficult to determine the value of SEMS, despite a detailed monitoring and evaluation process and extensive list of measurable indicators. The value placed on the social and environmental benefits is a political or social decision that will vary spatially and temporally. Without clear and predictable price signals for all SEMS performance indicators the system is likely to be undervalued.	The use of a virtual environment (also known as a digital twin) to model your existing energy system is a valuable resource. Try to make your model as accurate as possible. Don't worry about estimates or incomplete information in the early stages. You will refine and develop your model with your project.	A virtual environment will allow you to test new assets and technologies against a baseline of the current system. This can assist techno-economic modelling, support a business case and inform investment decisions. It can be used to test, validate and calibrate your algorithms before applying them to a live environment. It will also help with any monitoring and evaluation processes.
	Set realistic and achievable objectives for SEMS that account for your technical and resource limitations.	SEMS is a highly technical solution that requires significant budget and resources. Some challenges, such as integrating EV chargers or forecasting energy demand in a public space are very complex. Solutions are possible, but they are costly and time consuming.
Regulatory – The energy sector is subject to heavy regulation. Many of the new technologies being showcased here push the boundaries of this regulation. For example, energy trading or remote access requires lengthy, expensive and time-consuming processes which are unrealistic to achieve even within this project's timescale. Regulation in the energy sector needs to adapt in a more agile way to innovation. Until then, we will not see the full suite of optimisation solutions SEMS can offer.	Build and maintain strong relationships with project stakeholders. A system-energy solution involves many different actors from wide ranging industries. Many of these actors will have their own objectives which will regularly conflict or complicate the solution.	In a sector unused to integrated collaborative approaches, having close relationships with your stakeholders will smooth the rollout of technical solutions. More importantly, this is vital for establishing contracts around data sharing, asset/network performance and actuation. These arrangements are essential for the project to be delivered.
Commercial – Proprietary interests limit the scope of SEMS to provide a unified city-wide energy management solution. The social and environmental benefits underpinning SEMS are not easily folded into traditional business models. However, this fails to resolve the question of ownership. Without this, the adoption of SEMS will be limited.	Using a modular system architecture allows you to introduce new features over time. Anticipating further innovation in the energy system and planning your solution to accommodate this helps future-proof SEMS.	SEMs is intended to free cities from technological lock-in. Designing a system to accommodate future developments will also help you assess and choose the right ownership model.
	Having the right mix of partners, with the knowledge and technical ability to understand the city context, develop insightful use cases and create a system architecture that will fulfil the requirements of the city.	Makes sure the solution meets the requirements of the city and accelerates the delivery process. This also allows you to identify any skills gaps within your consortium and begin to fill these. In addition, it provides early opportunities to influence the tender process and specifications of new energy assets so they're compatible with SEMS.

3. What is the value of installing SEMS?

SEMS is a low-cost way to use an integrated and optimised energy system that can support the transition to zero-carbon. The benefits of applying SEMS are linked to how it's deployed to address a specific urban challenge, or achieve a certain policy objective.

Cities account for about 65 per cent of global energy demand and 70 per cent of energy-related CO_2 emissions. The generation and consumption of energy poses challenges for urban areas. For example, energy poverty, network reinforcement costs associated with increased electrification, air quality and load balancing. In a complex energy system, machine learning and advanced algorithms can process data inputs in real time. This improves decision making, reduces system inefficiencies, and brings financial, social and environmental benefits.

Not every city faces the same energy challenges. In London where the climate is cooler, heating is a major source of energy consumption, whereas in Lisbon, energy is mainly used for cooling. Depending on your project requirements you may want to optimise specific types of assets and include other energy applications such as electric mobility. In each context, you may want to manage your energy system differently to achieve your desired environmental, financial, and social benefits. These different applications are called **use cases**. You can read more about this in *Section 4, How to Rollout SEMS - Exploring opportunity.*

The system allows for the best combination of energy for a building, by maximising solar photovoltaic (PV) production, managing loads, and taking advantage of flexible energy tariffs. Most savings come from reduced energy consumption.

How citizens and other key stakeholders benefit from SEMS will depend upon how it is applied. This in an overview of how the SEMS was applied in each lighthouse city to address specific challenges, and the resulting benefits:

Environmental benefits	Lower carbon emissions	Reduced air pollution	Lower energy consumption		
Social benefits	Improved air quality	Improved indoor thermal comfort	More reliable energy supply	Increased distributed energy generation	
Financial benefits	Longer operational life of energy assets	Optimise financial return from assets	Reduced or delayed grid reinforcements or maintenance costs	Reduced energy costs for energy managers and end-user (including residents and/or landlords)	Revenue streams from capacity markets, balancing systems and increased system flexibility

SEMS is saving €5,000 per year in energy costs at Lisbon City Hall, generating savings of roughly €40-50 per month. It has also increased self-consumption of PV generated power by a factor of 10.

The average London household spends £1,171 a year on energy bills. In our trials, the SEMS is helping residents reduce their energy bills by 10 per cent.

LISBON / City Hall leads by example

City Hall is a historically significant building located in the heart of the city. It offers an opportunity to showcase Lisbon's ambitions to optimise building energy consumption to better match local renewable generation. This will help improve the business case for renewable installations (particularly solar photovoltaic) and deliver environmental and financial benefits.

Lisbon decided to install SEMS in City Hall for several reasons:

- **Scale of impact**: City Hall is one of the five highest energy consuming buildings owned by the municipality. Reducing consumption is thus a financial priority.
- **Lead by example**: The municipality using its own assets to demonstrate what is possible, encouraging developers and other building owners to follow.
- **Replicability**: City Hall is similar in nature to many buildings within the Lisbon downtown area. By choosing City Hall, the municipality shows how the measures can be taken up by other public and private buildings.
- **Alignment with city priorities**: Improving energy efficiency fits with the city's sustainable energy strategy and its Sustainable Energy and Climate Action Plan (2018). This is part of Lisbon's commitment to the Covenant of Mayors for Climate and Energy.
- **Amplify impact of building retrofit**: Retrofit works were also been done at City Hall through Sharing Cities. Installing SEMS optimises consumption of on-site solar/PV generation and minimise overall energy costs by making use of optimal tariff periods.

To achieve Lisbon's objectives, the SEMS consists of two parts:

1) On-site hardware responsible for gathering data and controlling several types of equipment. This allows the transmission of measurements to the software and receiving control orders, including:

- Smart Metering equipment measuring building overall, consumption, HVAC consumption and PV generation.
- Power reducers controlling electrical boilers.
- Smart plugs.
- Data concentrators (hub) to communicate with all the peripherals mentioned above between assets.

2) A software platform that can communicate with the equipment. This will handle the data, present the user interface for data analysis, control the equipment and allow interaction with other software platforms.

Lisbon also developed a **planning tool** to inform policy and planning to achieve sustainability goals, called the Sustainable Energy Planning System (SEPS). SEPS is intended for use by cities, their citizens and local stakeholders. It integrates different energy production and consumption infrastructures (such as renewable sources and electric mobility) to optimise city energy performance. ***Rather than 'monetary' benefits or revenues, using this system will bring mostly indirect and 'non-monetary' benefits***. More information, better energy savings and improving city energy performance and efficiency is a political objective to be funded by the public sector.

LONDON / Integrates open-source SEMS with residential demand-side response

Asset owner, the Royal Borough of Greenwich, deployed SEMS to:

- **Cut costs** for residents and asset owners linked to using less energy or cheaper energy sources.
- **Reduce carbon emissions** associated with reduced energy consumption and renewable generation.
- **Improve air quality** from substituting energy generated from combustible sources to clean sources of energy.

The London Datastore was integrated into the SEMS demonstration. It provided a local and independent data ingestion point. In choosing which data solution worked best, the requirements were that it:

- was sustainable beyond the life of the programme
- adhered to the core principles of SEMS (openness and ease of integration)
- did not jeopardise provision of essential services such as heating homes
- could be replicated and scaled elsewhere.

Greenwich also trialled a **residential demand side response service** which was integrated with SEMS. Greenwich Energy Hero was developed by partners Future Cities Catapult and Kiwi Power. Residents across the borough installed an app, connected to a CT clamp on their electricity meter, which gives them live information about their electricity use. They also get alerts 1-2 times a month, asking them to turn down their electricity use for an hour or two. They are allocated points based on their reduction compared to their baseline. These points are converted at regular intervals into a charity donation, or voucher. To find out more, see our **Digital Social Market playbook**.

One indirect benefit of the SEMS in London is that it uses open source. This means learning from its development can be exploited directly by users, communities, businesses and developers to deliver their own SEMS. Ultimately, working towards an open source 'toolkit' model enables the widespread creation of custom tools for different systems to be integrated over time. This allows a 'plug-and-play' approach to scale-up and adoption. The open source approach also supports and encourages the rapid spread of knowledge and understanding associated with the system. As such, it can become one of the means to create a systems approach to meet decarbonisation targets.

Greenwich Energy Hero enables residents to participate in Demand Side Response to manage energy use.

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MILAN / SEMS supports strategic investment decision-making

Through Sharing Cities, Milan, with Siemens IT, expanded the advanced energy management solution it had developed for the 2015 Milan Expo. Called “**Mastering and Operate Next generation of Energy of Things”, or Monet*, Milan’s SEMS seeks to**:

- Increase **energy efficiency** in the built environment through greater visibility and control.
- Inform **strategic investment decisions** to improve the potential for reducing energy consumption across the city.
- Support **regional level energy planning** to enable greater uptake of distributed renewable generation and avoid/delay network reinforcement costs.

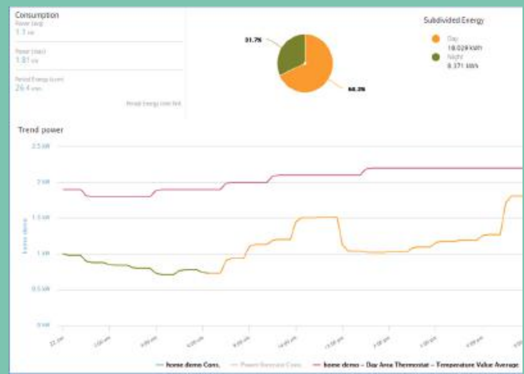
Several use cases for SEMS in Milan were identified to show how the system could be applied within a complex urban context. The selection criteria were based on forecast availability in the demonstration area, Porta Romana:

- This district represents a major regeneration opportunity for Milan and is a key strategic site for the municipality.
- The planned investment will introduce many new energy assets, particularly new building mounted devices and e-mobility charging stations. It will also reinvigorate existing buildings through deep retrofit and energy efficiency improvements.

In Milan, energy data was aggregated, analysed, and visually represented on a data platform. The forecasting and optimisation algorithms gave municipality energy managers detailed and (near) real-time information about local energy flows. SEMS calculates typical consumption patterns and provide forecasts of generation and consumption based on historical data and weather forecasts. The outputs are used to support decisions in terms of energy efficiency, asset investment and regional level energy planning.

In addition, SEMS will allow analysis of energy data to understand how retrofit and energy management can be applied to other buildings across Milan. This will create a legacy of best practice for future projects and tender processes.

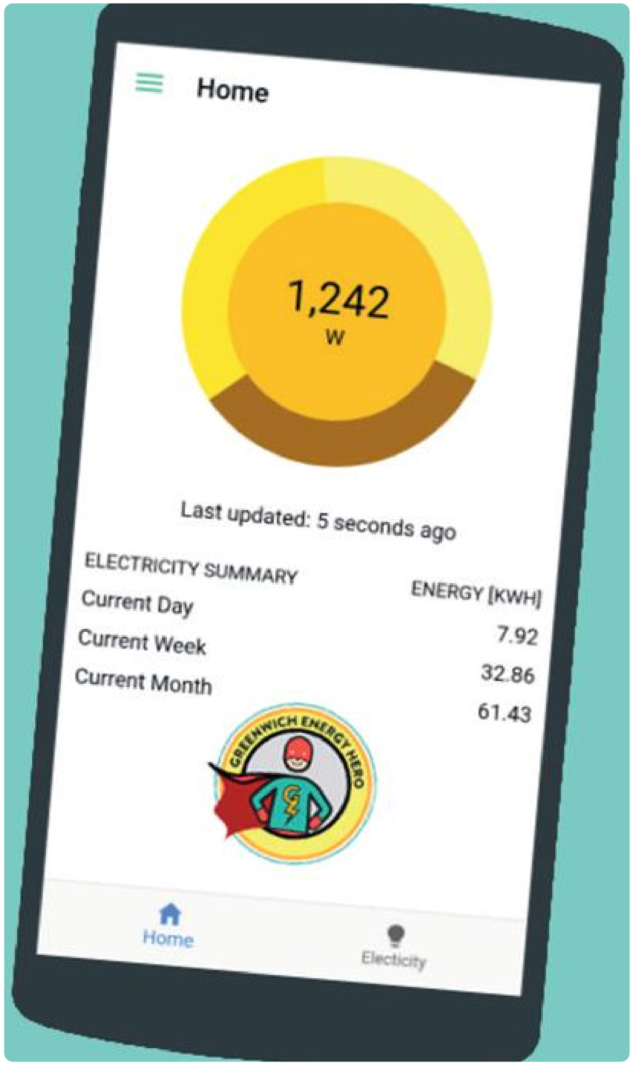
* in 2019, Monet was rebranded: EnergyIP Distributed Energy Optimization (DEOP)



Milan's Monet management dashboard

The table here summarises the benefits of SEMS in each of the three lighthouse cities. Out of these ten indicators, the five in bold are common to all cities, while the five not in bold are common in two.

	LISBON	LONDON	MILAN
Consumption reduction - energy saving	✓	✓	✓
Consumption reduction - energy from renewables	✓	✓	✓
Cost reduction (operator)	✓	✓	✓
Cost reduction (user)	✓	✓	✓
Peak demand reduction - no need for grid reinforcement	✓	✓	
Energy supply resilience		✓	✓
Carbon savings	✓	✓	✓
Air quality	✓	✓	
Real-time consumption awareness	✓	✓	✓
Investment attractiveness	✓		✓



4. How to rollout SEMS

The three lighthouse cities introduced SEMS to help address a range of different challenges. This section outlines what each city went through to rollout their scheme. and sums up the parts common to all cities. It covers some of the tools, processes and examples from the lighthouse cities. Email Sharing Cities: pmo@sharingcities.eu to find out more.

Exploring opportunity

- Conduct demand analysis
- Define goals with key stakeholders
- **Develop use cases**

Audience engagement

- Conduct stakeholder mapping
- Maintain stakeholder engagement

Technical design

- **Develop SEMS architecture**
- **Data collection**
- **Control strategy**
- **Integration**
- **Algorithm**
- **Interface**

Finance and implementation

- **Develop business model and financing plans**
- Commence procurement

Monitoring and sharing

- **Establish a common monitoring framework**
- Conduct data collection and surveys
- **Use data to inform policy**

Exploring opportunity

Demand use cases

SEMS is being rolled out at different scales and with different aims in each city. To account for this variation, we developed a set of use cases. This helped ensure our approach was consistent. This table summarises the use cases and their locations.

Each use case was developed by first identifying the specific issue that we wanted to resolve. On the following pages, we summarise the use cases defined for SEMS applications to achieve specific objectives in the three lighthouse cities.

Use cases	Objective	LISBON	LONDON	MILAN
Heat network optimization	Minimise end user heat costs		✓	
Building mounted solar PV	Maximise building-level use of renewable self-generation	✓		✓
Building energy management	Minimise building electricity costs by load management	✓		✓
EV/PV optimisation	Maximise the use of renewable electricity generation and minimise consumer electricity costs		✓	✓
EV/PV forecasting	Encourage effective integration of renewables and use of EVs	✓		
Demand side response (DSR)	Residential electricity consumers benefit from demand flexibility		✓	

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LISBON / Use cases for renewable generation, energy savings, and energy planning

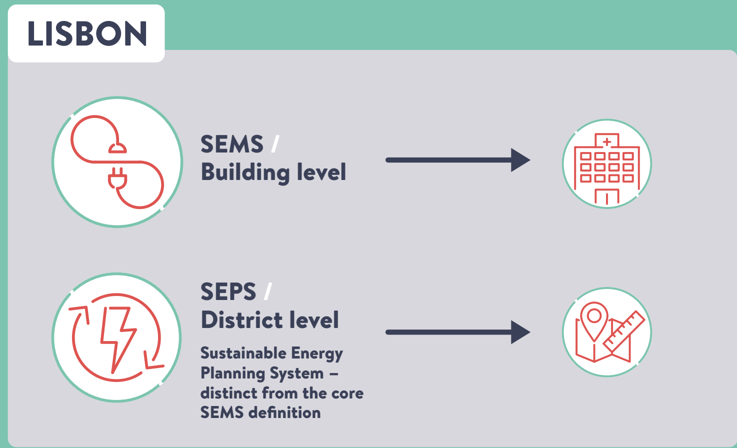
Lisbon wanted to demonstrate the potential benefits of energy monitoring and management in public services buildings and at city scale. The use cases are:

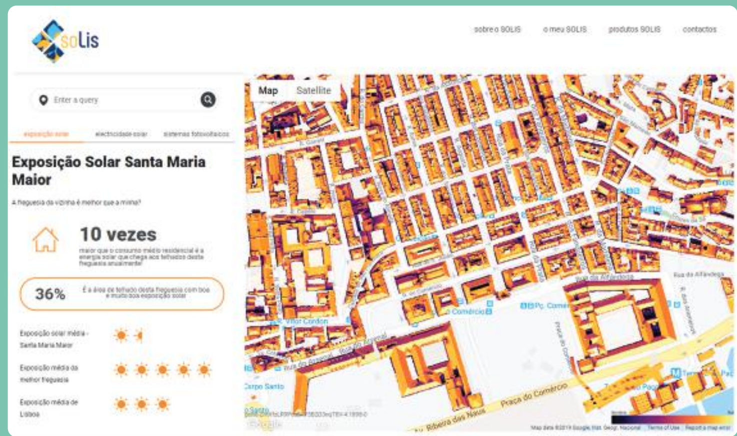
- **Lisbon UC1** – Building mounted photovoltaic (PV) panels to maximise building-level use of renewable self-generation.
- **Lisbon UC2** – Building energy management to minimise building electricity costs via load management. Local grid-connected PV micro grid management to maximise use of renewables (PV) electricity generation on local grid and minimise consumer electricity costs.

Adding mapping functionality created a third, distinct application from the core SEMS definition, called the Sustainable Energy Planning System (SEPS):

- **Lisbon UC3** – Forecasting EV/PV (district level) to promote behaviour change (encourage effective integration of renewables and EV/PV use). Create a consumption and production map by getting data from multiple sources (city specific application). Visualising estimated production and consumption balances for each building.

Rollout of the described use cases will be deployed as a SEMS at building level and a SEPS at district level.



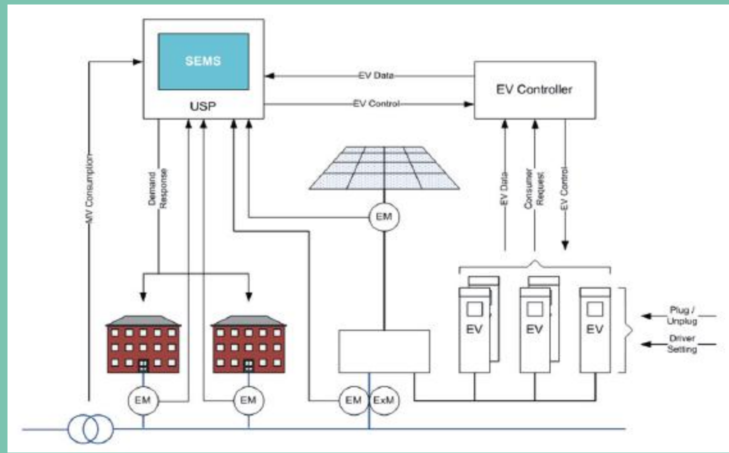


Lisbon solar radiation map in the SOLIS platform.

LONDON / Use cases for energy optimisation, demand side response and cost reductions

Greenwich wanted to introduce energy assets into the district energy mix through Sharing Cities, including the heat network and heat pump. The aim was to establish monitoring and achieve smart energy management at a building and district level. The use cases are:

- **London UC1** – Energy optimisation of a heat network to minimise costs for the end user. It involves deploying advanced process control (APC) allowing the smart integration of city infrastructure and equipment to achieve optimised and predictive control.
- **London UC2** – Demand side response (DSR) benefit. Data will be fed back to users so they can see how much electricity they are using. The aim is to help them reduce consumption. In addition, load shifting incentivises users to reduce and shift their energy consumption in response to increased demand.
- **London UC3** – Energy optimisation of power resources to minimise costs to the end user. Load reduction can be achieved by optimising at building level and at local control level through process change.

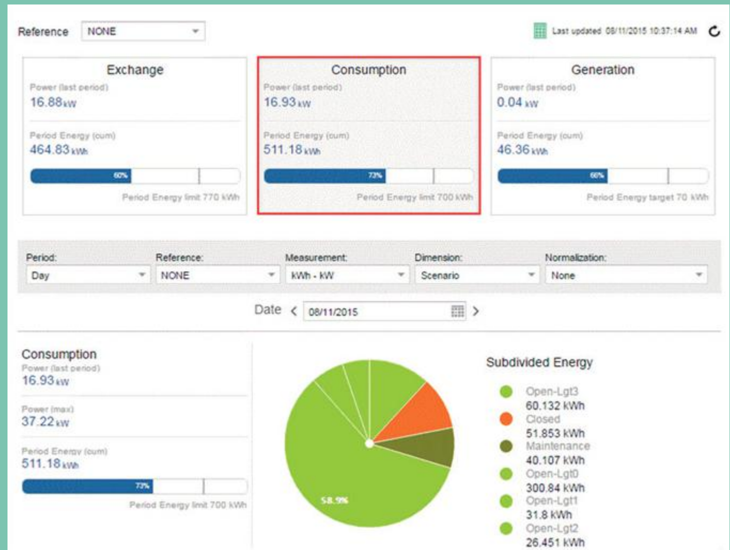


Greenwich explored smart energy management use cases at a building and district level.

MILAN / Use cases for renewable generation optimisation and cost reductions

Milan wanted to show the benefits of monitoring and smart energy management at both a building and district level. The use cases are:

- **Milan UC1** – Building-mounted PV to maximise building-level use of renewable self-generation.
- **Milan UC2** – Building energy management to minimise the energy cost of a building. For example, reducing the peak power of the building and/or using more suitable energy tariffs such as two-time/three-time period tariff. This also includes load shifting, the use of renewable energy and energy storage.
- **Milan UC3** – EV/PV optimisation (district level). A recharge island will be configured with PV and charging stations, with the potential of adding energy storage. The SEMS system will acquire data from the charging stations, through an e-mobility infrastructure management system, and PV. The system will control the recharge island to maintain the total power consumption under the grid power available.



Milan's Monet system – energy management dashboard

The use cases are live documents that are continually refined and updated during the programme. Below is an example of a fully built-out use case for Milan, UC01 – Building Energy Optimisation, using use case templates developed by Sharing Cities.

To find out more about our use cases, email: **pmo@sharingcities.eu** or tweet us **@CitiesSharing**.

Use case	**Milan UC01 – Optimisation (building energy)**
Title	Building-mounted PV
Pre-condition	
User insight/ need the use case responds to	Minimising grid consumption by maximising use of renewable production within the building.
Actors involved (stakeholders)	Building energy manager (the person responsible for energy management in the city), technology providers, users, facility managers, building visitors, etc.
Incentive for citizen	Citizens are not directly involved as renewable production is for the building. The municipality reaps the most benefits as it is the body that owns the electricity contract for this public building.
Description (narrative)	The use case shows how this resource can reduce the building's dependency on external energy and manage energy more efficiently. This will ready us for net zero energy buildings and reduce peak time pressure on the grid when energy costs are higher. This use case will promote consumption of local power (PV generation) through the SEMS (sustainable energy management system), while storing energy. It will thus show how the SEMS can operate the building infrastructure according to certain pre-defined options. In this case, the goal is to maximise consumption of renewable energy and minimise the power obtained from the grid. For that purpose, the building's energy demand must be managed in such a way to ensure maximum energy efficiency in operation.

Use case	**Milan UC01 – Optimisation (building energy)**
Description (narrative) [continued]	Information is aggregated by Monet system to provide different views to the energy manager (space view, electrical view, technical view) via a web application. Energy efficiency or demand-response behaviour will be defined by the energy manager using the Monet Energy Rules Engine. Rules provide flexibility in terms of: • Building temperature/luminosity set-points. • Load control/module. • Load shift. The Monet system uses the flexibility to optimise energy consumption or follow a specific demand curve.
User insight/ need the use case responds to	1. SEMS is realised by additional functionalities on Monet system, used to monitor and visualise data. These data embrace near real-time consumption and generation. 2. The SEMS will use also historical data, previously loaded, to create reports 3. SEMS will generate periodic reports based on a set of defined KPIs, which could support the strategies followed by the building energy manager. 4. A dashboard will be created to show the KPIs and other relevant data. There are two different user access profiles: a. For the end user: i. energy consumption ii. CO_2 emissions avoided iii. comparative analysis (ratios of consumption etc). b. For the building energy manager: i. all the items available for the end user plus ii. all the items applied to common parties plus iii. several warnings can be triggered when critical situations occur.

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Use case	Milan UC01 – Optimisation (building energy)
Pre-condition	
Policy	Renewable energy; sustainable energy.
Legal and regulation	Law for SEU in Italy.
People	N/A
Operational	N/A
Process	N/A
Data	1. Total energy consumption and energy consumption of the most energy intensive devices. 2. Energy production. 3. The SEMS will collect all data coming fom meters installed on the field.
Technology	The system measures the consumption and production energy.
Assets	Building with potential for PV.
Performance/ Criticality	N/A
Energy assets	
Select relevant energy assets for use case	• Renewable energy generation. • Energetic dependence of the building (electricity). • Energy storage consumption. • Energy storage production.

Use case	Milan UC01 – Optimisation (building energy)
Data platform requirements	
Sensors/devices	Meters for energy storage, PV and common parties.
Applications	
Data acquisition	1. Weather (hours and daily). 2. Power consumption from the grid. 3. Power generation from PV. 4. Power associated to energy storage. 5. Power consumption from common parties.
Data use	Data will be used to calculate a load profile for the microgrid, to maximise use of renewable energy.
Data flow	Data are acquired by local gateway and sent to Monet platform. Set points are sent from the cloud to local gateway.
Data volume and frequency	Frequency is 15 minutes.
Protocols	Locally data are acquired using radio and modbus protocol. Data sent to cloud env using MQTT over TLS protocol.
Datasets	Data are represented by power and energy.
Data analytics	Load optimisation, invest in PV.

Use case	Milan UC01 – Optimisation (building energy)
User requirements	
User profile	Building energy manager (the person responsible for energy management in City Hall); citizens.
Incentivisation mechanism	
User interface	Web portal/app.
Citizen engagement	For the municipality: reduce grid consumption for common parties.
Business engagement	Replicate SEMs for other services buildings.
Realisation	
Main responsible partners	Siemens IT
Impact of use case	Reduction of grid energy consumption.
Contributing partners	• Teicos • FutureEnergy • Unareti • A2A
Priority	High

Technical design

Develop SEMS architecture

Each city has a unique set of requirements for SEMS. For that reason, it isn't possible to wholly standardise the system architectures. However, there are core parts common across all cities. This section details the system architecture for the three city solutions, identifying and assessing some key similarities and differences.

SEMS has been designed and delivered around open interoperability that will function over different spatial contexts and at different scales of the energy system. The modular approach to system architecture comes from stakeholder outcome-driven design processes. It creates a fluid and flexible architecture that uses existing city assets and embraces new assets as they emerge.

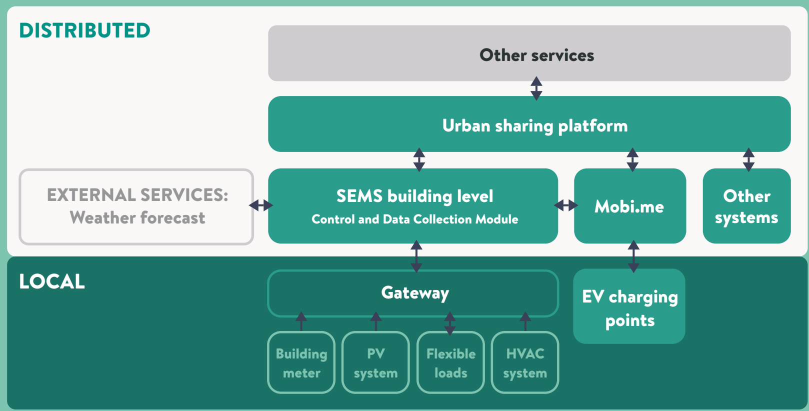
The architecture design should be future-proofed so that the SEMS stays relevant. It is hard to predict future technological developments in complex systems like energy, information technology and city planning. This can also be limiting when designing the architecture for SEMS. However, each city has future-proofed their system through modular-design. This will allow SEMS to be adapted as new technologies are developed.

The longevity of SEMS is crucial for its success. Most resources invested are in front-end development. And while there are immediate financial savings, it could take at least two years[1] for the initial investment to return. The longer the system is relevant and operational, the stronger the economic case. Over time, we are more likely to see the environmental and social benefits monetised and their value increase.

LISBON / SEMS architecture

The architecture of Lisbon SEMS is shown below, and highlights both a vertical and horizontal approach to integration. Local site data from meters, solar photovoltaics, energy storage systems and internal heating, ventilation and air conditioning systems is sent to a hub. The information is vertically integrated into SEMS, which hosts the centralised intelligence. However, while local EV charging data is vertically collated via the Mobi.me software solution, it is integrated into SEMS horizontally. This horizontal approach provides flexibility to incorporate additional city service systems and external data points like weather forecasts. This can be done either through third party software or via the USP.

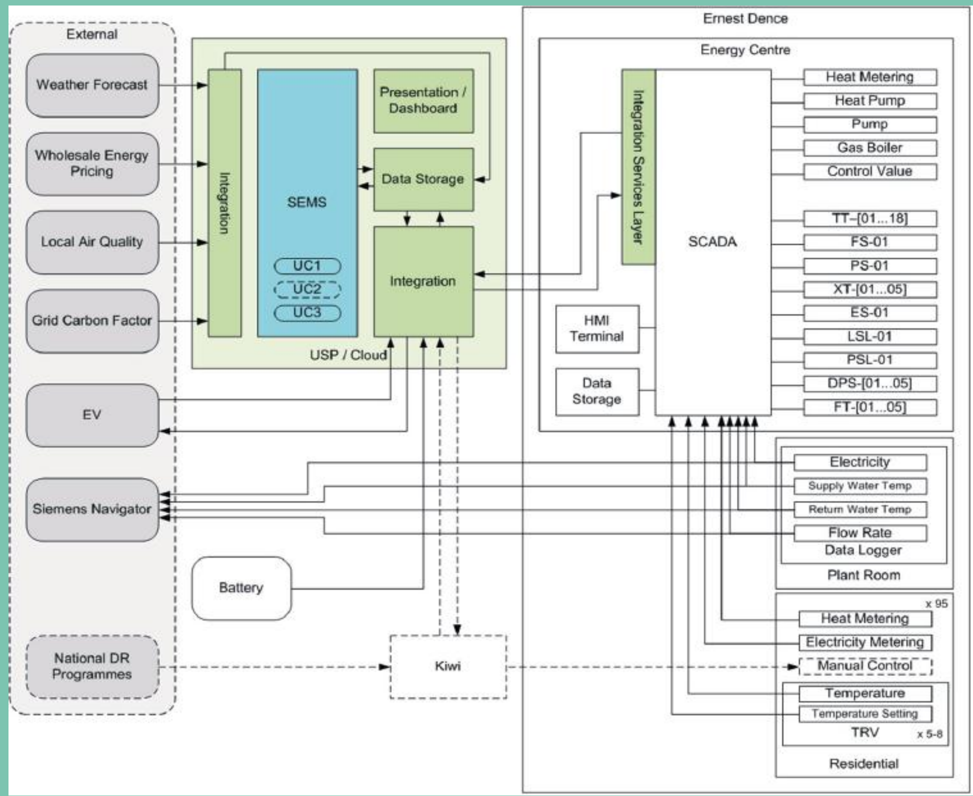
Finally, all the data is centralised in the SEMS. It incorporates prediction algorithms, data analytics and automation to optimise at a building or system level depending on desired outcomes and parameters.



LONDON / SEMS architecture

Greenwich's Ernest Dence housing estate and associated energy centre (including the proposed water source heat pump) form a major element of the SEMS architecture. This is described in London Use Case 1. We anticipate that the energy centre will have local asset management and control systems to gather data and carry out activities. This will be operated by a third party. The information collected will be integrated into the SEMS for building and system level optimisation.

Alongside building level operation, the architecture illustrates the role of additional energy assets (battery storage) and external information sources in the system. London Use Case 2 is a district-wide Demand Side Response programme. Greenwich Energy Hero will provide benefits to the distribution network operator, building managers and local residents via partner services (Kiwi Power).



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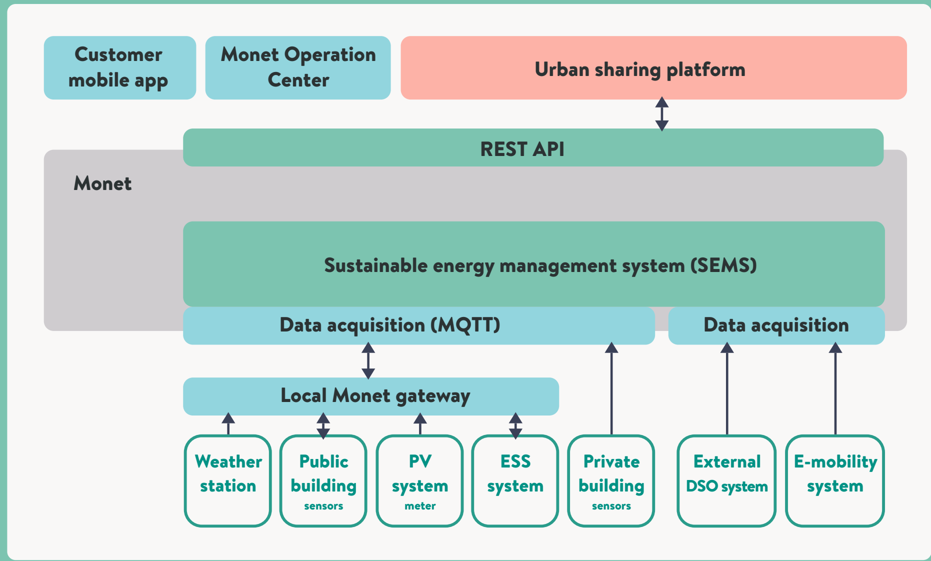
MILAN / SEMS architecture

Milan's SEMS will provide additional functionality to the Mastering and Operate Next generation of Energy of Things (Monet) system by applying the use cases. Further value is provided to the project by Monet's existing functionality.

The architecture is based on a multi-tenant concept. This offers differentiated services to the various stakeholders and manages multi-vendor devices. It is enabled to interact with other asset management and network management systems, electric mobility management systems, and public lighting management systems.

Milan's SEMS manages a public building, located in San Bernardo, alongside the integration of an electric-vehicle recharge island with the PV system. The system could potentially manage different buildings and/or service. It is designed to provide optimal energy management, delivering environmental and financial benefits. SEMS can receive meter readings to monitor maximum power demand and relate this to total peak grid demand.

The architecture of SEMS in Milan is shown here. The system collects real-time data from the field using a local gateway. The system can also collect data directly from sensors installed in the public building (using a LoRaWAN protocol). This allows for connection to additional devices and sensors in the future.



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Data collection

Presently, data is currency. The energy sector has seen an explosion of data in recent years. SEMS is perfectly placed to leverage this information with the IoT to drive system efficiency. The data collection methods used by SEMS are proving to be robust and appropriate to the scales, frequencies and quantities the system needs. This is the case in all three cities.

London and Milan, which include use cases that rely on automated control, require higher computing power and server space. This is due to the frequency and quantity of data being communicated and stored. The automated processes add a higher level of optimisation but through their energy requirements they increase total energy consumption. Evaluating the net impact of lies beyond the scope of this work but could be an area for future research.

Using a central integrated data platform has simplified data collection for SEMS in each city. However, data translation and formatting for existing assets is expensive and takes time. This cost can be mitigated in future by specifying preferential methods and languages during procurement. Alternatively, you could develop a standardised set of protocols for data communication with the platform.

Control strategy

Setting effective energy policy that aligns with specific objectives is very hard because the energy system is complex and uncertain. In addition, objectives are not homogenous across all actors. Often, the objectives of regional/national governments, industry and citizens will vary and compete. Broadly, however, energy objectives can be categorised as:

i. Security of supply.

ii. Cost minimisation (or profit maximisation).

iii. Emission reductions.

Within the energy system, inefficiencies, market failures and lack of information can be barriers to achieving these objectives, regardless of policy commitments. However, advances in computing power and process control theory offer the potential to reduce or remove these barriers. This will provide more detailed and immediate information, remove inefficiencies and align strategic objectives. SEMS will deliver a more effective and efficient system operation – and it will do this through via its control strategy.

Across all three areas of deployment, 'Intelligent' functionality is carried out in SEMS. This includes:

- **Advanced predictive controls (APC)**: This model will operate by predicting what's happening now, and what's going to happen in the future – calculating the 'correct' and optimum deployment strategy.
- **Real time management**: SEMS will integrate all of energy vectors within the system into a single model. By knowing the energy balance at any given time. It will be able to shift consumption and production as required.
- **Hard and soft actuation**: SEMS will send recommendations to local hub or gateway systems to carry out the actions. This will be either through automated proportional–integral–derivative (PID) controllers or by influencing human behaviour.
- **Dynamic learning**: SEMS will identify changes or incomplete information within the system and be able to adapt to this through learning from previous data and outcomes.

- **Active demand and load management**: Monitoring the most relevant parameters of each energy vector or group of vectors and knowing the status of each service.
- **Scenario planning**: Allows users to define specific operating modes or outcomes or automatically adopts an optimal scenario based on external conditions.

A common SEMS can perform all the functions described. They will however not all be deployed in each city and will be rolled out using different control strategies.

The use cases determine what control strategy is best. Broadly, the control strategy is either executed ‘online’ or ‘offline’. For example, in Lisbon the SEPS control strategy will be rolled out by city decision makers who will adopt policy using information it provides. In London, the heat network optimisation is managed by a wholly automated classical PID and rule-based controller operating within pre-defined system limits. Between these extremes, Milan’s control strategy for building optimisation combines an ‘online’ and ‘offline’ solution. Predetermined scenarios will carry out online actuation. However, the choice of the desired scenario is determined offline by human input.

An offline control strategy is critical if value judgments are to be made. An online strategy is better if you have a clearly defined objective that can be delivered without human influence on the SEMS.

Computer algorithms can deliver optimal outcomes based on pre-defined conditions. However, it cannot account for social changes, political ambition or individual will. Conversely, by adding a human element into the system you are adding uncertainty. In a system of high precision an element of offline control can lead to sub-optimal results.

The theoretical principles of the online control strategies have been tested and proven to work. But the commercial constraints and liabilities associated with a central management system performing online control of third-party assets have proven more complicated. Building managers are used to automated systems controlling aspects of their asset to improve performance. However, EV charging providers are less used to this situation and have a commercial obligation to provide power when needed to their customers.

A system objective to reduce emissions or restrict peak power may not be compatible with individual EV charging points requirements.

A future of home-chargers with integrated EV charging could potentially help overcome commercial barriers. Overnight EV charging could become the norm where speed and certainty of charge are less important than cost minimisation or grid capacity. However, present aspirations for online control of EV charging activity must be understood within the industry's commercial context. For this project, it has meant replacing aspirations for online control in Milan and Lisbon with offline control consisting of user recommendations.

Algorithm

Advanced Process Control (APC) and Model Predictive Control (MPC) principles allow control strategies to be developed allowing complex systems to operate more efficiently. Advances in computing power and process control theory offer the potential for more effective and efficient system operation. How these control strategies are rolled out in Sharing Cities is using algorithms within SEMS.

Algorithms deployed within SEMS are highly dependent on the specific use cases. Once these algorithms are developed, you can refocus attention on making them and their functions more adaptable to other situations. In Milan, this has been around developing the algorithm engine. This allows third parties to develop their own algorithms to be quickly and cheaply deployed in the SEMS. In London, the algorithms have moved from a monolithic to a modular structure so they're more adaptable to generic energy assets. In Lisbon, the algorithms associated with SEPS can be reapplied as the cityscape changes.

Integration

The ability to integrate with existing and future city assets is a core component of SEMS. In Milan, this is done by the Siemens' existing DEOP system and highlights the advantage of modular architecture. However, the physical integration of PV at the recharge islands is prohibited by the city's public space rules. The integration of established assets is replicated in London. There, the London Datastore performs the functions of the integrated data platform. This is known as the Urban Sharing Platform (USP) in Sharing Cities.

Direct and indirect interactions exist between parts of the SEMS in the form of information and/or control. Data can be acquired by SEMS through integration at various scales. This can be either with a single device, a local gateway or a service layer and pushed to a platform for visualisation. Likewise, SEMS' recommendations and set-points can be transferred directly to devices, local management systems or via service layers and gateways. In the Sharing Cities programme, these interactions are simplified through the USP.

The USP works to aggregate data and control from a wide variety of devices and sensors. It also stores and processes the data and supports visualisation of the information to the city and citizens. The USP, therefore, removes unnecessary vertical infrastructure, offering a simpler model for scale-up and replication. However, there are also potential issues associated with security and stability depending on how the USP is hosted. Questions around liability and risk will need to be resolved.

How SEMS integrates with the USP and local devices/gateways is a key consideration for each city and the project overall.

Interface

A key feature of the SEMS is how it interfaces with users. The decisions taken and subsequent outcomes must be visualised and understood to give confidence in the system and to verify its effectiveness. For city planners, energy managers and residents, visualisation is one of the ways in which they will interface with the system. As such, careful consideration must be given to the design, accessibility and security features.

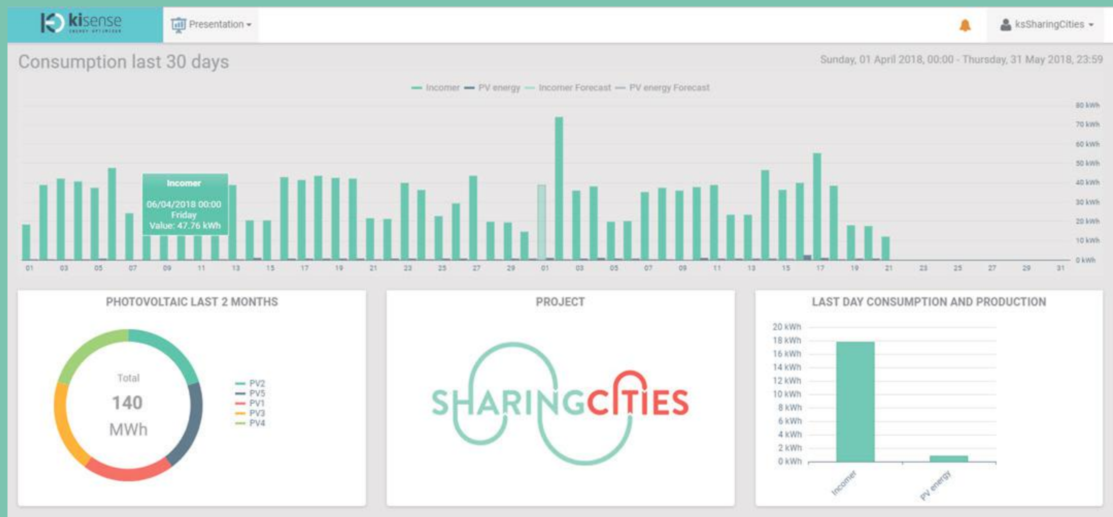
LISBON / SEMS user interface for building managers – Kisense

In Lisbon, the SEMS platform will be visualised for end users through an online web interface. Called Kisense, this will be accessible from any device connected to the internet and is aimed at building managers.

Kisense provides multiple functionalities that ensures the physically installed equipment is fully exploited.

Kisense is a secure interface. Users must enter a username and password to gain access, which will be provided by a system administrator.

This security feature enables the system to be scaled up if more buildings are added. Users can be assigned certain roles, restricting or limiting the visibility of information assigned to that role. This provides the necessary level of data privacy and ensures that users only see information which is relevant to them.



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LONDON / SEMS user interface for residents to support demand-side response – Greenwich Energy Hero

In Greenwich, residents directly interact with SEMS provided through a mobile app, Greenwich Energy Hero. It is operated by Sharing Cities' partner Kiwi Power and can be downloaded to any smartphone. The app links to a CT clamp and communication hub installed on a household's electricity meter.

The mobile app is designed and developed around a near-real time data model which is supported by the sensors installed in the building. The app aims to:

- Provide users with real time data about their energy usa. Information is aggregated and stored on a minute by minute level and used for historical charts, monetary conversions and peer comparison.
- Allow households to participate in Demand Response (DR) events by receiving notifications about upcoming DR events and see potential financial rewards. These are based on existing consumption levels and potential turndown.
- Introduce peer comparison by showing average and best group performers on the same chart. This also allows for future gaming developments to increase engagement.

Greenwich Energy Hero provides users with several features. The dashboard brings together a wide range of information and summarises it for easy access and interpretation by residents. This includes:

1. Real time power data (aggregated, individual and average).
2. CO_2 emissions (calculated based on electricity consumed and the carbon intensity of the UK electricity network).
3. Electricity charges for the month (updated in real time).
4. Household with the lowest energy consumption within the group.
5. Accumulated revenue from participating in DR events.
6. CO_2 emissions reductions as a result of participating in DR events.
7. Users position in overall standings of any 'mini-leagues' that they are participating in.

In addition, users can add or measure their own activities and/or devices by creating a power signature. To support this feature, data is sampled with the device on and off. The difference is then recorded as the nominal power use for that device.

For more information about Greenwich Energy Hero, see our **Digital Social Market playbook**.

MILAN / SEMS user interface for city planners – MONET/DEOP Operation Centre

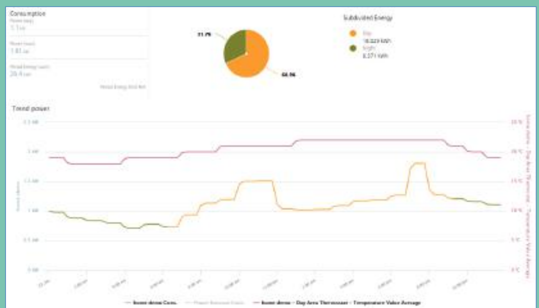
In Milan, Siemens' Monet/DEOP provides the visual interface. The end user is intended to be city planners and/or building managers. Monet can be accessed from any device connected to the internet, via a web browser. The Monet Operation Centre is an HTML5 web application that runs on any browser or device, even if optimised for desktop. There is also a smartphone app for iOS and Android.

Users can additionally create reports on the interface specifically related to energy data:

- Energy (electric, thermal, gas) consumption: it provides consumption data of the selected site(s); energy curves may be integrated with variables curves.
- Energy (electric, thermal, gas) generation: it provides generation data of the chosen site(s); energy curves may be integrated with variables curves.
- Energy (electric, thermal, gas) exchange: it provides exchange data of the chosen site(s); it covers the prosumer scenario – that is, it displays Fed-In and Fed-Out energy curves.

On the reporting page you can:

- Display energy/power data: average, min, max for the chosen period (day, week, month, year, and any range).
- Display energy/power data: power and energy curves; by scenario/mode/area/use.
- Compare between time periods and/or baseline.
- Compare any site/aggregator.
- Compare with any sensor data (environment data, production data, etc...).
- Normalise the energy data with any sensor data (such as trend of electric consumption divided by the external temperature).
- Export report data in CSV/Excel format.
- Export report data in PDF format.
- Save custom reports (per user and shared).



Samples of an energy consumption report are shown here. It visualises the consumption of the chosen site (home demo) with two variables (internal and external temperatures).

Finance and implementation

Business models

SEMS is still relatively new. As such, repeatable business models have not yet been developed. There are clear benefits and stakeholders are easily identified. However, different ownership models are still being explored, and investment and development of SEMS is not yet clearly incentivised in the market.

Ownership models

The following describes the existing or potential ownership models and its corresponding challenges. It is based on how SEMS was rolled out in each of Sharing Cities' lighthouse cities.

The solution developed by Milan is based on a proprietary system of Siemens Italy. This simplifies the ownership model but makes the route to market more complex. Asset owners, network operators and city planners/decision-makers are all obvious customers. However, balancing and satisfying their varied and often competing objectives would be commercially challenging.

For Lisbon, the client is clearer; with demonstrable value for the city's office buildings. This is particularly because generation and flexible energy assets are co-located within these buildings or nearby. EDP Distribuição represents an obvious candidate for ownership, however national regulation prevents this. While there is financial benefit to the municipality, it may be hard to commercialise the solution for an outside party. This is because significant value is derived via the environmental and social benefits of the system.

In London, Siemens is again a candidate to own and run the SEMS. However, this time it would be in a potential collaborative arrangement with the city and academic institutions. Bringing in city decision-makers is beneficial for deploying SEMS. This is because it reduces dependence on financial metrics, valuing instead social and environmental improvements (if compatible with political opinion). A city-led ownership model could also have more success balancing stakeholder requirements and diluting proprietary interests. However, cities often lack the technical and financial resources to maintain complex systems and may be reluctant to take on risk.

LISBON / SEMS generates savings

Any organisation continuing to develop SEMS should consider that the main interest in the Lisbon SEMS solution is likely to come from municipality and office building managers. The use case delivered through Sharing Cities shows greatest potential for office buildings where PV panels and electric vehicle infrastructure can be installed. Since the pilot was delivered on a municipality office building, promoting this solution within municipalities is an obvious starting point.

The major benefits of the solutions are within the SEMS concept itself. It allows for the best combination of energy for a building by maximising PV production, managing loads, and using flexible energy tariffs. Most savings come from reductions in energy use. The optimisation of City Hall has led to savings of roughly 40-50€/month. It has also increased self-consumption of PV generated power x 10 and reduced the associated CO_2 emissions of the building.

Actual savings will always depend on the amount of the PV installed, maximum generation capacity and available manageable loads in the building. It is difficult to estimate general savings for a building, but this study can provide a benchmark for potential users.

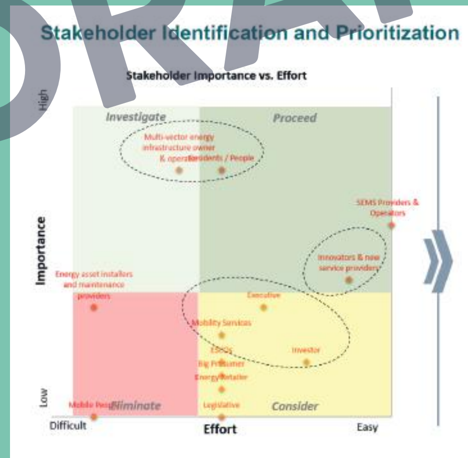
Maintenance and continuous costs are incorporated into a service agreement until the project ends. Future maintenance of equipment and software will become the responsibility of the municipality.

LONDON / Open source model

The SEMS in London is based around an open source deployment. This means learning from its development can be exploited directly by users, communities, businesses and developers to deliver their own SEMS. Ultimately, an open source 'toolkit' model enables the widespread creation of custom tools for different systems to be integrated over time. This allows a 'plug-and-play' approach to scale-up and adoption. The open source approach also supports and encourages the rapid spread of knowledge and understanding associated with the system. As such, it becomes a means to create a systems approach to meet decarbonisation targets.

In London, a series of business model workshops have been taking place, the first in November 2019. It aimed to understand what might be enabled both for the 'manufacturer' or underlying intellectual property (IP) owner of such toolkits. It also considered what using SEMS could unlock for a local authority, district, community or other entity using SEMS.

The business models will be shortlisted and developed from a value proposition exercise. In this, those taking part will seek the individual elements and touchpoints of value for particular 'personae'. This is a method where informed participants can enter into the mindset of the beneficiary of the potential business model. Further detail will be developed around a shortlist of value propositions which will be extended into business models. This includes outline costings, returns and next steps for development.



Stakeholder mapping.

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

MILAN / Software as a service (SaaS) model

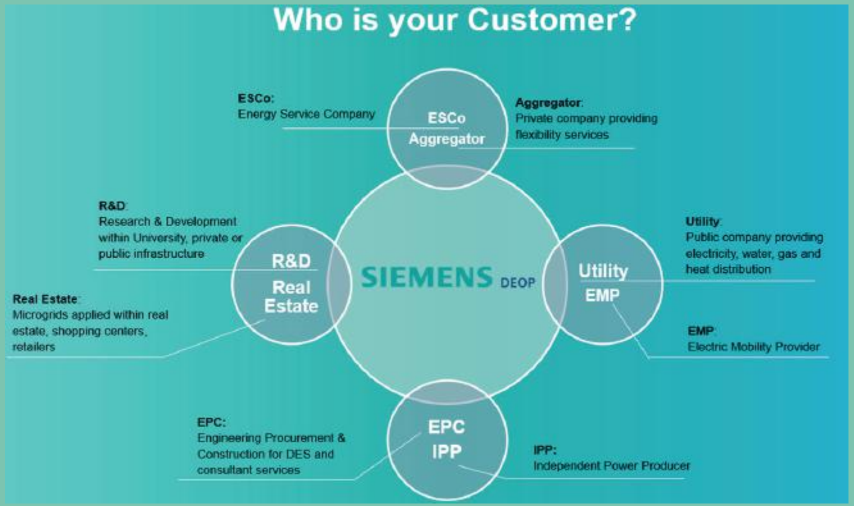
The business model for SEMS in Milan is based on a software as a service (SaaS) model. The algorithm will be part of a platform and customers would pay a yearly fee to use its functionality. If a customer wanted the system to be installed on their premises, a license could be considered.

Another solution being explored is based on the percentage of cost savings being paid by the customer. This is harder to deliver, both from client and provider, as it implies an uncertain fee that needs to be paid (and gained). This uncertainty can be problematic for budget forecasting.

The system will be maintained by Siemens IT. The main stakeholders involved are reported in the figure shown on this page (Siemens DEOP represents the Monet platform).

The main customers for the SEMS system will be microgrid, district, building or recharge island owners and operators seeking to optimise their systems. The payback period depends on many system variables and constraints and further analysis is needed in this area.

Anyone operating multiple assets within the energy system could benefit from SEMS. The rise of the 4D (Decentralisation, Decarbonisation, Digitalisation, Democratisation) agenda in the energy sector aligns closely with SEMS' functionality. It presents huge potential for the rollout of the system. However, more focus is needed on developing the proposal for final customers to highlight both its benefits and opportunities.



Monitoring and sharing

A good monitoring framework from the start of rollout will ensure the scheme continues to deliver value when it's in operation. There should be methods put in place to enable the impacts of specific measures to be understood, quantified and evaluated. Such methods will inform performance and areas of improvements.

Establish a common monitoring framework

Adopting a common monitoring framework allows you to compare metrics with other similar schemes globally, and 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.

Find out more at: www.citykeys-project.eu/citykeys/project

Sharing Cities also developed a common monitoring framework to evaluate the performance of the smart cities projects. As with all Sharing Cities projects, SEMS activities are evaluated from five perspectives: technical, economic, business, social, and system. To perform this holistic evaluation, we monitor several metrics including:

- **Input metrics**: exogenous (system level or technical) characteristics that must be controlled to assess the impact of SEMS interventions (like weather or local events).
- **Process metrics**: these are monitored to inform where specific SEMS intervention are viable from the technical, institutional and economic point of view (like type and level of incentives to users, financial viability, and procurement mechanisms).
- **Output metrics**: the techno-socioeconomic metrics measured to quantify the impacts of a SEMS intervention (such as household energy bill, sensor data, infrastructure installed, technologies developed).
- **Outcome metrics and impact KPIs**: these quantify the effect of an intervention along the six perspectives indicated above. For SEMS, these can be summarised as follows:
    - Increase operational reliability and stability of the electric grid, peak reduction & increase in RES generation (such as via DSR interventions).
    - Energy consumption reduction in household and decrease in fuel poverty.
    - Stakeholder satisfaction, authorities and citizen engagement, and replication of an adopted SEMS solution (short term business and social and system impacts).
    - Changes in societal energy use norms and attitudes towards energy saving behaviours (medium-longer term social & system impacts).

The 10 common evaluation indicators as identified in the table below are used as a basis for evaluation and monitoring.

	LISBON	LONDON	MILAN
Consumption reduction - energy saving	✓	✓	✓
Consumption reduction - energy from renewables	✓	✓	✓
Cost reduction (operator)	✓	✓	✓
Cost reduction (user)	✓	✓	✓
Peak demand reduction - no need for grid reinforcement	✓	✓	
Energy supply resilience		✓	✓
Carbon savings	✓	✓	✓
Air quality	✓	✓	
Real-time consumption awareness	✓	✓	✓
Investment attractiveness	✓		✓

These measurable indicators capture the co-benefits associated with launching SEMS. The methodology for identifying the measurable indicators included:

A common framework – The project created a common monitoring and evaluation framework to define both the evaluation targets to address and evaluation methods to use. These included processes covering data collection, data standards, data quality, data stewardship and the definition of key evaluation indicators.

Local rollout – The overall evaluation framework is developed centrally. However, responsibility for putting the framework in place resides locally with relevant research and delivery partners in each city. This is because the successful implementation of complex data collection protocols depends on detailed local knowledge. This is only available among local partners. Moreover, local knowledge is critical for the design of proper control.

Target salience – Each measure entails a set of technical developments which will impact directly and indirectly on people, business and the public sector. It isn't possible to monitor and evaluate every possible technical and impact dimension. Rather, the choice was based on several considerations. These include the salience of each potential evaluation target in respect of its policy and market significance; its practical contribution to scaling and replication, and the practical opportunities to collect relevant high-quality monitoring data.

Control of covariance – Each measure was introduced into a complex environment in which many different factors stood to influence a particular outcome or evaluation target. It is vital that the monitoring and evaluation activities collect enough data on these covariates to enable proper statistical control for their effect. Ensure that enough time is allowed for data to be collected both before and after measures are launched.

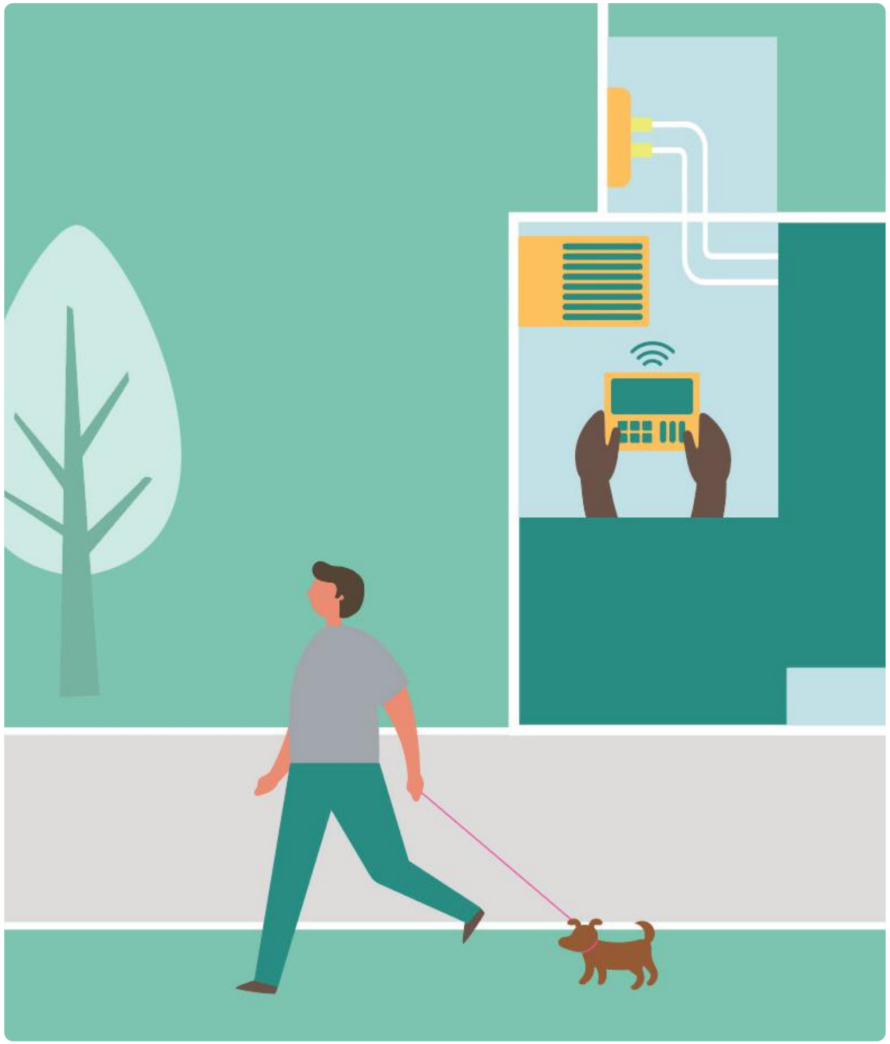
Common core of evaluation targets – A key part of the common evaluation framework is to develop a common core of evaluation targets and associated KPIs. In addition, data and measurement processes must be put in place consistently across all three cities.

This common core has provided a base for Sharing Cities to aggregate experience and learning across the participating cities and more widely. This common core has been selectively augmented by further evaluation targets that are specific to the city and/or measure.

Dynamic impacts – In developing evaluation targets, we realise the measures put in place by Sharing Cities will have a range of different impacts on different stakeholders. These impacts may change over time as stakeholders learn and adapt their behaviour and the measures themselves evolve. Our experience suggests these impacts may be considered under five broad headings:

- Technical performance.
- Institutional and business consequences.
- Impacts on attitudes and behaviours.
- Wider systemic impacts including environmental, security, safety and sustainability.
- Economic and social implications including those affected by efficiency, equity and social inclusion.

As SEMS developed over the course of the Sharing Cities project, we created a longer list of indicators to measure their impact. These are detailed on the following page.



KPI	Stage	ShC CMEF lvl	Perspective	Aggregation	Reference	City
Authorities engagement	Outcome	SEMS, Mobility, Lamppost, Smart City	Institutional	Scheme, City	ETSI TS 103463, CITYkeys	Lon
Citizen engagement	Impact	SEMS, Lamppost, Smart City	System	Scheme, City	ETSI TS 103463, CITYkeys	Mil
Data produced/transmitted	Output	Lamppost, Retrofit, SEMS, Mobility, Smart City	Technical	Scheme, City		Mil
Energy/fuel poverty	Outcome	SEMS, Smart City	Social	City	ETSI TS 103463, CITYkeys	Lon
Financial viability	Process	Retrofit, SEMS, Mobility, Lamppost, Smart City	Economic	Household, Building, Scheme	CITYkeys, SCIS	Lis, Lon, Mil
Grid stability/Peak load	Outcome	Retrofit, SEMS, Smart City	System	Local electricity substation	ISO37120, SCIS	Lis, Lon
Household energy bill	Output	SEMS, Retrofit	Social	Household, Building, City	ETSI TS 103463, CITYkeys	Mil
Household energy use	Outcome	Retrofit, SEMS, DSM, Smart City	Technical	Household, City	ETSI TS 103463, CITYkeys, ITU-T 1602, ISO37120, SCIS	Lon,Mil
Infrastructure installed	Output	Retrofit, SEMS, Mobility, Lamppost	Technical	Scheme		Lon, Mil
Level of incentivisation	Process	SEMS, Mobility, DSM	Technical	Scheme		
Operational reliability	Outcome	Retrofit, SEMS, Lamppost, Smart City	System	Household, building, local electricity substation	ITU-T 1602, ISO37120	Lis, Lon

KPI	Stage	ShC CMEF lvl	Perspective	Aggregation	Reference	City
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
Procurement mechanism	Process	SEMS, Mobility	Institutional	City	ETSI TS 103463, CITYkeys	
Societal energy use norms	Impact	SEMS, Smart City	Social	City	CITYkeys	
Societal mobility norms (like eco-driving)	Impact	Smart City	Attitude	City		
Solution replication	Impact	SEMS, Mobility, Lamppost, Retrofit	Business	City, Global	CITYkeys	Lis, Lon, Mil
Stakeholder satisfaction	Impact	Retrofit, SEMS, Mobility, Lamppost, Smart City	Business	Household, Building, Scheme	CITYkeys	Lis, Lon
Technologies developed	Output	Retrofit, SEMS, Mobility, Lamppost	Technical	Scheme		Mil
Type of incentivisation	Process	SEMS, Mobility, DSM	Technical	Scheme		

Use data to inform policy

Some of the data collected in measuring SEMS' performance has begun to inform the development of planning activities and policies. On the next page is an example from Lisbon.

LISBON

A set of data sources has been identified in order to ensure the desired data analytics and assessments. These included:

- Energy consumption – through energy (electricity and gas) smart meters installed 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 different stages of retrofit works and rollout.
- Comfort assessment – through surveying all residents during the different stages of retrofit works and rollout.
- Socio-economic characterisation – through surveys conducted with residents participating in the experimental group.

By collecting this data, we can enable project partners to understand the impact of the interventions at different scopes and levels. These include technical performance, socioeconomic 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.
- Additional environmental benefits.

Thus, more than the energy performance, the goal is to understand how such interventions can help alleviate other issues such as energy poverty.

In addition, there have also been meetings and interviews with the building operators and local stakeholders. These are an important part of the post-retrofit activities. The aim is to evaluate the perception and willingness of local actors to replicate and/or scale-up this approach across similar buildings in the city. The feedback from these entities has been very positive. This is because the outcomes are perfectly aligned with the housing policies and strategies defined for the city.

References

1 Based on simulation using the Digital Twin in London and the application of DEOPS at Casa Siemens

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