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BUILDING SMART CITIES TOGETHER

SHARINGCITIES

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Executive summary

The technical nature of SEMS dictates that a diverse consortium of project partners is required for effective development and delivery. While it is anticipated that technical skills and resources will be provided by private sector organisations and academic institutions, the City is a crucial stakeholder and enabler; providing strategic alignment with policy objectives and maximising the social benefit delivered by the measure.

This document, therefore, is written from the perspective of the City; providing a narrative on the delivery of SEMS in each of the three Sharing Cities Lighthouses. The context of SEMS from the experience of a city is designed to provide other urban areas, interested in implementing SEMS, with an indication of the resources, governance and delivery requirements.

While the energy challenge facing urban areas is universal, local objectives and key performance indicators may differ; shaped by the political, spatial and economic context. What our delivery process has shown, however, is that there is a commonality in our decision making when considering solutions to the fundamental overarching themes of openness, interoperability and scalability. The critical aspects of: understanding your energy assets, a modular system architecture, a virtual simulation environment, integrated delivery plans and considered objectives provide solid and common foundations from which a tailored SEMS solution can be deployed in your city.

During the design and implementation process many decisions were made that had an impact on the final SEMS solution. A selection of the key decisions is presented under the themes of spatial context, delivery methods, system design, and functionality. While other project may experience similar decisions, it is important to note that the actions undertaken here will not be the most appropriate in all situations. Throughout the design and delivery process we have discovered that while as ‘open and interoperable’ as possible, SEMS is not a one-size fits all solution for urban centres. A more considered approach of adapting the system to your own city context is required and therefore limits the direct application of a key decision support tool.

Despite this, there is significant value in documenting and reporting on the experiences of our lighthouse cities. The common decisions and challenges have been far more numerous than the city specific issues and therefore, it is hoped that this work can accelerate the learning

process for others, reducing the time and resource requirements for developing a city specific SEMS and facilitating the scale-up and replication of this Sharing Cities measure.

Acronyms and Abbreviations

APC	Advanced Process Control
API	Application Programming Interface
BEMS	Building Energy Management System
CEiiA	Centro de Excelência para a Inovação da Indústria Automóvel
CML	Câmara Municipal de Lisboa
CO2	Carbon dioxide
DHW	Domestic Hot Water
DSO	Distribution System Operator
DSR	Demand Side Response
EDP	EDP Distribuição
EMS	Energy Management System
EV	Electric Vehicle
GLA	Greater London Authority
H2020	Horizon 2020
ICL	Imperial College London
LBN	Lisboa E-Nova
IoT	Internet of Things
IT	Information Technology
KPI	Key Performance Indicator
M2M	Machine to Machine
Monet	Mastering and Operate Next generation of Energy of Things

PV	Photovoltaic
RBG	Royal Borough of Greenwich
RES	Renewable Energy Systems
SCADA	Supervisory Control and Data Acquisition
SEMS	Sustainable Energy Management System
SEPS	Sustainable Energy Planning System
UC	Use Case
USP	Urban Sharing Platform

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1 Introduction

1.1 About this Document

This document is produced to fulfil the requirements of Deliverable 3.4. It is designed to provide insight into the learning process of delivering a Sustainable Energy Management System in each of the three lighthouse cities. We also identify key decisions taken during the design and implementation process that were critical to the successful implementation.

The deliverable has been produced by the Lighthouse Cities and partners of Task 3.2 in month 42 of the programme.

This document will:

- Provide a narrative from the city perspective of the Sustainable Energy Management System (SEMS) design and implementation process
- Compare the experiences of the Lighthouse Cities, identifying similarities and differences in their approach
- Present readers with a list of critical aspects, lessons learnt and recommendations to consider when designing and implementing SEMS in their own city
- Reflect on key decisions taken during the process, providing a summary of the options and associated costs/benefits.

After reading this document, you should:

- Understand the reasons and methods for implementing SEMS in each Lighthouse City
- Be able to construct your own narrative and rationale for implementing SEMS in your city
- Avoid common pitfalls; accelerating the delivery process and minimising costs
- Make well informed decisions relating to the technical delivery that are aligned with your strategic aims and objectives

Report Structure

This report is produced for city leads. It is presented as an historical account of the implementation of SEMS and a reflection on the decisions taken.

This document represents the main narrative of the deliverable. A technical annex supplements this document and is intended to be used by technical partners appointed by city leaders. The technical annex identifies key technical decisions during the implementation process and is intended to guide and accelerate delivery.

2 The City Perspective

SEMS has been designed and developed by the Lighthouse cities as a collaborative process. The specifications, use cases and system objectives have provided a commonality and alignment for the SEMS system which has demonstrated its applicability to different urban centres.

A global definition of SEMS was established in month 7 (July 2016) of the programme, and a set of high level use cases were then created in support of this definition (as described in D3.5). However, deployment and implementation of the system is location specific and depends on the assets, management systems, stakeholders and prioritise of each city. Therefore, this section describes the individual journey of each of the three cities in delivering SEMS.

In addition to narratives of SEMS development from the city perspective, a timeline is provided in Appendix A. This shows the high-level processes that each city undertook to develop and implement SEMS.

2.1 Delivery Narrative

Lisbon

The City Hall is one of the most emblematic and historical buildings in the city. Located in the heart of Lisbon, it represented a key strategic priority for the municipality's ambitions of optimising building energy consumption to better match local renewable generation, improving the business case for renewable installations (particularly solar photovoltaic) and delivering environmental and financial benefits for the city.

The City Hall was selected for several reasons;

1) Scale of impact: The City Hall is amongst the five highest energy consuming buildings owned by the municipality. Reducing consumption is therefore a financial priority
2) Lead by example: A demonstration from the municipality using its own assets of what is possible, encouraging developers and other building owners to follow
3) Replicability: The City Hall is representative of the historical nature of many buildings within the Lisbon downtown area, by selecting City Hall, the municipality the measures will be taken up at other public and private buildings

This rationale is in accordance with the overall strategy for sustainable energy of the city and aligns with Lisbon's Sustainable Energy and Climate Action Plan (2018)[1], part of Lisbon's commitment to the Covenant of Mayors for Climate and Energy.

The starting point for the design of the Sustainable Energy Management System in Lisbon was the retrofit works being undertaken at the City Hall (refer to WP3.1 for details). SEMS would optimise the energy requirements of the building by maximising the self-consumption of PV generation at the site and minimising overall energy costs by making use of optimal tariff periods.

Therefore, as well as a stand-alone solution designed to optimise the existing reality of the building (in terms of characteristics, equipment and functions) SEMS was also intended to enhance the impact of the retrofit. At this stage, the compound impact of retrofit plus SEMS is not well understood, consequently the additional benefits of SEMS cannot be accounted for in the business case for the retrofit works. However, through demonstration projects like this it is hoped that the benefits can be more accurately estimated; increasing the attractiveness of further retrofit works in the future.

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

1) On-site hardware, responsible for acquiring data and controlling the several types of equipment, allowing the transmission of measurements to the software and receiving control orders;
    - Smart Metering equipment measuring building overall, consumption, HVAC consumption and PV generation. Three smart meters are used.
    - Power reducers controlling electrical boilers. Seven Power reducers are used.
    - Smart plugs. Fifteen plugs are used.
    - Data concentrators (Hub) to communicate with all the peripherals mentioned above. Five hubs are used.

2) The software platform capable of communicating with the equipment, handling the acquired data, presenting the user interface for data analysis, controlling the equipment and allowing interaction with other software platforms.

[1] http://www.cm-lisboa.pt/fileadmin/VIVER/Ambiente/Alteracoes_Climatericas/SECAP_EMAAC_parte2de2_20180423.pdf

Both elements of the system were specified by the technical project partners in Lisbon; EDP Distribuição (EDPD), EDP Centre for New Energy Technologies (EDP CNET) and Lisbon Municipality (CML). However, the solution was not developed by a Sharing Cities consortium partner as it required technical knowledge and expertise in the implementation of building energy automation at both a software and hardware level. Therefore, in the last quarter of 2016, EDP CNET launched a Request For Information (RFI) to perform a benchmark of the existing solutions available in the market.

Following an initial assessment, the definition and functionalities of SEMS were updated to reflect available technologies and the programme objectives. It was concluded, however, that no existing products aligned with the Sharing Cities goals; existing solutions were proprietary and not open and interoperable in a way that would facilitate replication and scalability. Subsequently, EDP CNET launched a tender process (through a Request for Proposal) in the first quarter of 2017 for a solution provider. The process was undertaken in accordance with the company's internal procurement rules and the EU H2020 funding programme rules.

EDP CNET received 3 tender responses. Following a technical and economical evaluation of the proposals, Virtual Power Solutions (VPS) – a Portuguese, Coimbra based SME – was awarded with the contract to develop the SEMS solution in Lisbon in September 2017.

EDP CNET have managed the delivery contract, with VPS responsible for the delivery of SEMS at the City Hall. A main contact was appointed by Sitio da Câmara Municipal de Lisboa (CML) to monitor the project for the municipality and provide necessary information. EDPD have provided project management support and lead the task in the context of the wider Sharing Cities programme, providing links to other work packages and dependencies.

At the scale of deployment in the City Hall, a full integration of SEMS with the newly developed Urban Sharing Platform (USP) was deemed too costly and time consuming for this project. Information is shared directly with the municipality through the SEMS platform, with the city owning all the generated data. SEMS does, however, have the capability of integrating with the USP in the future once the scale and functionality is expanded to incorporate more datasets. The format for sharing and visualising this information is still to be defined and will continue beyond the Sharing Cities programme.

London

As a large asset owner, the municipality (Royal Borough of Greenwich) was integral in establishing the context, assets and objectives for SEMS in London. Supported by the task lead and technical partners, RBG led on the identification and prioritization of city use cases according to the local context and priorities of the Borough. These priorities included:

- Cost savings for residents and asset owners associated with using less energy or using cheaper energy sources
- Carbon emissions reduction associated with reduced energy consumption and renewable generation
- Air quality improvements from substituting energy generated from combustible sources to clean sources of energy

RBG's position of developing the use cases was strengthened by the fact that they were also the responsible partner for delivering the building retrofit and e-mobility measures (Work packages 3.1 and 3.3). This provided the project with early sight of planned energy assets, allowing the design of SEMS to be both influenced by the new assets and influence the specification and procurement of assets to its own benefit. As a result, the use case templates remained 'live' documents throughout the project, being amended and refined as more asset details became available.

RBG continued to develop the use cases (adding details on energy assets and data) in the first year of the programme and undertook an asset mapping exercise to inform technical partners of the breadth of energy assets which could be involved in SEMS, providing detail of their technical characteristics and any baseline data.

Translating the city use cases into a technical and functional specification was the role of the local technical partners in London; Siemens UK and Kiwi Power. Early in the second year of the programme, the London technical partners had produced a system architecture for SEMS; diagrammatically mapping use cases, potential data collection processes and initial ideas on communication and control approaches. This process was critical in identifying a skills gap amongst consortium partners for the development of the optimisation algorithms that would be a core feature of SEMS. Subsequently, Siemens UK as lead technical partner for London, led the procurement and appointment of an additional project partner to provide the 'intelligent' functionality of SEMS.

Existing partners collaborated in creating a document of requirements (‘Requirements of best value for sub-contracting SEMS algorithm development’ – see Appendix B) to invite responses and identify market interest in the project. Following a process of procurement, Imperial College London (ICL) were appointed as the SEMS algorithm development partner in July 2017.

Along with the technical knowledge and expertise of developing Model Predictive Control (MPC) and Advanced Process Control (APC) algorithms, ICL also informed the creation of a ‘Digital Twin’, which would provide a virtual environment for modelling the existing and proposed local energy system. RBG provided a city perspective during the process to ensure the digital twin was representative of local context and buildings; and provide detail on expected system constraints (e.g. thermal comfort of residents) and objectives (e.g. cost savings & CO_2 reduction), ensuring that the virtual environment was representative of the real world which would subsequently allow for a smoother deployment of SEMS.

In addition to the WP3.2 technical partners, RBG also began regularly meeting with partners from WP4 responsible for the Urban Sharing Platform (USP) in London. These discussions explored the integration of SEMS and USP. However, by month 24 of the programme, there were still several architecture options for the integration of the USP and SEMS in London.

Following discussion, the London Datastore (a data platform operated by the Greater London Authority) emerged as a strategic fit for the project; providing a local and independent data ingestion point. Fundamental in the decision-making process was the requirement that the solution was: sustainable beyond the life of the programme; adhered to the core principles of SEMS (openness and ease of integration); did not jeopardize provision of essential services such as heating homes; and which could be replicated and scaled elsewhere.

A working version of the SEMS in its digital twin environment was demonstrated in month 32 of the programme. The system includes data transfer, modelled assets and forecasting and optimisation algorithms. Further refinement and validation of the system is required in the virtual environment and RBG also needs to ensure the provision of data which is yet to be integrated. Following this, the SEMS is ready to be transferred into the real-world environment once the energy assets are fully installed and the control and actuation processes can be tested. The principles of control are an important consideration as they will directly impact any operational strategies of asset owners. Market acceptance of this is yet to be tested but it will provide interesting learning as to how compatible SEMS is with common energy asset operation & maintenance contracts.

Over the remainder of the Sharing Cities programme, all partners will also be exploring how to further develop SEMS, providing additional functionalities (e.g. a human machine interface) and adding greater value for the city.

Milan

The Municipality of Milan have had an ongoing partnership with Siemens IT since they developed an advanced energy management solution for the pavilions and exposition areas for the 2015 Milan Expo. The product of this relationship was a system named "Mastering and Operate Next generation of Energy of Things" (Monet).

Within the scope of Sharing Cities, Monet is one of the fully integrated components of the USP, able to collect energy data from the field and share them with the USP. After the end of the project, thanks to this modular approach, the Municipality of Milan will evaluate further development of the system, either in partnership with Siemens or a new provider of SEMS components.

Through Sharing Cities, the Municipality of Milan were interested in expanding the functionality of Monet to fulfil the objectives of SEMS in the city. These objectives included:

- Increasing 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 facilitate greater uptake of distributed renewable generation and avoid/delay network reinforcement costs.

Based on these objectives Siemens IT developed three specific use cases for SEMS in Milan which would demonstrate the application of the Monet system within the complex urban context:

UC1 – Building mounted PV, with the objective of maximizing building-level utilisation of renewable self-generation;

UC2 – Building energy management, with the objective of minimizing the energy cost of a building by reducing the peak power of the building and/or using more suitable energy tariffs such as two-time period tariff or three-time period tariff, along with load shifting, the use of renewable energy and the energy storage.

UC3 – EV/PV optimization (district level). A recharge island will be configured with a PV and many charging stations, optional is the energy storage. The SEMS system will acquire data from PV, charging stations through e-mobility infrastructure management system, storage if present and control the recharge island to maintain the total power consumption under the grid power available.

The selection of assets for the use cases was based on forecast availability in the demonstration area. The demonstration area for the Sharing Cities project in Milan is the Porta Romana District. This represents a significant regeneration opportunity for the city and is a key strategic site for the Municipality. The planned investment will introduce significant numbers of new energy assets, particularly new building mounted devices and e-mobility charging stations and reinvigorate existing buildings through deep-retro fit and energy efficiency improvements.

To ensure that the new assets would be compatible for integration with SEMS, Politecnico of Milan supported Siemens IT to analyse historical data of public buildings and energy demand of the site. The findings were incorporated into the specifications for photovoltaic and energy storage solutions, allowing the Municipality to prepare accurate tender documentation for its other work-packages with well-defined technical specifications and constraints.

Early knowledge of the asset specifications allowed Siemens IT to understand the data connection protocols early in the project timeline. The connection between local devices and the SEMS system would be maintained in a cloud environment, eliminating the need for a physical server. The connections are based on a LoraWan and GSM connection which are long-ranged but low powered and allow the connection of multiple devices without proprietary licenses; supporting the programme ethos of openness and replication.

The specifications and data connections with the USP were defined by the Municipality, represented by its IT department, in collaboration with Siemens and partners from WP3 and WP4. An 'OpenID Connect' security layer implemented by Monet provides the integration with the Digital Social Market and other USP components, providing authorisation for these platforms to access data within the Monet system.

Energy data is visualized, aggregated, and analysed via the Urban Sharing Platform (USP). The forecasting and optimisation algorithms within Monet are providing municipality energy managers with detailed and (near) real-time information about energy flows in the district. Furthermore, SEMS will calculate typical consumption patterns and provide forecasts of generation & consumption based on both historical data and weather forecasts. The outputs will be used to support decisions in terms of energy efficiency, asset investment and regional level energy planning.

Once the recharge islands have been installed, the control element of SEMS will be introduced and tested. The actuation functionality developed by Siemens IT will allow greater e-vehicle market penetration in the future by avoiding additional costs for grid network connectivity (maintaining the normal connection up to 100kW) without the installation of a secondary sub-station, enabling recharge islands to be deployed at much greater scale.

In addition, SEMS will allow analysis of energy data to understand the potential for applying a similar model of retro-fit and energy management at other buildings across Milan. Creating a legacy of best practice for future projects and tender processes.

2.2 Critical Aspects & Lessons Learnt

When considering the delivery of a Sustainable Energy Management System, it is important to consider the unique characteristics of the locations, organisations and challenges involved. Within our project, each lighthouse city has encountered obstacles and challenges that have been new to them; a process that has added new skill sets and experiences to the delivery teams. In this section, the delivery teams share some of the lessons they have learnt during the process and why these are critical to the successful delivery of SEMS with the objective of accelerating the learning process for others.

What?

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.

Why?

Makes sure the solution meets the requirements of the city and accelerates the delivery process. It also allows you to identify any skills gaps within your consortium and begin to fill these. It also provides early opportunities to influence the tender process and specifications of new energy assets to ensure compatibility with SEMS.

What?

Understand your existing energy assets, including the available data and control functionalities that they provide.

Why?

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 and it is better to know this as early as possible as it can be time consuming.

What?

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.

Why?

SEMs is intended to free cities from technological lock-in. The modular nature allows new innovations to be introduced into the system without making the existing system redundant, saving time and money.

What?

The use of a virtual environment to model your existing energy system has been a valuable resource. Try to make your model as accurate as possible, but don't worry about estimates or incomplete information in the early stages; your model should be refined and developed along with your project.

Why?

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 also be used to test, validate and calibrate your algorithms before they are applied to a live environment and will also assist with any monitoring and evaluation processes.

What?

Build and maintain strong relationships with project stakeholders. A system wide-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.

Why?

In a sector that is not used to integrated collaborative approaches, having close relationships with your stakeholders will ease the implementation of technical solutions. More importantly, it is critical for establishing the contractual arrangements around data sharing, asset/network performance and actuation that are essential for the project to be delivered.

What?

Integrate your delivery plan with other planned activity in your city; aligning the scope of this activity with your aspiration for SEMS. This might include building upgrades and retro-fit, e-mobility infrastructure and vehicle deployment, renewable energy installations.

Why?

An understanding of planned activity will inform the scope of SEMS in your city and allow for a smoother integration of new functionalities, assets and systems. An awareness of the timescales for delivery will also improve project planning, enabling an anticipation of key periods of implementation and allowing for suitable resourcing.

What?

Set realistic and achievable objectives for SEMS that take into account your technical and resource limitations.

Why?

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, and while solutions are possible, they are expensive and time consuming.

3 Decision Support Tool

This section is intended to provide the reader with a summary of the key decisions made during the design and implementation phase of SEMS. Compiled from the experiences of city leads and technical partners, it is structured into four themes covering: Spatial context; Delivery Methods; System design; and Functionality. The summary presented here is synthesised from the detailed responses provided in Appendix C.

3.1 Spatial Context

SEMS is designed to be an entirely open and interoperable system, allowing any energy assets or management systems to be integrated; this makes any location a potential site for deploying SEMS. However, when deciding on the geographical location there are a number of key considerations:

- Availability & 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 performance and functionality of the system.
- Asset Diversity – System integration and optimisation will have a greater impact if there is a diverse mix of energy vectors available. This will provide greater demand and generation diversity, providing SEMS with 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 (environmental savings, cost savings, renewable generation, etc…).
- Significance – For political or institutional reasons, you may choose to include 'statement' assets within the SEMS portfolio. This could be 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, selecting a geographical area that is energy constrained, or is expected to be constrained in the future, maximises the benefits attained from SEMs.

While the above are important considerations for the location of deployment in the real-world, the speed at which software solutions can be developed will often outstrip physical infrastructure installations and upgrades. Therefore, an important decision is the use of a 'Virtual Simulation' to test the system before implementation. The Virtual Simulation can take the form of anything from a simple model, generating artificial data to calibrate and validate the algorithms, to a fully modelled energy system compiled using known specifications for future assets with virtual links to shadow data platforms and control simulators.

While the form of Simulation will depend on the time and budget available, a more detailed simulation provides the additional benefit of eliminating uncertainty. It can be used as a support tool for validating energy infrastructure investment decisions and identify future constraint areas.

3.2 Delivery Methods

SEMS is made up of several components; advanced process control algorithms, model predictive controls, forecasting, human machine interfaces, data storage and programming interfaces. A decision must be made, therefore, as to whether a single 'turnkey' provider is appointed to deliver the whole system or if a consortium of providers collaborate on the solution.

On one hand, the highly technical nature of the system components and the communication between them could be more reliable if the same entity developed the entire solution. A single solution provider may also be able to provide the solution more quickly and cost efficiently than a consortium as resources may be more readily available and internal working processes will already be established. However, the highly technical nature of the tender specification meant that very few organisations (if any) will be able to deliver all of the elements. Even if they claim to have the ability and capacity to provide all of the requirements, they may not be specialists in each area. Therefore, the procurement of highly skilled technical partners to form a collaborative consortium presents an alternative. Under this situation, skilled and significant project management resources are required to ensure alignment and integration, but it also allows for a modular and non-proprietary system to be developed which can be amended and added to in the future. It also reduces your exposure to the risk of a single organisation withdrawing from a project or not being able to deliver.

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

3.3 System Design

To avoid excessive data transfer, storage memory and processing power, SEMS is designed to integrate with the Urban Sharing Platform (USP); providing a horizontal mechanism for integration. At small scale, it is possible for SEMS to undertake the function of data collection – making it a fully autonomous system and able to operate independently from a USP. This is a much cheaper and quicker solution and may seem appropriate if your budget and timescales are tight. However, this design limits the future scale-up and replicability of the system.

Therefore, as a minimum SEMS should integrate with a data store. Other useful functionalities of the USP include a graphical interface and data reporting. The USP could also provide the interface between SCADA and SEMS; however, this will require a long-term plan for operation and maintenance services (which could be more complicated in a collaborated solution).

The system design must also consider whether licensed or open software is most appropriate. While licensed software often consists of more comprehensive functionality and dedicated support services, 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 sufficient functionality to meet the requirements of your project, it also prevents 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 of mitigating this issue. Ultimately the system design you choose will be directed by your project aims and stakeholder objectives.

3.4 Functionality

SEMS could be formulated as a single algorithm in which all assets are handled in a single optimisation. Alternatively, a more modular approach – in which different modules are managed by a co-ordination layer – could also be deployed. Given the numerous and diverse types of energy vectors and objectives to be managed by SEMS (in particular considering future scalability), it would be more practical to deploy the modular solution. While a modular approach to deploying algorithms will require additional resources to develop the co-ordination layer, it also allows new assets to be added separately and at different times, which is more robust and scalable. It also prevents the risk of issues within a single algorithm from causing a total system failure, as problems can be isolated from the wider system.

If a modular approach is being taken, an 'algorithm engine' which identifies algorithms using a system of tags and labels to identify the responsibilities of different modules and associate hem with specific assets or groups of assets will be an important component. This inventory of algorithms could also be supplemented with an asset template, which will stipulate the information requirements to be used new algorithms.

The control functionality of SEMS presents another key decision. The solution presented by the algorithms can be actuated directly through SEMS or provided to local management systems in the form of 'recommendations'. While a direct control strategy would provide more optimised performance, ensuring that the whole system is operating in a fully integrated and co-ordinated manner, 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 is utilising open-source software. Therefore, your system may opt to delegate actuation to a local management system, limiting its influence to sending recommendations which will be actuated if they are within pre-defined parameters of the local system.

4 Appendix

Appendix A: SEMS delivery timeline

Appendix B: Requirements of best value for sub-contracting SEMS algorithm development

Appendix C: Key decisions matrix