EnergyREV

Skills for Smart Local Energy Systems: Integrated case study briefing

Ruzanna Chitchyan and Caroline Bird

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Authors

- **Ruzanna Chitchyan** | University of Bristol, UK
- **Caroline Bird** | University of Bristol, UK

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Part 1: Overview

Summary and recommendations

This briefing aims to help those engaged with local energy system transitions. It demonstrates how the different parts of the local energy system are interrelated, and what skills and measures are needed to support emerging smart local energy systems (SLES). This report presents an analysis of three smart local energy (SLE) case studies undertaken within the city of Bristol, the Energy Superhub project in Oxford and ReFLEX project in Orkney. This briefing builds on an earlier briefing note focused on the Bristol case study.

SLES are comprised of a set of loosely interconnected, independently evolved, managed and operated subsystems and can usefully be viewed as a system of systems (SoS). The subsystems considered in this study are: energy supply; building and retrofit; transport and mobility; local government; community energy; information and communications technology (ICT) for energy services; and local communities and citizens. All of these play a part in the journey of a particular locality to meet its net zero ambitions.

This report summarises the findings from the case studies at this SoS level, while considering the challenges and skills needed to bring the local subsystems together for a common goal of clean, local energy commitments.

Skills needs must be considered both within each subsystem, and also for the SoS as a whole, i.e. across subsystems. This briefing is focused on the cross-subsystem issues of a SLE SoS. (The full technical reports for each case study detail skills needs for the subsystems.)

There are **three key challenges** to be addressed in order to transition towards a successful SLES, all of which also have associated skills needs:

1. **Subsystems integration**, requiring physical interconnections as well as data and information exchange. Skills such as hardware and software installation, networking and communications, data analysis and machine learning, data protection and standardisation are critical.
2. **SLES governance and operation** brings together the sub-systems in developing common goals and ensuring that different aspects can operate for a common good without unintended negative outcomes. Skills such as cross-institutional project management, supportive policy making, evaluation and assessment, and consistent regulation are key.
3. **Stakeholder and citizen engagement** will help to develop common understanding and support new business models in the evolution of the SLES. Skills such as technological literacy, risk management, financial planning, partnership building, communication and engagement are necessary.

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Below are the key recommendations that address the challenges of developing an integrated SLES:

- Set a common and agreed upon goal relevant to all subsystems;
- Set up a cross-subsystem SLES coordination body;
- Share an understanding of physical connection issues;
- Build a general understanding of renewable, clean energy technologies;
- Coordinate investment in data collection and control infrastructure;
- Develop a framework for conflict resolution.

These should be supported by training in specific aspects of the following generic skills areas:

- Managerial skills – e.g. cross-sector project management, outcomes evaluation, financial planning, partnership building;
- Policy and regulation skills – e.g. standardisation, holistic and supportive policy, contracts and legal oversight;
- Engineering skills – e.g. hardware and software design and installation, data analysis and machine learning, building services design;
- Trades skills – e.g. installation of new technologies;
- 'Soft' skills in communication and engagement.

Part 2: Smart Local Energy Systems of systems

Assessing the skills needs for SLES

The UK's energy system is undergoing a rapid change, driven by both technological progress and policy goals of achieving carbon-neutrality by 2050. The UK must train the workforce that will deliver and operate this new system, as well as engage the citizens and communities into whose homes and environments this system will have to be integrated.

The key research questions addressed in this report are:

- **What (skills) challenges does the UK face in transitioning to SLES?**
- **What specific skills are needed for the UK's successful transition to SLES?**

To answer these questions, this report reviews three case studies where such a transition is already underway. This is a qualitative study, based on data obtained through documentary analysis, interviews and focus groups. The findings from this study are grounded on the evidence from the three case studies and are sufficiently generic to serve as 'food for thought' for similar challenges within other localities.

The case studies

The three case studies comprise one city example and two demonstrator projects trialling technologies at scale:

1. City of Bristol[1] is one of the UK's energy champion cities, and has hosted a number of energy transition projects and initiatives. This case study reviews the city as a whole as a local energy system in transition to a smart local energy model;
2. Energy Superhub Oxford[2] (ESO) is a demonstrator project consisting of rapid electric vehicle charging, 50MW hybrid battery system connected to the transmission grid, low carbon heating using ground source heat pumps, smart energy management and vehicle fleet electrification in the city of Oxford. This is a project-based case study, focused on the project stakeholders only.

1 See Bristol as a smart local energy system of systems: Skills case study for full details.

2 See Transition to smart local energy systems: Energy Superhub Oxford skills case study for full details.

3. Renewable Flexibility (ReFLEX) Orkney is aiming to create a low carbon, affordable integrated energy system (IES) which maximises use of local electricity from renewable sources, connecting this to electrified transport, energy storage and heat on the islands of Orkney. The project developed to utilise the excess renewable energy generated on the islands which cannot be exported to the mainland due to constraints on transmission network capacity. Similar to the case of ESO, this is a project-focused case study, looking at the project stakeholders only.

What is a Smart Local Energy System?

A **smart local energy system** aims to manage and balance the supply, storage and use of local energy across all vectors, bringing efficiencies to energy supply and demand alongside social, environmental and economic benefits to the given locality. In line with the UK's commitments of a net zero carbon economy by 2050, all energy system assets should be carbon neutral or carbon reducing. Investment in assets other than these will either jeopardise the UK's national targets, or will lead to stranding these assets within the next 30 years. Therefore, this study focuses on green and renewable based energy initiatives.

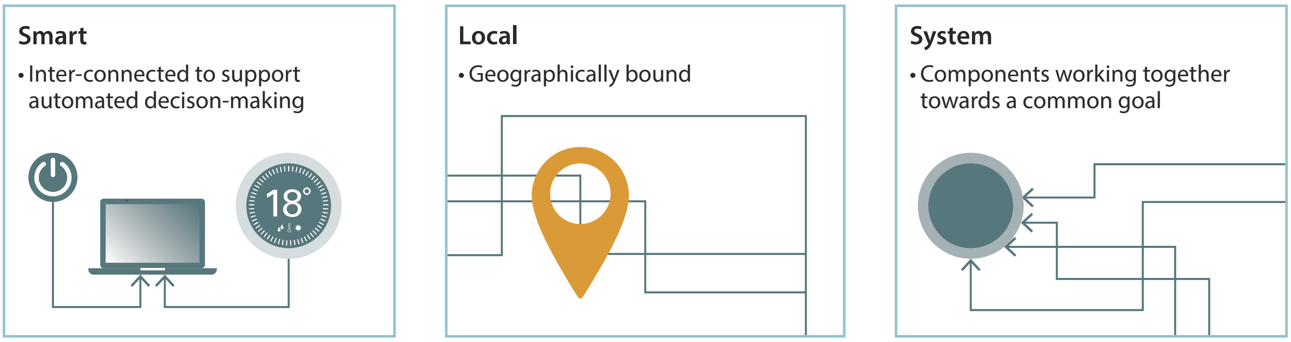

Figure 1: Terms of a smart local energy system.

Within this context (as shown in Figure 1):

Local refers to a defined geographical area where energy initiatives take place. This covers a range of organisations, including partnerships between public, private and non-profit sectors. Public authorities may take a coordinating role to leverage private sector investment in the provision of local energy. The **locally-based energy activities** include generation and storage, as well as consumption and its reduction through a variety of energy efficiency and behaviour change, energy management and balancing of supply and demand, and delivering non-financial societal value (such as, for example, health and educational improvement through warmer homes).

Each local geographic area is also endowed with its **locally distributed renewable energy sources**: e.g. sun, wind, tidal, waste recycling, etc. Therefore, **decentralisation** is a key part of the 'local' aspect of SLE. Most renewable energy technologies are dependent on locally distributed sources. For instance, tidal energy can only be generated in coastal locations, while solar generation can be secured locally through panels mounted on roofs and fields at a range of scales.

The **smart** aspect of energy implies a **digitally supported coordination of decision-making** *for (sub-) systems* to optimise their resource use and waste reduction (both generation and consumption) and support for human decision-making for efficiency and comfort. However, the smart energy system will not fulfil its potential without **smart users**, thus household and business users will also need to acquire skills in the functioning and the use of digital energy systems.

SLES as a system of systems (SoS)

A smart local energy system is itself a system of systems (SoS), the simplified overview of which is presented in Figure 2. Here, the set of individual (sectoral) subsystems are integrated through digital and physical infrastructure to create a SLE SoS. These individual subsystems have their own boundaries and behaviours, although they do collaborate for the *common goal of achieving net-zero localities, for which they must optimise the use of local renewable energy*. For this to happen, they exchange data and exercise control over the energy exchange itself (e.g. drawing on, or storing into batteries, switching consumption equipment on/off, etc.).

The sectoral subsystems[3] which were identified and researched for these 3 case studies are:

- **Energy supply**, which refers to the traditional energy sector and integration of the local energy assets and services with those of the UK's distribution and transmission grids.
- **ICT infrastructure for the delivery of digital energy services**, which includes the human, hardware and software assets (from networking infrastructure and servers to algorithms and data) that enable coordination and control of optimised energy generation, storage and consumption.
- **Transport and mobility**, which integrates battery storage through electric vehicles (EV), electricity drawn through EV charge points, use of alternative fuels (e.g. biofuels and hydrogen) for transportation, optimisation of travel routes and schedules, etc.
- **Building and retrofit**, which addresses energy efficiency and carbon neutrality of buildings. Buildings contribute to energy generation, (e.g. through solar PV panels) and consumption.
- **Local government**, which refers to regional, city and area-scale policies, regulations and actions which foster or preclude energy-related activities (e.g. a local regulation in Bristol: any new build dwelling must have at least 20% of its energy needs met through its own renewable sources).
- **Community energy**, which refers to the community organisations that enable and engage local communities with energy generation, sharing, storage, consumption, (dis-)investment and other activities.
- **Citizens and communities**, who must be engaged in contributing to generation, storage and energy efficiency activities. Citizens and communities are the key players in all other energy activities. The more engaged the citizens and communities are, the more efficient the SLE SoS that they underpin will be.

A SLES therefore comprises a number of semi-independent subsystems, each operated for its own purpose by separate management structures, with different time horizons, technological and professional heterogeneity, and evolutionary paths.

3 Although this hasn't been discussed in this report, within each sectoral area, each subsystem can be viewed as a further set of sub-subsystems, with shared technological and infrastructural approaches.

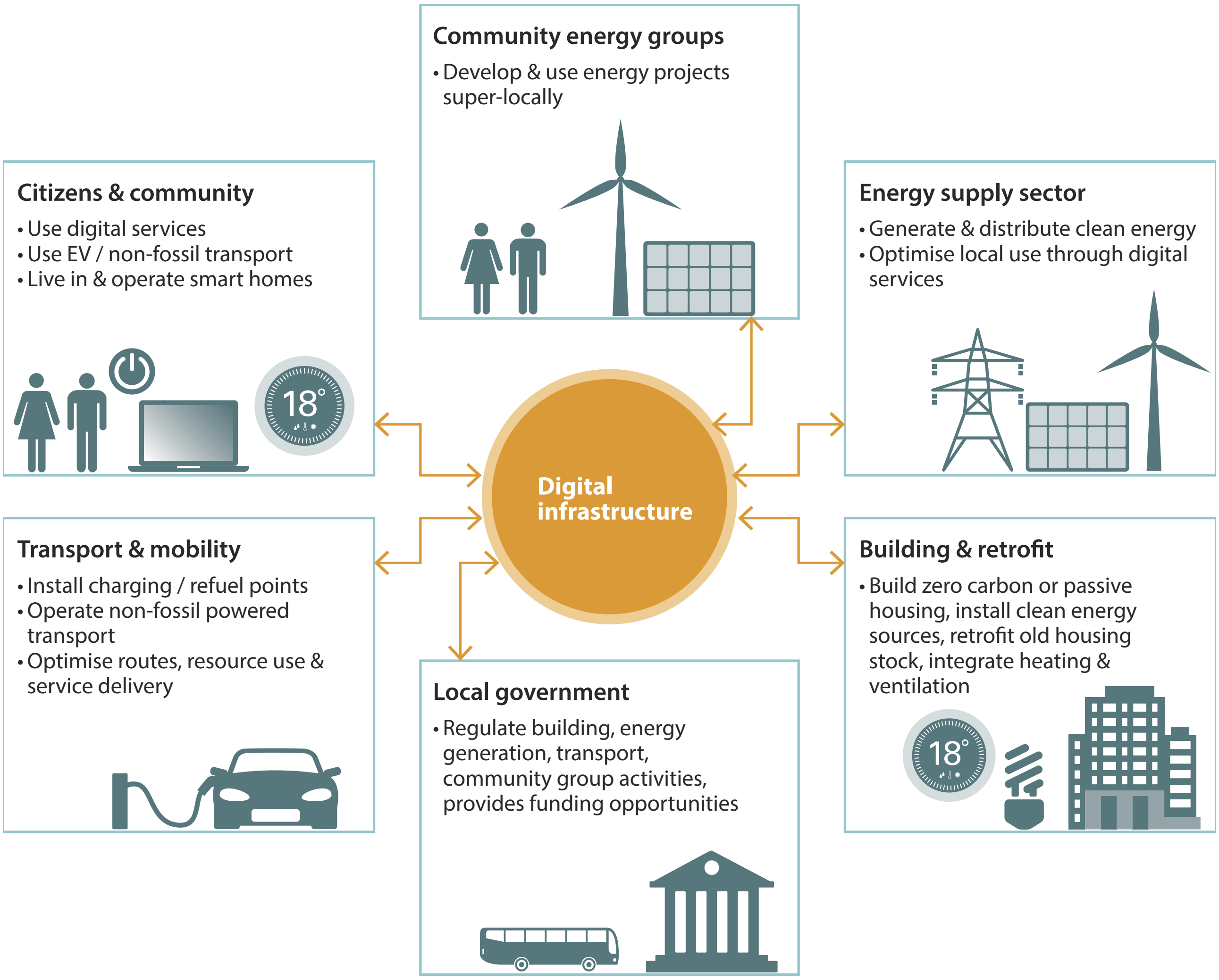

Figure 2: A simplified overview of a smart local energy system as a System of Systems.

Architecting SLES

In order to create a coherent SLES, the subsystems must be able to interact and collaborate towards a **common goal**, which, for all three case study SLES, **is achieving a net zero emissions local energy system by 2030**. However, these subsystems, due to their independent evolutionary development (see Box 1), have well-established boundaries and operate largely independently of each other. The only way of creating a common SoS architecture for SLES is by integrating subsystems through common interfaces. Drawing on the 3 case studies (as illustrated in Fig. 3), we observe that these are:

1. **Interfaces with the energy distribution and transmission networks** that operate at the hardware level to interlink the generation, storage and consumption equipment with the electricity and gas/heat grids (shown as orange cluster in Fig. 3).

2. **ICT interfaces** that integrate data collection and exchange as well as decision support and control over the various generation, consumption and storage devices located within the component subsystems and their interconnection platforms (shown as black cluster in Fig. 3).

3. **Policies and regulations** that constrain and stimulate various activities within and across these subsystems (shown as green cluster in Fig. 3).
4. **Education and training provision** that fosters knowledge and cooperation towards common goals across the various stakeholders within and across the SLE subsystems (shown as purple cluster in Fig. 3).

Given their independent development, one cannot expect to see a homogeneous set of skills, work practices or educational environments across all of the SLE subsystems. Thus, to ascertain skills needs for the SLE SoS:

a. skills needs for each SLE subsystem are studied separately (as each subsystem needs to transition to net-zero and clean energy for the SoS as a whole to transition as well),
b. then the common skills needed across-subsystem are identified, noting the skills that are particularly critical because they are needed by most subsystems, as well as the cross-subsystem skills which are needed to integrate the subsystems into a SoS.

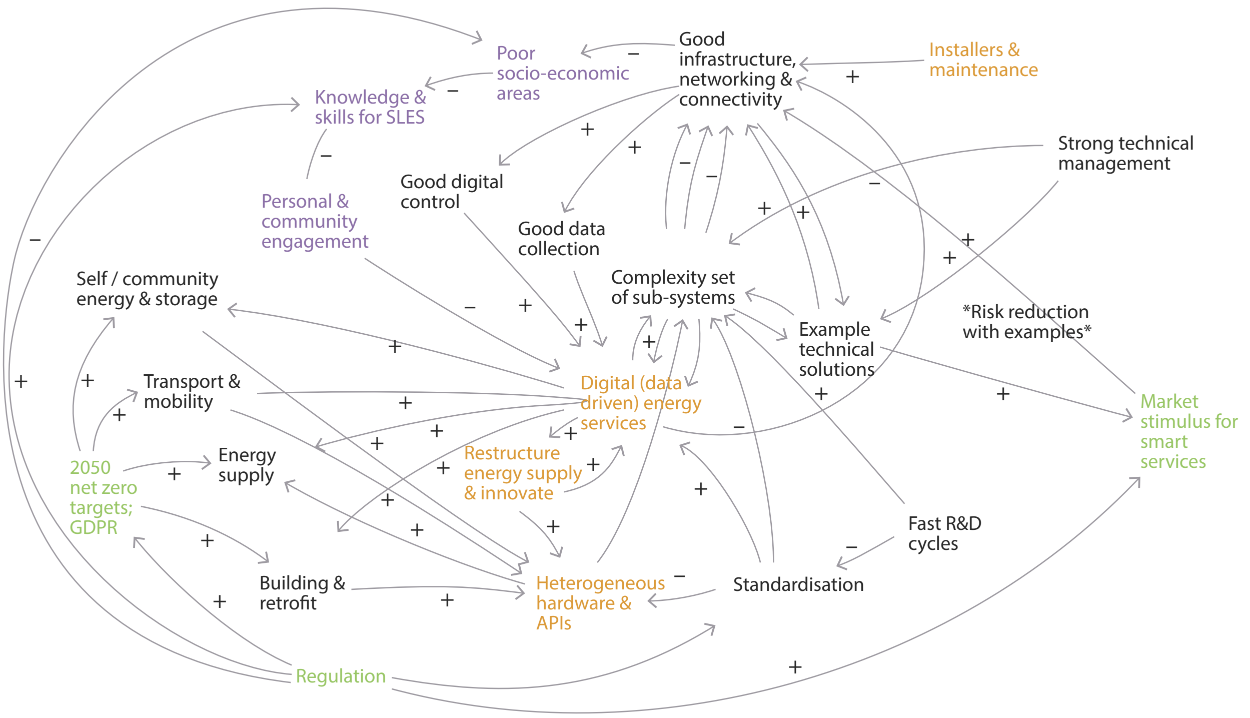

Figure 3: Integrated overview of SLE SoS transition drivers and obstacles.

Box 1: System of systems traits in smart local energy

How systems-of-systems traits[4] apply to SLES

The common system-of-systems characteristics and their relation to SLES are explained below:

- **Operational independence**: subsystems can *usefully* operate independently so, for instance, the Energy Supply sector will deliver energy to its household or business customers with or without the Transport and Mobility or Building and Retrofit subsystems.
- **Managerial independence**: subsystems are delivered and operated by independent organisations which belong both to a wide set of different owners, and are also located within quite different sectors such as transport, energy, government, etc. While, as part of the SoS, the subsystems collaborate towards a common goal, each of the subsystems also continues to deliver its own goals. For example, a Transport and Mobility subsystem moves people and goods to the required destinations as its primary goal, irrespective of also storing and re-supplying electricity to the grid via EV batteries.
- **Evolutionary development**: the SoS will be able to deliver useful services even before the complete deployment of all its components. Similarly, the SoS will still be operational even if some subsystems are removed. Thus, a reduced form of SLE SoS can start to optimise use of local energy and reduce carbon impact, even if, for instance, Community Energy generation is not present, and the Transport and Mobility sector is fully fossil-fuel based. As the subsystems are, at least partially, independent in their development and operation, there can be no guarantee of their availability.
- **Emergent behaviour**: by working as a SoS, the subsystems deliver more than the simple sum of their services. They are able to provide new (levels) of services, for example flexibility to the grid via EVs from the Transport sector, and demand side response (DSR) services over Citizens' household appliances.
- **Geographical distribution** leads to looser coupling between the subsystems.
- **Heterogeneity**: the components of each subsystem are different. For example, each subsystem has hardware components – from wind turbines to EV charge points and washing machines – and software systems to monitor and control them. They pursue different goals, serve different stakeholders and operate different economic models. To create a SoS, interfaces between the subsystems must be developed and integrated.

4 Vargas, G. and Braga, R.T.V. 2020. Understanding system of systems management: A systematic review and key concepts. IEEE Systems Journal, pp 1–10.

Part 3: Findings and recommendations

Key findings: the main challenges of SLES

Integrating the SLES subsystems through the identified interfaces poses a set of challenges that must be addressed:

Challenge 1: Integration, interconnection and communication between subsystems

Physical connection: In order to operate in a coordinated way, the subsystems within the SLES system must support physical interconnections for energy exchange, as well as data and information exchange for decision support and control in optimisation of operations.

The infrastructure for physical integration, in most cases, is developed along with technology installations. For example, solar PVs are integrated with the electricity network at installation time, as are EV charge points and heating and ventilation equipment in building retrofits. However, challenges remain, for instance, where the existing electricity distribution infrastructure requires reinforcement for new EV charge point connections, or the gas distribution network cannot handle the chemical components of the new gas fuels, such as hydrogen.

Communications needs for data and information exchange are implicit across the SLE SoS subsystems, although poor communication for interactions between the subsystems negatively affects the efficiency of the SoS operation and its evolution (e.g. greyouts or blackouts due to poor coordination of peak time electricity demand and EV fleet charging, etc.). Notably, the collection and interchange of such data may not be a key requirement for the subsystems themselves, even though it will primarily be a requirement of the SoS as a whole.

Challenge 2: Holistic policy and governance for SLES

Lack of common goals: Each subsystem within the case study SLES works towards its own goals (e.g., the transport subsystem works to transport passengers and goods in an affordable and reliable manner, etc.). All subsystems interact through energy supply and demand, and each separately also wishes to reduce its sectoral carbon emissions. Yet, none of the subsystems, except, to some degree, the local authority, has the transition of the *locality as a whole* to net zero, or optimisation of local clean energy production and consumption, as its key goals.

While each subsystem will be managed by its respective structures, there is a need for an additional governance mechanism for the holistic SLES, along with the impacts that interactions between the subsystems could cause. Examples of the impacts of these interactions include:

- **Privacy impacts** from the aggregation and sharing of householders' data across subsystems.
- **Exacerbated inequalities** if, for example, the well-off and well networked areas of the city can acquire new digital energy services which are not accessible to less affluent areas.

- **Stifling of business opportunities** if, for example, one subsystem, such as an EV chargepoint operator, refuses (or lacks the networking infrastructure) to share its data with others such as energy suppliers. The latter cannot deliver new services, such as demand response management, as a result.

Challenge 3: Stakeholder and citizen engagement, education and training

Individual sectoral challenges: Each subsystem within the case studies faces a set of its own challenges. For example, the Building and Retrofit subsystem suffers from a lack of professional esteem and public trust in retrofit and a lack of incentives to change building practices. At the same time, the ICT for digital energy sector is concerned with building consumer engagement and trust for adoption of their services. Thus, each subsystem looks inwards towards its own sector to address its challenges; working on common solutions with other subsystems is hardly even considered. The subsystems may not acknowledge the relevance of one or several of the other subsystems. For example, the Building and Retrofit sector is disengaged from Transportation, as is Transportation from Community Energy, etc.

Cross-sectoral understanding: The subsystems may even lack a common vocabulary to discuss common issues, which may lead to miscommunication and misunderstanding. For instance, they may use different terms to refer to the same subject and/or use the same term to refer to different subjects. To give an example: the citizens 'optimise consumption' by using as much of their own solar energy as possible, while electricity suppliers 'optimise consumption' by shifting electricity use away from peak demand time. Furthermore, knowledge of renewable technologies and willingness and ability to use them across various subsystems is also low and citizens lack understanding of the opportunities available and incentives to change practices.

Recommendations: addressing the challenges

A. Setting a common, agreed upon goal: This would require broad collaborations across all levels of the SLES and subsystems stakeholders. Setting a common goal within a project, as in the case of ESO or ReFLEX, is somewhat easier as they have to explicitly collaborate on defined goals and objectives.

EXAMPLE: Looking at a more general case of SLES outside of a single project context: in Bristol, the City Council (BCC) has taken leadership in this area and since 2019 has supported the development of Bristol's One City Plan in collaboration with a broad group of city stakeholders. This defines how city stakeholders will work together to create a 'Fair, healthy and sustainable city' with a set of agreed upon goals and a collective vision for organisations and individuals across the city.

Focusing particularly on energy, Bristol City Leap is a city council initiative to develop an energy joint venture to bring investment into the city. In addition, BCC owns a significant amount of property (including schools, libraries, offices and depots) as well as approximately 40% of the land in the city, so it can set a strong trend in defining the essential set of goals that its property operators must address.

B. Setting up a cross-subsystem SLES coordination body: An example of this would be a 'Committee for SLES Transition'. This could be made up of relevant business, community and training provider representatives to facilitate cross-subsystem engagement and cooperation and help to build mutual understanding and common vocabularies. It would also identify and address emerging issues. While there is presently no such mechanism in place, this is not entirely unfamiliar ground in our case study areas.

EXAMPLE 1: Within a single project context, as is the case in ESO, such a coordination body naturally emerges as part of the project management where the respective project managers at each partner organisation collaborate with each other and work as part of the management team. When the project management team identifies a key point of potential conflict, a specialist coordination body could be additionally set up, as is the case with the Data Working Group set up within ReFLEX to ensure that data collection, exchange, processing and use is consistent with GDPR, as well as with the interests of all the stakeholders, and is clearly communicated to the citizens.

EXAMPLE 2: Outside of the single project context, such cross-subsystem sharing often happens through collaboration and interaction between groups. For instance, in Bristol, the Cold Home Energy Efficiency Survey Experts (CHEESE) group has engaged with the Ambition Laurence Weston (ALW) community group to support energy efficiency improvements within local homes. ALW also operates a PV array and is currently deploying a wind turbine for community use. Thus, the community in the Lawrence Weston area of Bristol is actively engaged with learning about retrofit as well as energy generation technologies.

The task of a coordination body would be to consider interdependencies and impacts that the behaviour specific to one subsystem could cause by deviating from the agreed upon goals and vision of the intended SLES. For example, is the optimising of EVs charging schedule that the Transport subsystem wants to use acceptable to the Energy Supply subsystem, etc.?

C. Share understanding of physical connection issues: All subsystems must interact with, and learn about, the electricity (and/or gas) supply distribution networks, as they all need to connect their appliances and equipment with the distribution networks, and often, with the transmission networks as well. This leads to a common understanding of issues, such as network constraints that a distribution service operator would likely experience. It can also highlight opportunities for a new service delivery, for example enabling shifting away from peak time consumption through EV and/or battery storage and (dis)-charging. Addressing the issues of interconnection requires coordination and communication from across and within the subsystems. The physical connection dependencies are often immediately apparent for new projects and must be regulated.

EXAMPLE 1: Pivot Power's business model within ESO is based on addressing the capacity limitation of the local distribution grid by enabling EV charge point installation via a transmission-connected battery for EV charging. Essentially, this business is set up to facilitate cross-subsystem integration and enable EV charging within areas of limited distribution network capacity.

EXAMPLE 2: The Islands of Orkney generate more renewable electricity than they need and would like to export the excess to the mainland but the capacity of the connecting cables curtails the amount that can be exported (these are issues of the Energy Supply subsystem). Therefore, the ReFLEX project aims to develop an ICT solution that interconnects, through flexibility management, 3 different subsystems. These are the Transport subsystem through EVs, community mobility services (such as community buses and car share schemes) and hydrogen powered ferries; heat pumps and home energy use from the Building and Retrofit subsystem and conversion of wind energy into hydrogen as an alternative fuel in Energy supply.

D. Build a general understanding of renewable and clean energy technologies: Each subsystem is evolving at an unprecedented speed. As a result, it is difficult for those already in a specific sector to keep up with innovations. It is even more difficult for those in other sectors to keep up to date with developments in neighbouring sectors. Therefore, general and continuous upskilling is required across all of the SLES subsystems on available technologies, risk management and financial planning for projects where these technologies are used. The wider public also need some understanding of how the energy system is evolving and its relevance to their everyday lives.

EXAMPLE 1: The Community and Energy Groups across Bristol have been taking an active role in raising awareness about climate emergency and energy transition challenges.

EXAMPLE 2: ReFLEX Orkney has developed a membership model for local citizens to engage with the project and learn more about its aims. In parallel, project partners have been collaborating to upskill on particular areas critical to the overall project such as data management.

E. **Coordinated investment in data collection and control infrastructure: Poor interactions between the subsystems will negatively affect the efficiency of the SLES operation and its evolution. Coordinated investment into data collection and control infrastructure is required at the SLES level. This includes the installation of telecommunication networks, development of software platforms and application programming interfaces (APIs) for data exchange and support for external control functionality. In addition, policy and regulatory constraints around data and control must be defined, monitored and enforced.**

F. **Develop a framework for conflict resolution: Conflicts can emerge from incompatible goals and worldviews between stakeholders. For example, optimising traffic routes for smart mobility providers may conflict with minimising the through-traffic objectives of community groups, while wind turbine installation goals may conflict with biodiversity preservation or other land uses.**

   Similarly, technological solutions across various subsystems may lead to conflicting implementation requirements. For example, distribution network operators may wish to minimise network reinforcements, while EV charge point providers require such reinforcements for operating within a given locality. Likewise, data may need to be shared for the optimisation of electricity network management, although this may conflict with the privacy preferences of citizens.

Skills required to address the challenges of SLES

Smart local energy systems comprise interlinked sub-systems with key connecting components such as policy, local government facilitation, physical and virtual infrastructure (e.g., buildings, roads and telecommunications) and, at the core of it all, the people that design, install, maintain and use all of the components.

While each subsystem within a SLES requires upskilling (as discussed in case study reports) there are also some common skillsets required across all subsystems, such as:

- need for increasing knowledge about how the energy system works and how the different elements are relevant and interdependent;
- communication skills to make sure that collaboration is agreed between stakeholders and citizens are fully engaged and able to participate;
- engagement with local policy and planning;
- development of new business models;
- software and data management;
- changing procurement approaches and rules;
- skills for delivering and maintaining the integrated infrastructure.

We observe that, within all professions, it is becoming increasingly necessary to have a wider skillset rather than a single specialism in order to navigate and integrate the multiple elements that make up a local energy system. For example, software engineers need to understand how the energy system works, citizens need to have the knowledge to make informed choices and be comfortable with using technologies, electricians need to connect and use smart devices in their daily work.

Table 1 below presents the list of skills which, according to participants in our three case studies, cut across all SLE subsystems and are relevant at the SoS level for smart local energy systems.

For full details on per-subsystem skills, please refer to the Working List of Skills document (note, this is a live document, which will be updated at least till Oct 2022) and the individual case study reports.

Table 1: Overview of the skills relevant across Subsystems and for the whole SLE SoS (Case study data)

Skill	Bristol	ESO	ReFLEX
Engineering and design skills			
Data Analytics and Machine Learning	x	x	x
Algorithms Design and Monitoring	x	x	x
Data Management and security	x	x	x
Application Development/Programming	x	x	x
Systems Engineering and Integration	x	x	x
Connectivity, Networking and Telecoms	x	x	x
Research and Simulation Skills	x	x	x
Software Engineering	x	x	x
Electrical Engineering	x	x	x
Specialised infrastructure design and construction	x	x	x
Trades skills			
Operation and Management of renewable energy hardware	x	x	x
Gas boilers/network decommissioning	x		
Retrofit skills	x		x
Installation & Integration (e.g. heat, smart meters, charge points)	x	x	x
Managerial Skills			
Building Partnerships/Core Trusted Team	x	x	x
Procurement (materials and services)	x	x	x
Cross-Institutional/Technology Project Management	x	x	x

Skill	Bristol	ESO	ReFLEX
Energy Domain Skills			
Overview of Renewables/SLE Technology	x	x	x
Designing renewables projects and understanding localisation	x		x
Integration of key sectors into SLE delivery	x	x	x
Finance and business skills			
New Business and Finance Models for renewables and energy markets	x	x	x
Commercialisation, securing investment		x	x
Legal skills			
Contract Reading/Writing for SLES projects	x	x	x
Handling User Data (GDPR compliant)	x	x	x
Policy skills			
Stable supportive policy	x	x	x
Regulating Quality and Qualifications (e.g. quality of work, heat installations, security, privacy)	x	x	x
Liaison with local authority, understanding policy drivers	x	x	x
Soft skills			
Educating and Engaging General Public	x	x	x
Social inclusion, ensuring equitable outcomes	x	x	x

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About EnergyREV

EnergyREV was established in 2018 (December) under the UK's Industrial Strategy Challenge Fund Prospering from the Energy Revolution programme. It brings together a team of over 50 people across 22 UK universities to help drive forward research and innovation in Smart Local Energy Systems.

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