EnergyREV

The SLES Pathway Guide: Navigating drivers, barriers and action plans

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Contents

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1. Introduction and outline

The upscaling of Smart Local Energy Systems (SLES) is regarded as a key avenue to realise the UK's Net Zero future (36) This is because increasing the deployment of SLES which use information/communication technologies (ICT) and automation to integrate, optimise and manage local energy systems, will significantly contribute to climate change mitigation, enhance energy security and improve access to local and affordable energy.

This guidebook presents the SLES pathway tool, which is designed for stakeholders, as well as present and future SLES actors who wish to establish and upscale their systems. It accompanies an earlier report, Pathways for the upscaling of smart local energy systems. Developed by WP6.1 of the EnergyREV consortium, the tool explores the pathways in more detail and then provides guidance on the avenues by which these pathways can lead to the upscaling of SLES.

The guidebook is structured in two parts: Part 1 first provides an overview of the research that underpins the pathway tool. Secondly, the transition map, the four key pathways and their hybrids are briefly described, as well as the location, and function of each key pathway in the map. Part 2 presents the pathway tool, which is a conceptual flow diagram that depicts the underlying drivers and barriers for each pathway and recommends action plans, categorised into different aspects of the system and actors that should collaborate and facilitate pathway progress and hence the upscaling of SLES.

Note to pathway tool users: It is advisable to read Part 1 first before attempting to use the tool in Part 2, especially the notes to pathway tool users found at the start of key sections in Part 1. The information provided will help to enhance user experience and aid understanding, so that the user can use the tool knowledgeably and effectively.

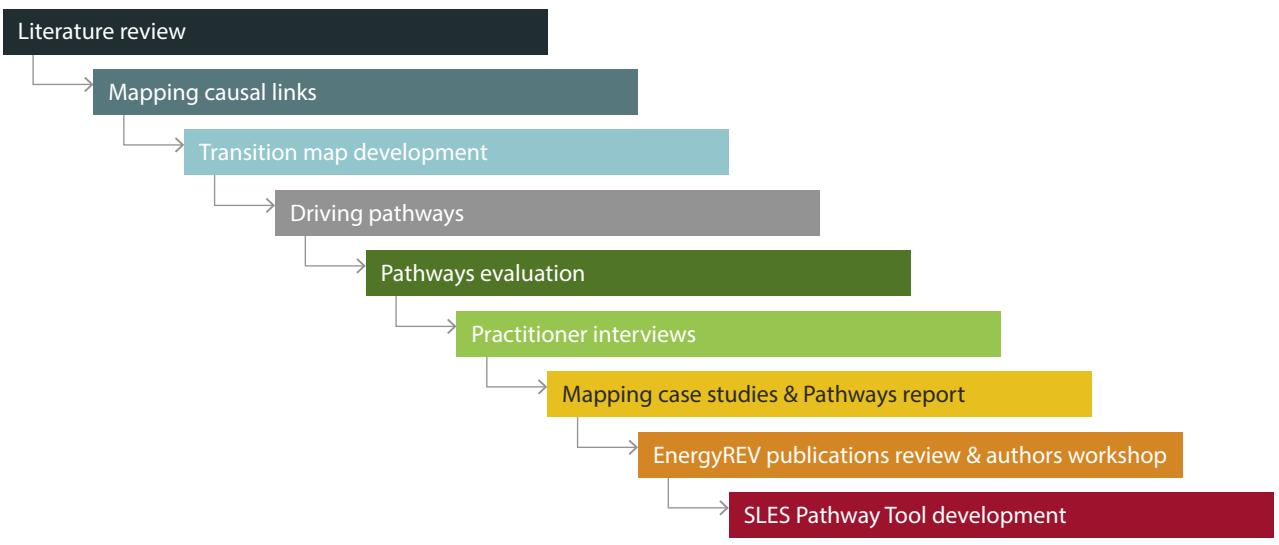
PART 1

2. Research overview

Note to pathway tool users: This section highlights the research process that underpinned the development of the pathways tool. It demonstrates that the insights provided in the tool are from an extensive and iterative research process which draws from several sources of information.

The aim of our research was to investigate the drivers and barriers that support or prevent the upscaling of SLES and to develop a framework that depicts how upscaling works, taking into consideration the technological, economic, political, or social context factors that can be employed to support the upscaling of SLES in practice. Figure 1 describe the steps in our research to the development of the pathway tool.

Figure 1: Outline of research steps



A broad literature review was undertaken to identify barriers to, and drivers of, the upscaling of SLES. This revealed that literature on the upscaling of SLES was limited because it is an emerging and multidisciplinary issue (more information on the literature review can be found in Chapter 2 of the main report).

Two workshops with expert participants from the EnergyREV consortium were conducted to derive and map casual links from literature and then to form the transition map. (Please see Appendix 1 and 2 of the main report).

Subsequently pathways generation and evaluation workshops were conducted to derive and further assess the pathways leading to the identification of six driver pathways (please see Chapter 4 and Appendix 3 of the main report).

These six driver pathways were then reviewed by SLES practitioners in interviews, where four key driver pathways were identified drawing from the experiences of SLES actors. The key pathways are Local Authority pathway, the Case Study athway, the Economic competitiveness pathway, and the Grid Technology pathway. (Please see Chapter 4 of the main report).

The four key driver pathways were then mapped onto real life illustrations of SLES case studies to gain further insights into how the development and upscaling of SLES works in practice. The results of first seven steps in the research outlined in Fig 1 were presented and published in the main report.

Further, 36 publications mainly comprising of EnergyREV reports and journal papers, as well as other relevant publications, were reviewed. The authors of most of the publications participated in a workshop, where they provided rich insights on the upscaling of SLES, drawing from wide range of work done by the EnergyREV consortium.

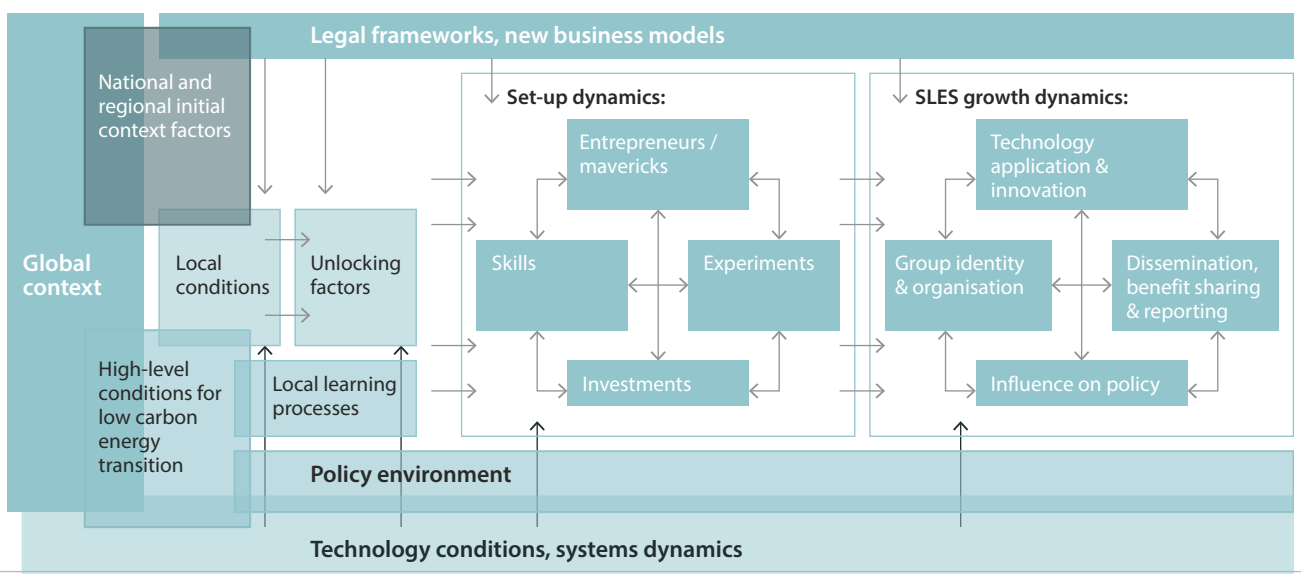
Finally, the SLES pathway tool was developed, based on insights derived from all the steps and results of our research.

3. The Transition Map and the pathways

Note to pathway tool users: This section will help users to familiarise themselves with the Transition map and the pathways, as they are not fully described in the tool in Part 2. They can also begin to think about how these pathways compare to their current or proposed systems.

This section briefly describes the Transition map, a diagram designed to show an overall dynamic of SLES development and upscaling along with the key pathways. (Please see the main report for the full descriptions). Afterwards, the location of each pathway in the Transition map is indicated in Figure 7, to provide further details as indicated in the tool.

Figure 2: The Transition map



3.1 The Transition map

The Transition map reveals how overlapping context factors, such as global/national/ regional/high level conditions for low carbon energy transition, as well as local context/conditions and local learning processes and framework conditions such as legal and business model frameworks, as well as the policy environment and technology conditions and dynamics, impact on two distinct evolving systems: SLES set up dynamics and SLES growth dynamics.

The SLES set up dynamic could result in the establishment of SLES i.e., the initial set up or the replication process of SLES into other local contexts. It represents the interplay of mutually reinforcing factors, such as existing mavericks, provision of local skills, the ability to experiment and try pilots out and the mobilisation of economic resources. The SLES growth dynamic could describe the growth of an existing SLES into additional functionality, greater capacity, or different service provision. It represents the interplay of a functioning SLES developing its own dynamics and identity, successful economic performance and the dissemination of revenues, technology application/ innovation and influencing policy.

3.2 The four key pathways

The four key pathways are the Local Authority, Case Study, Economic Competitiveness and Grid Technology pathways. These key pathways are comparable to other models of local energy systems (34, 35). They are briefly described in Figures 3 to 6.

Figure 3: The Local Authority pathway

- The pathway is typically driven by the 'Local Authority'.
- Driven by international and national policy translated to local institutional priorities and preferences.
- Technical, management, financial and Energy Service company (ESCO) support, facilitates the initial set up.
- Pathway progress is facilitated by support from the LA to meet community sustainability concerns. This in turn facilitates community support for SLES.
- Openness to innovation then gives rise to systems innovations and hence the emergence of Smart grids.

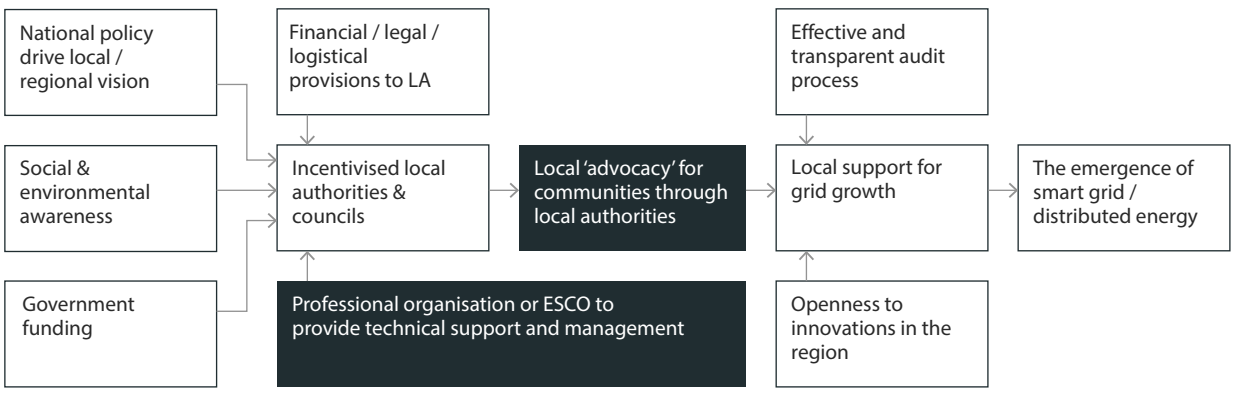


Figure 4: The Case Study pathway

- The pathway typically depicts a demonstration project or an exemplar project.
- It is being driven by innovation capabilities and a network of local skills and social capital..
- Lessons from experiments and experience are harnessed, leading to increased demand, market participation and socioeconomic benefits.
- Also, system improvement based on verified grid performance leads to improved profitability and business case. This leads to increased SLES acceptance and upscaling.

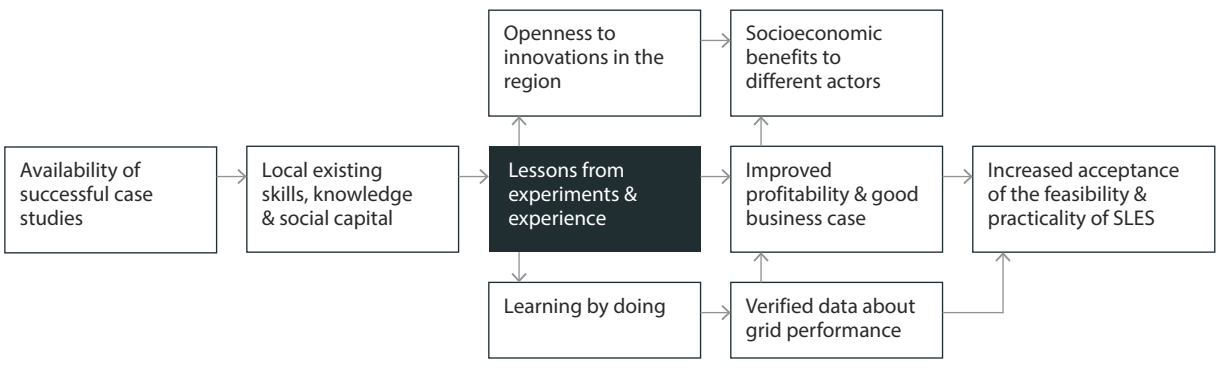


Figure 5: The Economic Competitiveness pathway

- Pathway shaped by economic opportunities.
- Driven by policy targets and facilitated by incentives and derogation of market constraints.
- Economically competitive renewable energy and infrastructure investment are key factors.
- 'Early adopters' both individuals and local businesses promote SLES.
- The economic benefits are shared in this commercial venture, which attracts further interest to join, leading to SLES growth.

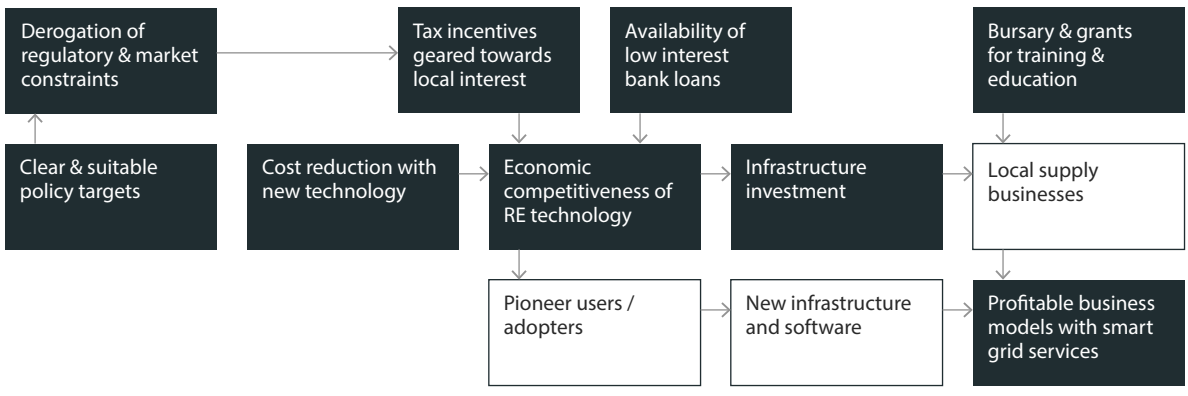
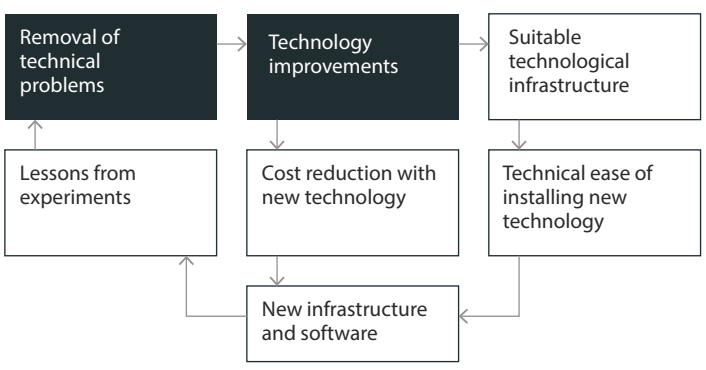


Figure 6: The Grid Technology pathway

- The Grid Technology pathway starts as an SLES in a Demonstration Project, or publicly-funded research.
- First, experimentation results in the removal of technical problems and technology improvements.
- This leads to technology adoption and infrastructural investment.
- Further improvement in technology application facilities integration with new infrastructures and smart software, e.g. billing and trading platforms.
- The pathways move in a continuous improvement loop based on two distinct cycles: removal of technical barriers and improvement in technology application and implementation.

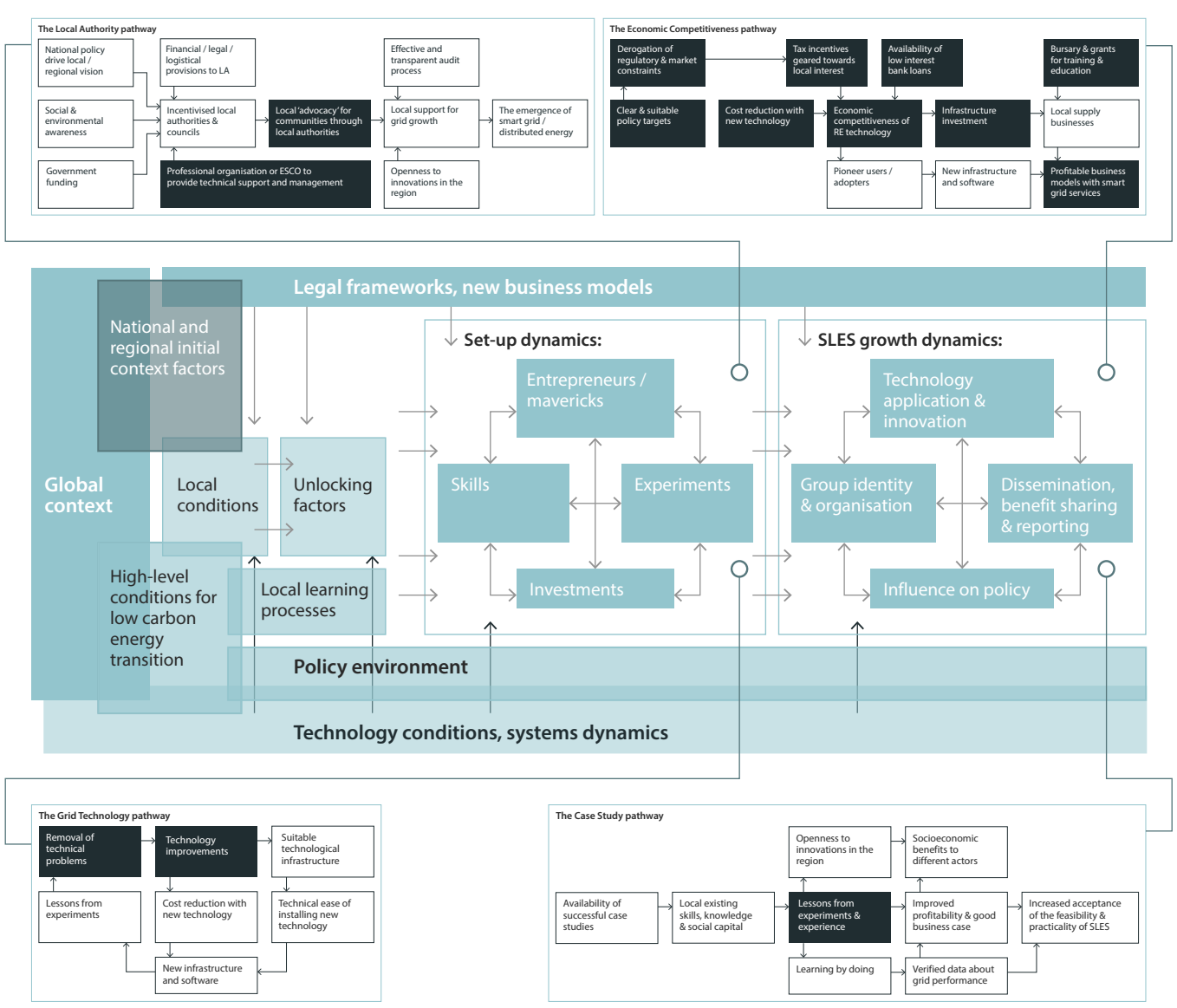


3.3 The location and function of the key pathways in the Transition map

Note to Pathway tool users: The information about the location and function of each pathway should enable users to determine which of the pathways apply to their current system, or which of the pathways they can adopt as a model for proposed systems. This will depend on whether the main objective of their systems is to set-up SLES or to facilitate SLES growth.

The first section of the SLES pathway tool displays the Transition map and the location of the pathways in the map as shown in Figure 7.

Figure 7: The Transition map and location of the pathways



The following explains the reason and logic behind the location, and hence the function, of each pathway in the map.

The Local Authority pathway is a key pathway in the setting-up phase of SLES. Some initial drivers in the Local Authority pathway such as the 'the national policy drives local and regional vision' and the 'social and environmental awareness' drivers depict the global and local context and act as a background influence on the pathway. However, the core of the pathway relates to the setting up phase of SLES, where the Local Authority, which is a major actor and decision maker, is supported by skilled organisations and Government funding. This facilitates community engagement and local support as well as innovation that gives rise to the emergence of a smart grid.

The Case Study pathway also features in the setting up phase of the pathway. It is observed that most SLES are either demonstration/exemplar projects or were derived from such projects. As such its drivers are directly related to the skills, experiments, mavericks/entrepreneurs, and investment dynamics found in the set-up phase.

The Economic Competitiveness pathway is a key pathway in the growth phase of SLES. Its first three drivers illustrate the national/local context, showing the impact of regulation, policies, and tax incentives. However, the interplay of its core drivers i.e., the cost reduction/economic competitiveness of renewable energy (RE) technology, attracts pioneer users and adopters. This in turn leads to new infrastructures/software and then profitable local supply businesses relating to the growth dynamic in the transition map. They feature, technology application and innovation, group identification/ organisation, dissemination, and benefit sharing.

The Grid Technology pathway is also relevant in the growth phase because improvement in technology, technology application and innovation drive upscaling of SLES, due to more efficient and integrative systems that may cut costs or improve usability.

3.4 Hybrid pathways

Note to pathway tool users: The information on possible hybrid pathways in this section, should help users to further characterise their current systems beyond the stand-alone pathways. They could also serve as hybrid models for future systems based on whether the objective of the system is either set up or growth or both set-up and growth. It will also enable users to choose a combination of these pathways in the tool, so that the tool will provide more comprehensive information on their current or future systems.

During the research, and in our interactions with SLES actors, it became apparent that in practice, the pathways often form hybrid pathways. These are a combination of two pathways: usually a set-up and a growth pathway, or two set-up and two growth pathways.

Examples of possible hybrid pathways are:

- Local Authority/ Grid Technology pathway
- Case Study / Economic Competitiveness pathway
- Local Authority/ Economic Competitiveness pathway
- Case Study/Grid Technology pathway
- Local Authority/Case Study pathway
- Grid Technology/Economic Competitiveness pathway

Figures 8 and 9 illustrates two of these hybrid pathways:

Figure 8: Hybrid Local Authority and Grid Technology pathway

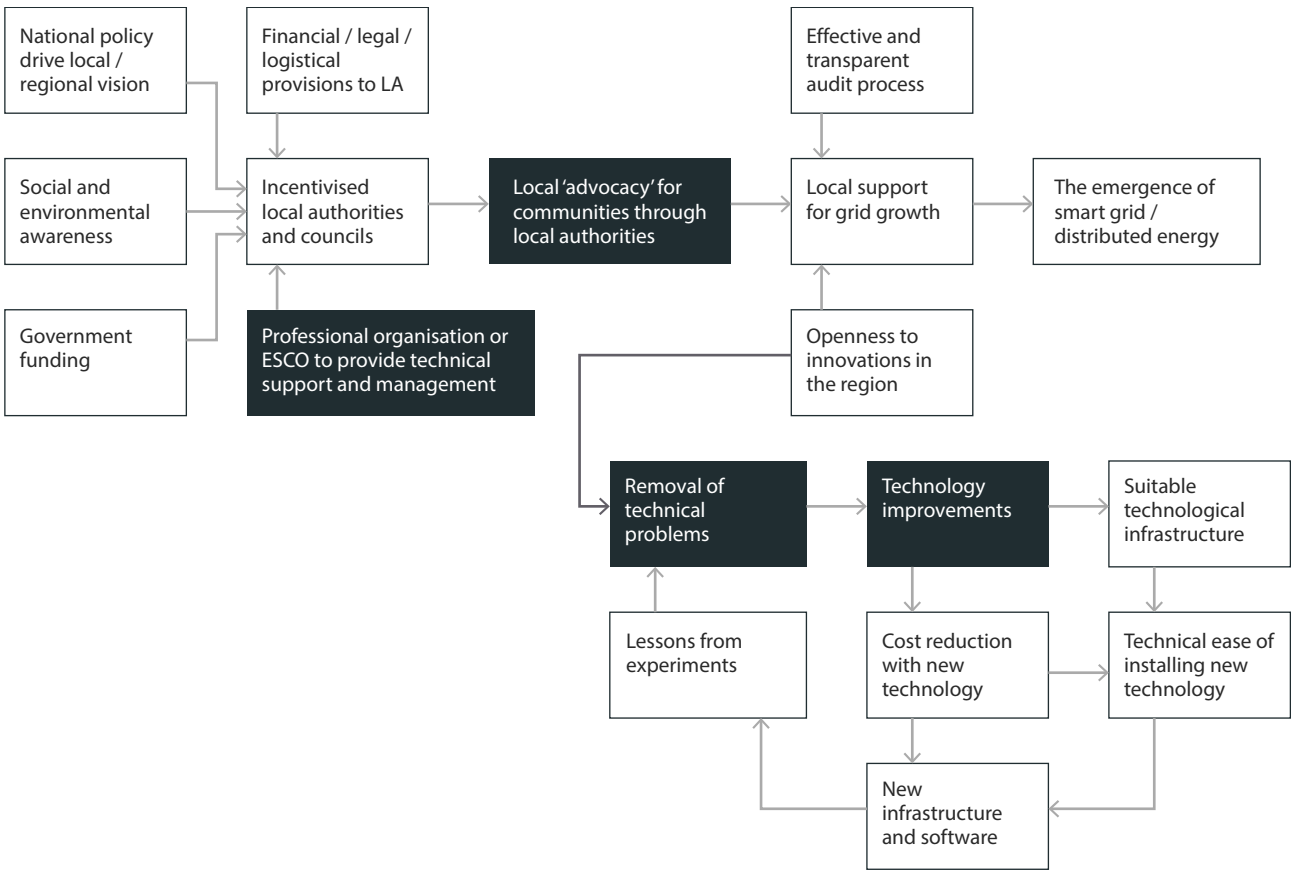
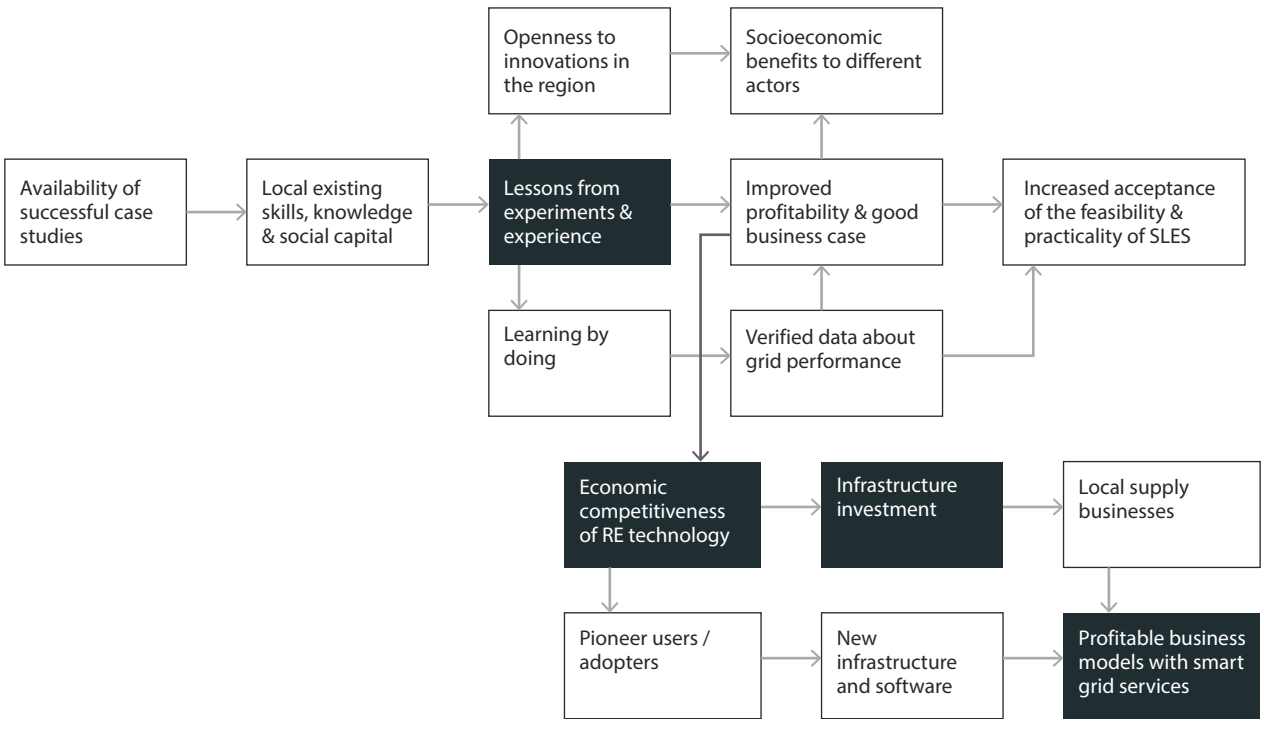


Figure 9: Hybrid Pathway: Case Study pathway and Economic Competitiveness pathway



PART 2

4. The SLES Pathway Tool Description

The Pathway tool is conceptual flow diagram made up of 3 sections:

- The first section of the tool depicts the transition map and the areas in the map from which the four key pathways are derived. The first section is an expanded version of Figure 7 in part 1.
- The second section of the tool maps out each pathway in the following order: Local authority, Case study, Economic competitiveness and lastly the Grid technology pathway.
    * Each pathway has four tiers: the first tier maps each pathway describing its elements as drivers (in black) and enablers (in white with a black border)
    * The second tier describes underlying drivers for each element (in pale yellow)
    * The third tier describes related underlying barriers (in light orange) for each underlying driver.
    * The fourth-tier highlights recommended actions (in grey) that may help to overcome the barriers and / or facilitate drivers based on key aspects of the system namely policy/regulation, business finance and markets, organisations and skills, technology and systems and user and communities (in oval shape) and also indicates lead actors/ organisations and collaborators for each action (in rounded oblongs, with specific colour for each lead organisation). The organisations in italics are suggested, not necessarily that they exist.
- The third section of the tool lists the References
    * [Numbers]: Published references, numbered according to reference list (report/journal)
    * WP: workshop participant
    * Int: Interview 1–10

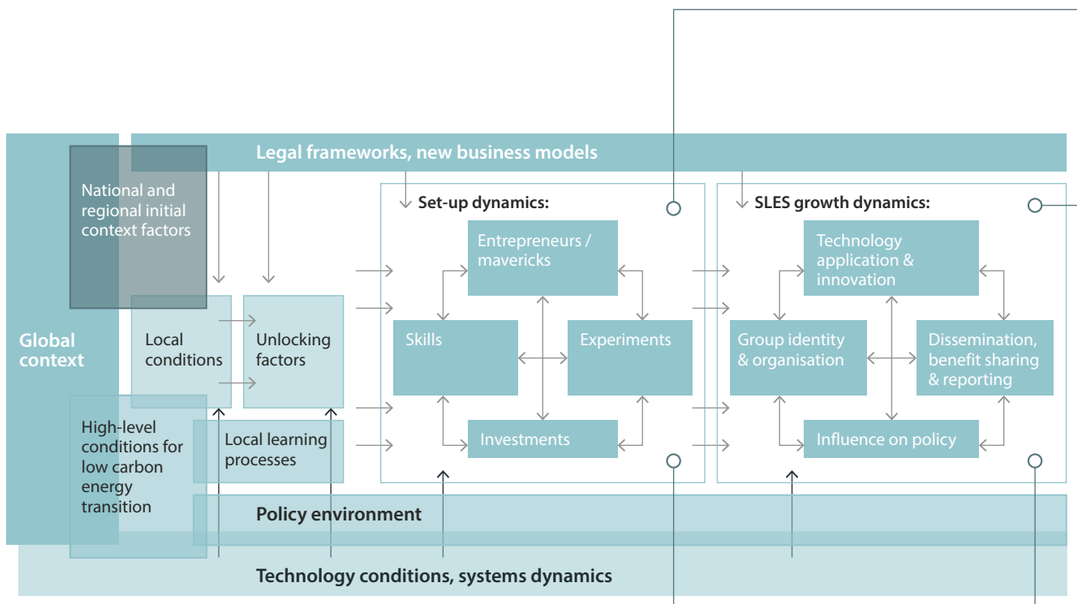
4.1 The SLES Pathway Tool Instructions

The following are suggested steps for pathway tool users

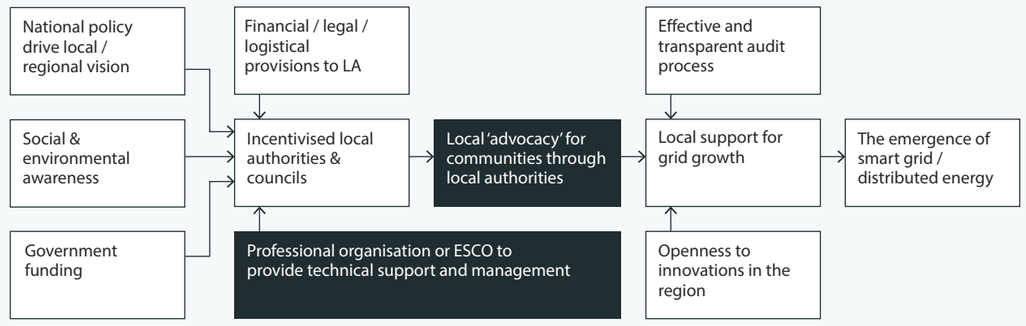
Note to pathway tool users: Remember to read the Part 1 of this guidebook first and familiarise yourself with the transition map, the pathways, and the tool. Please also read the notes to pathway tool users.

- Familiarise yourself with the layout of the tool.
- Identify which pathways or hybrid pathways best describe your system or proposed systems.
- Examine the drivers and the linked underlying drivers and compare with your system. You can also identify key drivers and underlying drivers that may enhance the set-up or upscale of your current system, which are not present in your system. Or identify key underlying drivers that may facilitate the set up or upscale of your proposed systems.
- Examine the corresponding underlying barriers to the underlying drivers and compare with your current system. You can also identify current or possible underlying barriers of your current system or proposed system.
- Examine the corresponding action plans on aspects of the systems, that are required to overcome the barriers or facilitate the drivers with suggested groups of actors to implement the action.
- Finally, using the key provided, you can determine which actor you or your organisation represents or are interested in, note the frequency of the actor/organisation either as a lead actor or a co-collaborator as they appear the pathways, and then examine the associated action plans either as a lead actor/organisation or a co-collaborator.

The transition map

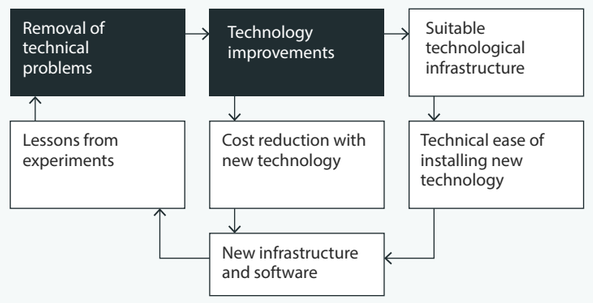


Local authority pathway

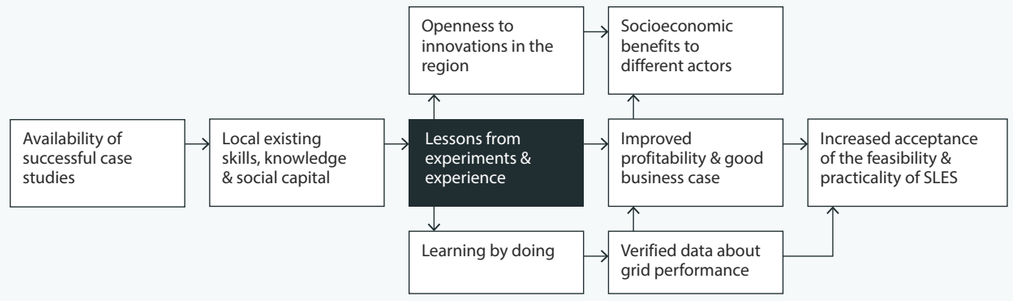


Economic competitiveness pathway

Grid technology pathway



Case study pathway



Local authority pathway

National policy drive local / regional vision

Financial / legal / logistical provisions to LA

Effective and transparent audit process

Social & environmental awareness

Incentivised local authorities & councils

Local 'advocacy' for communities through local authorities

Local support for grid growth

The emergence of smart grid / distributed energy

Government funding

Professional organisation or ESCO to provide technical support and management

Openness to innovations in the region

Underlying drivers

National policy driving regional policy

- The UK Government's Net Zero target (Interview 1)
- Increasing requirements for carbon performance standards in buildings (Interview 2,6)
- Strong in-principle support for decarbonisation and decentralisation (WP)

Social & environmental awareness

Local Authorities are becoming increasingly aware of public / statutory duty to achieve Net Zero (WP)

Government funding

Available but limited Government funding for SLES

Incentivised local authority

- Enhanced energy systems capacity at the Local authority level. Successful SLES roll out are mostly in large cities / council (Interview 5)
- Derogations from some of the network charging structures or environmental levies that are built into energy costs (Interview 5, 6)
- Support from commercial partners incentivise the Local authority and profitable returns incentivise private companies to build other SLES systems (Interview 8)

Financial / legal logistics

Employing specialist financial, technical and legal expertise where required

Professional organisation support

- A close-knit relationship between all the companies and public authorities (Interview 1, 2)
- Revenue incentive to utilise their learning and experience to reproduce and upscale in other locations (Interview 1)

Local advocacy for local communities

- LAs can bring wider array of stakeholders together, they are more trusted than energy companies or the national government (WP)
- The LA have multi vector interests. They can also represent and advocate for local residents, to ensure that the benefits are distributed fairly (WP)

Effective & transparent audit process

- Appraisal of project technical plans and impact. Project reports during and after completion [4]
- A wide range of project databases are available [4]

Openness to innovation in the region

- A network of green technology businesses facilitate the establishment and upscaling of SLES (Interview 1)
- Local vertical integration of the energy value chain i.e. generation, distribution, retail & demand-side services & horizontal integration across power, heating and transport (1)

Local support for grid growth

Allows more direct local bespoke benefits to communities, based on community needs/wants (WP)

SLES grid emergence

Interconnected LA deliverables can be supported by SLES such as retrofitting, improved green transport, affordable energy bills, alleviating fuel poverty. All which impact voting behaviour (WP)

Underlying barriers

- LAs have varying commitment levels to carbon neutral targets (Interview 2,10)
- The National Planning Policy Framework are light on enforcing LAs to use low carbon solutions (Interview 8,10)
- Continued support for gas fired CHP (WP)
- Extremely centralised decision-making process and lack of vision from national government on long-term energy strategy and SLES (WP)
- Ofgem is too far removed from local networks and local opportunities to provide proper oversight (Interview 5,3)
- Politics/policy makers and stakeholders have a complex range of interest that may inhibit progress (WP)
- Lack of long-term/strategic public funding and limited funding (WP)
- Loss of project funding mid-project, loss of project momentum and abandonment of projects which had upscaling potential [4]
- Current absence of price support such as feed in tariffs(FITs), the Renewables Obligation, or Contracts for Difference (WP)
- Lack of capacity at the Local authority to deal with energy, dependence on commercial partners (Interview 1)
- Regulation and market constraints impact on the return on investment of SLES (Interview 5)
- Engaging with organisations & stakeholders of differing sizes, cultures and locations with different project priorities may create tensions and impede progress [4]
- Geographical differences on the availability of some specialist skills and so dependency on a national specialist for key SLES management, operating and maintenance work (Interview 1,3)
- Uncertainties on what commercial basis to engage? How do you share financial risks? Like companies going bust or being bought out by bigger firms (Interview.1)
- Uncertainties around logistics and the procurement for the different components of the system? (Interview 1)
- A general lack of technical and specialist legal expertise for SLES. It is very difficult for a small/community organisation to understand contractual arrangements.
- Lack of in-depth understanding on what the residents and local businesses value in terms of SLES [1]
- LA Energy decision makers don't consider co-benefits of SLES such as fuel poverty alleviation, green transport , improved air quality & Climate change mitigation and energy security [1]
- The UK lacks a function or institution with a role to plan and coordinate local energy (including SLES) in view of the net-zero target [3]
- Lack of capacity at the combined authority or unitary authority to play a public accountability role over SLES (Interview 4,5)
- The information in the project databases are variable and less than transparent [4]
- The quality, quantity and accessibility of appraisals, project reporting and knowledge sharing is highly variable and reports from historical projects are sometimes not available [4]
- Network and ecosystems of green technology businesses takes decades to establish, and it will be very difficult to reproduce in other LAs (Interview 1)
- Potential for tensions to arise because of different organisations and stakeholders of differing sizes, cultures and locations, and with different project priorities
- A lack of common goals and agreed action plans may inhibit collaboration of all sub systems and may cause unintended negative outcomes [5]
- Physical integration of different parts of the value chain may be faced with challenges such as lack of interoperability of some components and the need for effective data and information exchange for the control and optimisation of operations [5]
- Lack of awareness of what SLES are, and how they impact individuals (WP)
- Fear for LAs of political impact of failure (WP)

Action plans

Policy & regulation

Establish statutory responsibilities for energy in local authorities, to facilitate SLES / low carbon energy, because there is an incentive to meet the carbon budgets and resources will be allocated towards that end (Interview 9)

Govt policy makers / LAs

Policy & regulation

Provide incentives and more support for low carbon solutions in the built environment (WP)

Govt policy makers / LAs

Policy & regulation

Develop regional governance models to govern SLES projects and the short and long term outcomes or co-benefits that they will create (Interview 7,8)

Govt (DESNZ) / LAs / *regional SLES organisation*, catalyst communities

Policy & regulation

Develop decisions models and tools that are designed to ensure energy decisions are evaluated against wider benefits and that the benefits of SLES are fair and realised [3]

Govt (DESNZ) / LAs / industry & academic research

Business, finance & markets

Improve access to project funding and comprehensive financial proposals because SLES require diverse skill sets, increased development and testing time, greater deployment complexity and end-user / consumer engagement than other energy projects [4]

Input contingency into project budgets, especially highly uncertain & innovative projects [4]

Alignment of proposals with current policy drivers and funder priorities [4]

Govt / policymakers, funding bodies / LAs / SLES / technology provider / SLES projects / DNO, DSO

Organisations & skills

Build skills and capacity across all regions to avoid dependency on one or two specialists. Also build capability in energy in LAs so that they can undertake energy and spatial planning together [3] (Interview 5)

Govt (DESNZ) / LAs / regional SLES organisation, catalyst communities

Establish a network of green businesses in the region. Facilitate and support the demand for greater local energy integration in terms of services i.e. generation, retail and demand services and also across multiple vectors such as power, heat and transport [1]

Govt (DESNZ) / LAs / *regional SLES organisations*

Business, finance & markets

Reform of supplier hub model and markets to ensure value of local / national energy & flexibility and to enable SLES [3]

Ofgem Sandbox reform to facilitate SLES innovation by helping businesses to lunch instead of running trials and also signal low regulatory risk to investors [3]

Ofgem / Govt (DESNZ) / SLES technology providers / SLES projects DSO & DNOs

Organisations & skills

Strategic alignment and collaboration with SLES actors, Distribution Network Operators (DNO) and LA planning teams can establish SLES that achieves mutual goals of economic development and place making (Interview 5)

A coordinating project team or organisation can also help to manage the different partners [4]

SLES projects / SLES technology providers / DSO and DNOs / LA planning

Organisations & skills

Establish a project information standard across SLES (4) that records the setbacks and successes SLES experiences in terms of procurement, contracts and managing time frames, learning processes and apply the lessons in similar projects [4]

Establish a Memorandum of understanding, with collective names, authoritative text on the collaborations purpose and work contracts, flexibility clauses in contracts taxonomies, and standards to enable shared understanding [3,4]

Establish a Management Team and Advisory committee as well as **performance indicators** [3,4]

Govt (DESNZ) / private funders or investors SLES projects / *national SLES coordination body*

Organisations & skills

Provide training for specialist skills in ICT, data management, financial and business planning, legal as well as communication and liaison [1,2]

Increase access to technical and legal specialists considering the potential complexities of future SLES considering the potential complexities of future SLES [4]

Educators / certification bodies, SLES technology providers SLES projects

Users & communities

Improve and reform consumer protection for SLES to ensure benefits are realised and terms are favourable [3]

Provide training for communication & liaison officers to engage with catalyst communities that can use examples and experiences to clarify the benefits and terms of the SLES (Interview 9,10)

Ofgem / LAs /customers / catalyst communities/

Users & communities

Overcome community resistance to SLES by determining the relative importance of different value propositions like lower energy bills, local ownership and environmental benefits to communities [3]

LAs, Govt (DESNZ) / customers and communities

Policy & regulation

Establish a regional governance model or an accountability structure / framework to govern and guide the operations of SLES systems against purely profit motives and actions (Interview 7,8)

Govt (DESNZ) / Ofgem / policy makers / *regional SLES organisation* / SLES projects & technology providers

Organisations & skills

Enforce comprehensive, transparent and accessible project reporting [4]

Overhaul current project reporting, knowledge sharing and dissemination practices and develop / apply a project information standard, including it as part of funder requirements [4]

Develop a centralised, combined and freely accessible project database, based on the project information standard as suggested above [4]

SLES projects / *national SLES coordination body* / Govt (DESNZ) / private funders or investors

Business, finance & markets

Adequate revenue incentives and right conditions can encourage green business in a particular region to go to other locations to establish or upscale SLES. They can also train and use local actors, thereby setting up a local network (Interview 2,1)

Organisations & skills

SLES governance and operation should bring together the sub-systems in developing common goals and ensuring that different aspects can operate for a common good without unintended negative outcomes [5]

Development of skills such as cross-institutional project management [5]

SLES projects / SLES technology providers / educators / certification bodies / *regional SLES organisation*

Technology & systems

The potential need for integration and Interoperability of systems should be built into the system from the start [4]

Improved SLES specific skills training for hardware and software installation, networking and communications data analysis and machine learning, data protection and standardisation are critical [5]

SLES projects / SLES technology providers / educators / certification bodies / *regional SLES organisation*

Users & communities

Identify the range of benefits and co-benefits of different SLES, as well as success factors [3,4]

Govt (DESNZ) / customers and communities / LA, SLES projects

Organisations & skills

Build capability in energy in LAs so that they can create integrated plans, and energy becomes a cross cutting concern that helps them achieve goals in all those other areas which are within their democratic mandate (Interview 5)

Develop smart and fair neighbourhoods with a low carbon hub community, where a network operator manages the substation and communities (Interview 7)

Review how upscaling can be promoted, considering steps taken to promote / deliver scalability across a variety project types and sizes as well as different funding models and team compositions [4]

LAs / Govt (DESNZ) / funders & investors / SLES projects / DNOs, DSOs / communities

Actor / organisations in action plan

Lead organisation in collaboration with other organisations (frequency as lead) (frequency as a co-collaborator)

Aspects of the systems as lead organisation

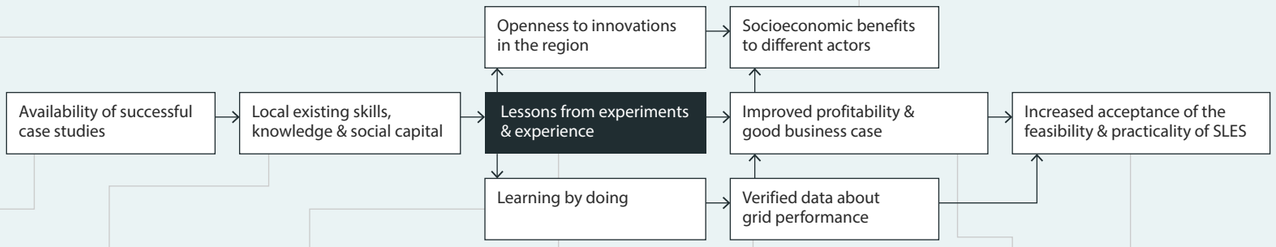
- Govt | policymaker (3)(1) — Policy and regulation; Business, finance & markets
- Govt | Department of Energy Security and Net Zero (DESNZ) (6)(3) — Policy & regulation, Organisations & skills; Users & communities
- Ofgem (2)(1) — Business, finance & markets; Users & communities
- Local authority (LA) (2)(7) — Organisations & skills; Users & communities
- SLES projects (4)(6) — Organisations & skills; Business, finance & markets; Technology & systems
- Educators / certification bodies (1)(2) — Organisations & skills

Other co-collaborator organisations or actors (frequency in LA pathway)

- Developers (1)
- Funding bodies (1)
- SLES technology providers (4)
- Catalyst community (1)
- Industry & academic researchers (1)
- Distributed Network Operators (DNO) (4)
- Distributed Systems Operators (DSO) (4)
- Private funders and investors (2)
- *Local / Regional / National SLES organisations* (suggested new institutions) (3)

INDUSTRIAL STRATEGY
UK Research and Innovation

Case study pathway



Underlying drivers

Openness to innovation in the region

A network of green technology businesses in collaboration with government and academia (Interview 1,4,21)

Local vertical integration of the energy value chain i.e. generation, distribution, retail & demand-side services & horizontal integration across power, heating and transport [1]

Availability of successful case studies

Net-zero transition creates interest in wide range of related case studies (WP)

Local skills and knowledge / social capital

Projects owned/led by local actors have stronger longevity (WP) [15]

Local partnership & collaboration between industry, academia and government (Interview 4)

Engaging catalyst communities e.g. interested groups, local businesses & public institutions to generate social capital & engage with SLES technology solutions (Interview 8)

Learning by doing

Early adopters were often driven by environmental benefits. Currently, adopters may be driven by a desire to reduce their energy costs, while helping the environment (Interview 5,20)

Lessons from experience & experiments

Increasing awareness that sharing learnings is essential to the upscaling of SLES (WP).

A project team that has relevant and transferable knowledge, skills and experience to share [4]

Knowledge of the successes and limitations of related previous/existing projects [4]

Verified data about grid performance

Real evidence from case studies demonstrating real benefits (WP) based on transparent and honest reporting [4]

Increased acceptability & feasibility of SLES

Mutual advantage & gain [6]. SLES solve specific local challenges, Increased acceptance from showing feasibility (WP). Stronger engagement from community as local stakeholders are more trusted (WP)

Improved profitability & good business case

SLES provides multiple sources of revenue to maximise economic resilience [2]. SLES/distributed energy is cheaper than grid supply & emissions trading (WP). Commercialisation can drive creation of 'blueprints' for wider roll-out (WP)

Peer-to-peer (P2P) trading platforms can help prosumers generate profit while addressing network constraint issues, which may drive investment in distributed energy resources [14,17]

Socioeconomic benefits to different actors

Revenue and savings from peer to peer trading for prosumers and customers resulting from investment in distributed energy/SLES [14,17]

Possible benefits for actors without generation, including welfare benefits and the use of dynamic network tariffs [14,18,19]

Fairness and distribution of social and economic benefits can be discussed using effective & innovative methods for engaging the community e.g. social media, IOT devices and face-to-face meetings (Interview 4,20)

Underlying barriers

Network and ecosystems of green technology businesses takes decades to establish, and it will be very difficult to reproduce in other LAs (Interview 1)

Potential for tensions to arise because of different organisations and stakeholders of differing sizes, cultures and locations, and with different project priorities.

A lack of common goals and agreed action plans may inhibit collaboration of all sub systems and may cause unintended negative outcomes [5]

Physical integration of different parts of the value chain may be faced with challenges such as lack of interoperability of some components and the need for effective data and information exchange for the control and optimisation of operations [5]

SLES are generally highly site and context specific which may limit transferability of experience and knowledge [4]

SLES pilot projects in particular might be too specific / bespoke in scale and specification and too local, so they may not be generalisable or reusable (WP)

They may be too reliant on grant funding or not realistic (WP). Further, gaps between pilot grant funding to 'real' investment inhibit potential case studies (WP)

A lack of equitable funding and resource sharing is a common barrier to collaboration [6] Lack of trust. Trust will vary depending on who is the main case study stakeholders (WP)

Ownership of different elements, variable impacts and risks for different stakeholders and integration challenges may inhibit progress (WP)

The current duties and responsibilities of the DNOs (and other local network companies) as well as Ofgem hinder the emergence of SLES [3,24]

Lack of skills and platforms to communicate case studies to wider audience, lack of knowledge of impact and replicability, limited driven and knowledgeable participants (WP) [20]

Technology uptake for research or usage depends on the willingness of users. Projects underestimate how much time and effort is required to get these consumers and willing participants (Interview 4,20)

Responsibility for knowledge sharing and dissemination falls to intermediary and support organisations, although this is not their primary function [4]

Tendency to focus on success & downplay failures. Limited ability to learn from both positive and negative experience within the sector [4] (WP, [6]

Inapplicable & highly bespoke and specified projects (WP) Technological challenges, compatibility issues and solutions may not be transferable (WP)

Lack of honesty around grid connection costs, lack of transparency (particularly negative results from private partners (WP)

Projects tend to have whole system benefits, that are hard to access at the moment (WP)

Engagement with specific communities or individuals may not be transferable if participants move or become disengaged (WP)

Diverse interests may impact acceptability. (WP) [21]

Single or limited sources of revenue and dependence on grants from public bodies or reserve funds from operating organisation like the LA [1,2]

Potential loss of project funding mid-project, resulting in the loss of project momentum and the abandonment of projects [4]

Regulatory gaps and uncertainties about consumer protection laws and business regulations for actors in these new forms of trading platforms [14,22]

Supply license barriers and skills for development of new trading platforms, areas with skills benefit more than other areas [14] (WP)

Depends on motivations of project leaders (social good / profit motive?)(WP). Inclusivity – lack of desire to bring in new stakeholders due to competition (WP)

Overall extent and nature of the local benefits and co-benefits yielded are not clearly defined and measured

Action plans

Business, finance & markets

Adequate revenue incentives and right conditions can encourage green business in a particular region to go to other locations to establish or upscale SLES. They can also train and use local actors, thereby setting up a local network (Interview 2,6)

Organisations & skills

SLES governance and operation should bring together the sub-systems in developing common goals and ensuring that different aspects can operate for a common good without unintended negative outcomes [5]

Development of skills such as cross-institutional project management [5]

SLES projects / SLES technology providers / educators / certification bodies / *regional SLES organisation*

Technology & systems

The potential need for integration and interoperability of systems should be built into the system from the

Improved SLES specific skills training for hardware and software installation, networking and communications, data analysis and machine learning, data protection and standardisation are critical [5,33]

SLES projects / technology providers / educators / certification bodies

Users & communities

Energy Innovation Zones (EIZ) can be an effective step following pilot projects to make use of a wide range of different and tested commercial and social models within a region or local authority (Interview 5,8)

Business, finance & markets

Mandated purchasing of community-generated energy by public bodies to help in meeting funding gaps [7,23]

Govt (DESNZ) / Ofgem / LAs / *regional SLES organisation* / public funding bodies / catalyst communities

Users & communities

SLES providers should harness grassroots support where possible as community-led initiatives tend to endure longer and produce greater local co-benefits than company-led investment in local energy schemes [14,16]

LA / catalyst community / SLES projects / DNO / DSO

Organisations & skills

Strategies to balance differences in power, resources and interests include stating goals and formalising them into agreements, sharing skills and knowledge and resources in shared meetings in diverse ways, sharing time and financial resources through pooled budgets and face-to-face meetings [6]

SLES projects / LA / catalyst community / academia / research organisations

Organisations & skills

Determine the roles and responsibilities of actors and institutions with clear and transparent procedures for decision making & accountability, effective utilisation of skills and knowledge of members, empowering members to participate and valuing their contributions [6]

Greater coordination between key actors, with evolving roles namely the DNOs, ESO, LAs and SLES actors. This coordination could be facilitated by a new coordinating body [3,24]

Govt (DESNZ) / LAs / *local or regional SLES organisation* / DNO or DSO / ESO / catalyst communities / SLES projects

Organisations & skills

Effective recruitment methods should be determined and adopted within the context as well as good communication and marketing strategies (Interview 2,4)

Users & communities

Stakeholder and citizen engagement will help to develop common understanding and facilitate technology uptake. Skills such as technological literacy, risk management, financial planning, partnership building, communication and engagement are necessary [5]

LA / catalyst community / SLES projects / *local or regional organisations* / research organisations / certification bodies

Organisations & skills

Develop procedures and / or a framework from successful learning and sharing activities to facilitate effective learnings from case studies [4]

Business, finance & markets

Specific funding for learning and replication to be applied on other projects with similar potential from the onset (WP)

SLES projects / *SLES local / regional organisation* / Govt (DESNZ) / SLES demonstrators

Organisations & skills

Identify scalable or transferable project elements or concepts with clear links to future opportunities [4]

Business, finance & markets

Appropriate venture funding can be used to further develop product-based outputs from demonstrator projects (Interview 5)

SLES projects / Govt funding bodies / *SLES local / regional organisation* / research organisation

Organisations & skills

Define SLES project success factors such as local benefits as well as commercial and technical performance indicators. This allows targets and performance to be measured and quantified [4]

Assess project models and governance, skills development and the establishment of project legacy e.g. creation of successful partnerships [4]

SLES projects / technology provider or demonstrators / developers / *SLES local / regional organisations* / academic research organisation

Organisations & skills

Strategies to activate mutual advantage and mutual gain could include the help of a kind of "broker" who can meditate between diverse interests and be a source of information of the project's legacy subsequently [6]

Mutual advantage and gain could be reinforced by regular updates against agreed milestones of success, demonstrating the continued success and value the system as well as identifying risks and mitigations to the project early on [6]

Catalyst community / *SLES local or regional organisations* / LA / SLES projects/

Business, finance & markets

Identify multiple revenue opportunities to maximise economic resilience [2]

Support organisations to manage complex systems with multiple revenue streams by accessing or developing the necessary management skills [2,5]

SLES projects / developers / *SLES local / regional organisations* / educators / academic research organisation

Policy & regulation

Identify and deal with regulatory gaps and consumer law protection issues [14,22]

"Insulate the consumer from innovation risk": insurance mechanism or indemnity guarantee to allow consumers to experiment [22]

"Regulatory system to maximise cross system value": Change the regulatory system to regulate producers, networks, consumer markets, rather than by sector [22]

Ofgem / Govt (DESNZ) / SLES projects / DNOs and ESO

Business, finance & markets

Remove supply license barriers to facilitate P2P energy trading [22,8,9]

Organisations & skills

Identify skills gaps and develop a national skills development strategy [5]

Ofgem / Govt (DESNZ) / DNO / ESO / SLES projects / academic or industry research organisation / educators / certification bodies

Users & communities

Encourage and establish communal assets, which ensure fairness for people that can't afford solar PVC and electric cars etc. so that the system is inclusive (Interview 9)

LAs / SLES projects / technology providers / developers / catalyst communities / *SLES local / regional organisations*

Users & communities

Develop and clearly define local benefits and co-benefits from the on-set, as well as key performance indicators using effective stakeholder consultations [3,4]

Catalyst community / SLES projects / *SLES local or regional organisations* / LAs / research organisation / demonstrators / private investors

Actor / organisations in action plan

Lead organisation in collaboration with other organisations (frequency as lead) (frequency as a co-collaborator)

Aspects of the systems as lead organisation

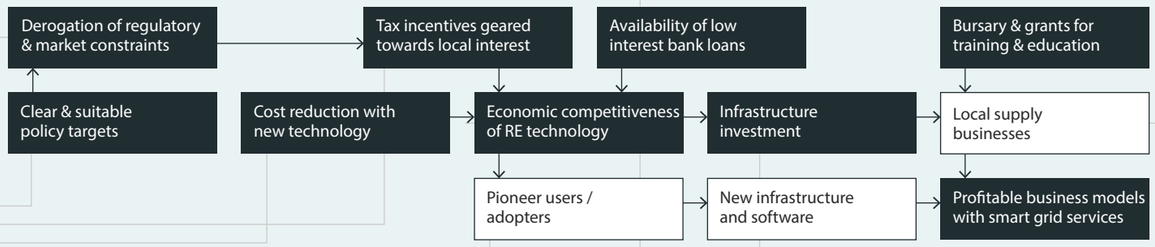
Govt | Department of Energy Security and Net Zero (DESNZ) (2)(3)	Business, finance & markets; Organisations & skills
SLES projects (7)(4)	Business, finance & markets; Organisations & skills
Local authority (LA) (3)(5)	Users & communities
Ofgem (2)(1)	Organisations & skills; Business, finance & markets; Policy and regulation
Catalyst community (2)(6)	Organisations & skills; Users & communities

Other co-collaborator organisations or actors (frequency in Case study pathway)

- Educators / certification bodies (5)
- Public funding bodies (2)
- SLES technology providers (3)
- Industry & academic researchers (6)
- Distibuted Network Operators (DNO) (2)
- Distibuted Systems Operators (DSO) (2)
- Electric Systems Operators (ESO) (3)
- Private funders & investors(1)
- Developers (1)
- SLES demonstrators (2)
- *Local / regional/ national SLES organisations* (suggested new institutions) (9)

INDUSTRIAL STRATEGY
UK Research and Innovation

Economic competitiveness pathway



Underlying drivers

Derogation of regulation & market constraints

Increasing awareness of the need to change market design and structures to enable SLES (Interview 5,6)

Financial / tax incentives geared towards local interests

Private funding and investments are key, with most SLES having some private funding to complement government funding

Incentives from government help to pay for some components of the SLES system (Interview 1,6)

Clear and suitable policy targets

Suitable and flexible policies, regulations and market structures help to foster the opportunities that technology provides (Interview 5)

Provide powers to local Governments to set targets and implement them (Interview 5,8)

Cost reduction with new technology (flexibility, DSR)

Significant potential for cost reduction for consumer and the system with the use of demand-side response (DSR) (8, Interview 6)

DSR leads to avoidance of local network reinforcement through reduction of peak demand. efficiency measures, local energy storage and self-consump-tion from rooftop solar PV (8, Interview 6).

Pioneer users / adopters

Interest / motivation of people / individuals for clean energy (WP). Political drive for self-reliance and energy security(WP) .

Values such as environmental benefits, ability to control their supply and generate within their community (interview 5)

Housing developers, local councils and institutional owners of housing are key targets for SLES solutions because they have access to 10,000–100,000 houses (Interview 6,8)

Economic competitiveness of RE technology

Decreasing prices for key components of SLES systems such as storage batteries and electric vehicles will help to facilitate and improve the economics of SLES systems (Interview 4)

Economies competitiveness from using community heat pumps in comparison to high energy prices (WP). Local supply arrangement provides a reliable income (7)

Proven and profitable systems Integration and optimised technologies reduces operating costs,and investment risks (Interview, 10)

Infrastructure Investment (flexibility)

Increasing appetite in investment community for this field with the right kind of investor, who is patient and want to invest long term (WP)

Local Supply Businesses

Grassroots support as community-led initiatives tend to endure longer and produce greater local co-benefits (16)

Consumers value local sustainable energy and ability to trace the source of the energy and enable the decarbonisation of energy generation (2)

Availability of low interest bank loans

Research or government funding is the major source of capital for SLES. third party funding and low interest loans were two key sources of funding (Interview 6)

For more marginal projects, housing companies, public bodies, social housing providers and councils have access to very cheap capital (Interview 6)

Underlying barriers

The role of Ofgem limit the emergence of SLES. Currently, they do not have specific duties that could better enable the development of SLES [3]

Market design and regulator barriers still present and are affected by politics (WP) Regulation and market constraints impact the return on investment of SLES, current market arrangements limits locational pricing and options to realise value from local energy trading e.g. peer-to-peer trading or local energy markets [3]

Those who don't have assets or certain capabilities cannot participate in the market (Interview 5,6)

Lack of specific incentives for SLES, stop / start incentives (WP)

Political cycles negatively imparts on long term planning , policy aims not always financially measurable (WP) Policy makers change priories, affecting willingness to invest (WP)

There is currently no drive to incorporate flexibility in the UK energy system. Current retail market structures, policies and regulation are not well equipped for innovative flexible technologies and operations [8,9]

Transitional complexity for new entrants, need for a minimum level of participation before the effectiveness and value of flexibility can be realised [9]

Fixed upfront costs or hurdles e.g. minimum capacity thresholds for flexibility, beyond the reach of single SLES [9]

Unwilling individual participants as well as concerns over consumer protection issues, i.e. lack of trust of energy supplier and data protection issues [8,9]

Relatively high levels of engagements required for SLES beyond the norm especially for DSR [8,9]

Privacy concerns on the use of technology for surveillance and control. Lack of clear regulation (e.g. unclear GDPR, i.e. which part of energy data is private / protected (WP)

Lack of knowledge from SLES providers on how best to engage and incentivise potential customers to the SLES services (WP)

Lack of trust and confidence in the benefits of engagement, a low level of trust in energy companies sometimes due to unfulfilled promises on the benefits of flexibility engagement [8,9]

Risk that the value from flexibility and systems integration and RE technologies may be less than expected due to technical performance levels and systems integration / optimisation issues [8] (Interview 6)

Regulatory changes affecting revenue opportunities, or competition between diverse sources of flexibility. Smaller systems may become unsustainable in the longer term or the system, or elements of the system, stop being commercially viable [8,9]

Currently, lack of available attractive time-of-use tariffs [8,9]

Need to realise value from flexibility which impact on return on investment as risk-return perceptions not aligned because of lack of understanding of how to value these projects [4] (WP)

Most flexibility-related mechanisms are still dominated by fossil fuel contracts [9]. Complexity of flexibility provision and procurement processes, concerns about the length of contracts, too short does not justify investment and fixed costs and too long may be subject to uncertainties [8,9]

Local energy businesses are making limited contribution to the assets and turnover of the sector than other, less local energy businesses [7]

Local businesses are highly reliant on long term debt. Local energy businesses are also less profitable, which may mean that they are unable to invest in development [7]

Lack of transparency of business processes and knowledge dissemination limits flow of information (WP)

Considerable focus on technological innovation, when the focus should be on deriving workable and commercially viable business models first (Interview 6,8)

Lack of business development skills, lack of knowledge around multiple finance streams [5]

Longer term loans less available to community group (proven track-record usually required)(WP). Long-time required for pay-back to SLES investments (much longer than 5 years, which discourages investment(WP)

Investors that want high ROI in a short time, which may impact on benefits to consumers (Interview 6)

Action plans

Policy & regulation

Derogations from some of the network charging structures or environmental levies that are built into energy costs may potentially make the difference (Interview 5,6).

The role of Ofgem in the establishment and upscale of SLES should be re-evaluated(3)

Business, finance & markets

Whole restructuring market design to enable peer-to peer trading and local energy markets (Interview 5)

Ofgem / Govt / policy makers / DNO / ESO / SLES projects

Users & communities

Communal assets ensures benefits from the smart system can be received by all in the community (Interview 4,9)

Catalyst communities / SLES projects / technology providers / developers / *SLES local organisations*

Policy & regulation

Specific government-backed subsidies for SLES solutions (Interview 6)

Govt / policy makers / Ofgem / DNO / ESO / SLES projects

Policy & regulation

A long term and strategic vision for decarbonisation and urgent need to determine and communicate the role of SLES [3]

Govt (DESNZ) / Ofgem / policy makers / DNO / ESO / SLES projects

Policy & regulation

Development of national guidelines and sharing of knowledge of best practice to improve consistency in standards and conventions [8,9]

Govt (DESNZ) / Ofgem / policy makers / DNO / ESO / SLES projects

Business, finance & markets

Reduce thresholds for market participation to encourage wider and more diverse entrants. Support local authority and commercial premises to lead on flexibility and provide incentives [9]

Users & communities

Engage with consumers by increasing transparency of communications and setting realistic expectations of savings. Possible use of Facebook and Twitter for near real time interactions with consumers [8,9]

Ofgem / Govt (DESNZ) / LAs / DNO / ESO / SLES projects / catalyst communities

Users & communities

Provide support for individual and community groups, to participate in SLES programmes and markets, by simplifying processes and providing advice, training and resources. Develop user-centred design processes [9]

SLES providers to seek to mitigate privacy concerns through means such as user involvement, collaboration with trusted local actors, and clear consent processes (14)

Policy & regulation

Government and regulators should set out clearly what standards are mandatory and regulate data management. Clear definitions and guidelines on SLES should be a priority to ensure data security, confidentiality and identity protection [10]

Ofgem /Govt (DESNZ) / LAs / catalyst communities

Business, finance & markets

Given the right powers and market conditions, SLES can provide more scope to create different products for different consumers where increasingly desired attributes such as environment, control and locality can be valued and rewarded (Interview 5)

Govt (DESNZ) / Ofgem policy makers / DNO / ESO / SLES projects

Users & communities

Good communication and marketing strategies as well as increasing transparency of communications and setting realistic expectations of savings (Interview 2,9)

Employ social media platforms such as Twitter and Facebook for near real time communication [9]

Catalyst Community / SLES *local or regional organisations* / LAs / SLES projects

Policy & regulation

Minimise investment risk by announcing and consulting on SLES-related policies and policy adjustments well in advance (Interview 6,8)

Technology & systems

Improve the interoperability of not just technologies, but also the data they collect or generate, helping ensure that it is accessible to different actors within the system [8]

Govt (DESNZ) / Ofgem / DNO / ESO / SLES projects

Business, finance & markets

Differentiate price signals to incentivise flexibility in the network, through short term load shifting or long term investment in storage [9]

Price support for exported electricity in the form of a price floor or Contract for Difference arrangement [23]

Ofgem / Govt (DESNZ) / policy makers / DNO / ESO / SLES projects

Business, finance & markets

Tap into revenue streams by unlocking investment, maximising ease of access to a range of flexibility incentives and markets, including local ones [8,9] and creating viability for the new types of products that will attract prosumers, consumers and small businesses (Interview 5,8)

A standardised flexibility agreement by the ENA's Open Networks programme will help to simplify engagement. There are also standardised contracts planned to ease entry into the market [8,9]

Ofgem / Govt (DESNZ) / policy makers / DNO / ESO / SLES projects

Organisations & skills

A mix of private, public, and community-oriented businesses and cooperatives are required for SLES, providing avenues for collaboration and partnerships to secure local benefits [7]

Local energy businesses in partnerships with stakeholders, involving them in more decision making to strengthen ties and unlock non-monetary benefits [1]

Business, finance & markets

Access to appropriate financing mechanisms or instruments are needed to leverage opportunities for increasing or strengthening revenue sources [7]

Policy & regulation

Policy support for investment in local energy businesses include tax exemptions or other benefits, with increased transparency through a unified financial, business disclosure regime [1]

SLES project / Govt (DESNZ) / Ofgem / public funding bodies / catalyst communities

Business, finance & markets

More transparency is important in financial and business disclosure of LEBs, so that investors or financiers willing to provide resources, can gain insights into risks, costs, and benefits, as well as prospects for future income [7]

New approaches such as multiple supplier models could encourage consumers to engage with local energy suppliers or other new entrants while allowing incumbent providers to explore SLES specific new business models with less risk [27]

Organisations & skills

Specific trainings in managerial skills – e.g. cross-sector project management, outcomes evaluation, financial planning, partnership building & business development [5]

SLES project / Govt (DESNZ) / Ofgem / investors / public funding bodies / education / certification bodies / catalyst communities

Policy & regulation

A policy framework should include the promotion of different financial mechanisms or instruments designed to meet local energy business needs, such as working capital, refinancing, and long-term (re-)investments [7]

Policy instruments to attract investment, reduce risk and increase returns include; feed-in premiums, feed in tariffs, production tax credit/relief and property tax & sales tax which directly affects the return of projects and public loans and funds to generate financial resources [9]

Business, finance & markets

Further research is required on the full range of investment models, types and sources which could finance net zero carbon localities, including joint ventures and private-sector-led investment [26]

Govt (DESNZ) / Ofgem / policy makers / DNO / ESO / SLES projects

Actor / organisations in action plan

Lead organisation in collaboration with other organisations
(frequency as lead) (frequency as a co-collaborator)

- Ofgem (5)(7)
- SLES projects (2)(12)
- Govt | Department of Energy Security and Net Zero (DESNZ) (5)(5)
- Catalyst community (2)(4)
- Govt | Policy makers (1)(5)

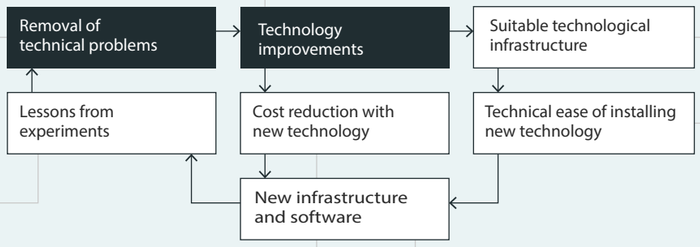
Aspects of the systems as lead organisation

- Business, finance & markets
- Policy & regulation
- Users & communities
- Business, finance & markets
- Organisations & skills
- Policy & regulation
- Policy and regulation
- Business, finance & markets
- Technology & systems
- Users & communities
- Policy and regulation

Other co-collaborator organisations or actors
(frequency in Economic competitiveness pathway)

- Local authority (LA) (4)
- Developers (1)
- Technology providers (1)
- Public funding bodies (1)
- Distibuted Network Operators (DNO) (9)
- Electric Systems operators (ESO)(9)
- Private funders and investors
- *Local / regional / national SLES organisations* (suggested new institutions) (2)

Grid technology pathway



Underlying drivers

Removal of technical problems

Island / rural communities have strong incentives to utilise SLES, especially areas with potential electricity network balancing constraints (WP) [11,12]

Opportunities for wide range of technology applications and solutions (WP).

Lessons from experiments

Exemplar successful projects allow for technology replication, reducing investment risk (WP)

The need for standardisation of SLES procedure and the provision of ready made technical solution [4] (WP)

Cost reduction with new technology

Technology integration and optimisation reduces cost, improve efficiencies, and benefit the consumer (Interview 2,6)

Technology agnostic approach allows for a whole range of available or novel technologies (Interview 6,8).

New economic models facilitated by access to data (WP),

New infrastructure and technology

Increasing awareness of the need for a more digitalised and optimised energy system (29)

Falling prices for key components e.g. storage batteries and electric vehicles facilitates and improve the economics (Interview 4)

Quality energy data that is presumed open as well as open markets facilitated by new infrastructure and assets (WP) [29]

Technical ease of installing new technology

Private sector organisations such as an ESCO can provide the competences to facilitates SLES by building, operating, optimising and maintaining the systems (Interview 2,6,11)

The need for subsystems integration, requiring physical interconnections as well as data and information exchange

Suitable technological infrastructure

The need for more or improved infrastructure to accommodate SLES technologies (WP)

Short 'shelf life' of SLES technologies compared to national grid infrastructure (e.g. inverters 10 years vs decades for grid infrastructure) creates potential for retrofits (WP)

Technology improvements

Rapid technological development underway (WP, 13) Technical solutions demonstrate the positive impact and role of ICT-based solutions, thus facilitating adoption, replication and improved network connectivity provision (13)

The ability to upgrade and replace components more frequently to allow for rapid improvement cycles and so greater innovation (14)

Underlying barriers

Networking and connectivity infrastructure is uneven across UK especially in rural and deprived areas

Lack of technical or project management assistance to address gaps in local expertise, lack of interest in learning new skills when existing skills are still viable [26,14] (Interview 4)

Lack of expertise and experience in systems integration and software engineering for SLES (WP) [13] Insufficient training: Installation and ICY skills for SLES are not yet be widely taught (WP) [13]. Lack of local skill and interest in using available data for digital service provision (WP)

Lack of access to individual homes for experimentation (WP) Commercially useful data may not be shared (WP) Lessons from experiences not always shared (WP)

Lack of expertise and standard procedures for SLES

Lack of communication and leadership skills in harnessing lessons and experience lack of process clarity from network operators (WP)

The adoption of any technology takes time and effort so adopting multiple small-scale technologies will likely involve more time and money than larger, single schemes

Lack of interest / capacity in new economic models (WP)

Long lasting infrastructure and locked-in to incumbent technologies prevent the emergence of a new energy systems (WP)

Policy / regulatory uncertainty, such as the regulatory status and ownership of energy storage, the attractiveness of flexibility mechanism and the impact of network charging reviews on prospective revenues [14]

Skill shortages of knowledgeable and experienced practitioners (WP) (Interview 6)

Users / communities may not use the technology optimally and have to deal with the uncertainty, risks and costs involved with adopting novel approaches

Integration challenges include interoperability issues with existing systems, . Practicality of installation of multiple technologies into properties (WP)

Further, technological barriers can stem from reliability issues due to technological immaturity and novel or complex combinations of mature / established technologies

Interoperability / interconnections, decentralisation could lead to disparities in networking and connectivity – in some areas technology deployment would require full infrastructure upgrade(WP)

Pace of individual elements development (e.g. infrastructure vs new technologies) conflicting (WP) [10]

Rapid roll out of technologies leads to hard ware and software obsolescence (WP) [13]

Technological flux makes project planning very difficult and prevents standardisation (WP) [13]. It is also a barriers to uptake and adoption (WP) [13]

Action plans

Policy & regulation

Proactive regulations and funding required to facilitate upskilling and technical assistance in local areas, e.g. European-funded Elena project, which provided €150 million to support local energy teams across Europe. [26,14]

Govt (DESNZ) / funding bodies / policy makers / LAs / educators / academia

Organisations & skills

Practical top-up trainings beyond University degrees are required and essential [13]. On the job training and peer training should be facilitated by 'training the trainer' i.e. improving the skills and knowledge transfer capacity of senior and experienced personnel [13] (WP)

Capacity and expertise training to derive facilitate digital service provision and value from available data [13,15]

Educators / academia / Govt funding bodies / policy makers / LAs

Organisations & skills

Incentivise participating homes / individual with a variety of rewards that have worked in other projects (WP)

Policy & regulation

Develop and establish an understanding of ethical practices and frameworks for the sector in addition to full compliance to existing data sharing practices which emphasise legislation around data protection [10,14]

Ofgem / Govt (DESNZ) / catalyst communities / national / *regional SLES organisation*

Technology & systems

Facilitate standardisation of SLES procedures which means adopting common approaches to design, activity, operations, etc. Standards allow for the development of product and services that can be integrated more widely [30,14]

Outcomes and lessons from technology improvement experiments need to be properly documented to ensure that all the principles, technology and experience can be transferred to a succeeding projects (WP) [4]

SLES projects / technology providers / Govt (DESNZ) / *national SLES organisation* / technology providers / DNO / ESO / developers

Technology & systems

Smart Energy Management Systems (SEMS), with open interoperable energy management capabilities where two or more devices can exchange information and cooperate to perform a required function, can help to optimise energy assets within a neighbourhood, energy system, building and network to reduce cost or CO2 emissions (Interview 3,8)

Whole system planning and optimisation will promote cost efficiencies & demonstrates commitment to policy goals, supporting investor confidence [31,14]

SLES technology provider / energy systems organisation / team / DNO / ESO / developers / LAs

Technology & systems

Microsystems made up of individually optimised systems which consist of integrated low carbon technologies can be built at the neighbourhood scale. These can be connected to a piece of private wire, operated as a portfolio and managed by an operator. This will help to improve efficiency and cost for individual homes and help to creating a distributed operating architecture for an electricity market (Interview 6,15)

SLES technology provider / energy systems organisation / team / DNO / ESO / developers

Business, finance & markets

Urgent need to develop and demonstrate new economic models to build interest and facilitate trainings and capacity (WP)

Ofgem / Govt, (DESNZ) / LAs / educators / academia / research bodies

Technology & systems

Using a combination of central and local solutions to maintain the robustness of existing industry procedures, while providing the flexibility and time needed to scale up SLES using new infrastructure and systems [32]

SLES projects Technology provider / energy systems organisation / DNO / ESO / developers

Policy & Regulation

Urgent need to address specific regulatory uncertainties regarding these new technologies to encourage an open energy market and facilitate investments and participation (WP)

Ofgem / Govt (DESNZ)v / DNOs / ESO / *national, regional SLES organisation*

Business, finance & markets

Act on the recommendations of the EDTF, ie. facilitate a digitalised energy system, improve the value of data by the presumed open principle and increase data , infrastructure and assets visibility [29]

Ofgem / SLES technology provider / SLES / energy systems organisation / DNO / ESO / developers

Organisations & skills

Improving access to skills such as hardware and software installation, networking and communications, data analysis and machine learning, data protection and standardisation are critical [5]

Technology & systems

Standardisation of SLES Systems can provide a better user experience by reducing the number of technologies and approaches that a user needs to participate in to receive a range of services or by reducing the amount of time and effort needed to familiarise with these approaches [28]

SLES Technology providers / SLES energy systems team / educators / trainers / catalyst communities / *national or regional SLES organisations*

Technology & systems

Technical and implementation barriers can be overcome by using simpler, technologies or interoperable components that can be easily integrated within larger systems [28,30]

Technology & systems

Further standardised components and connections can facilitate scalable systems but this potentially limits the innovation and approaches that can be taken to meet local [15, 32]

SLES Technology provider / energy systems organisation / team, DNO / ESO / developers

Technology & systems

The setting up and upscaling of SLES systems may require the planning and installation of new technology infrastructure across all areas Also, there is a need for flexible planning algorithms to take into account future changes in behaviour and events e.g. Covid-19 (Interview 4)

LAs / planners/ SLES Technology provider / energy systems organisation / DNO / ESO / developers

Technology & systems

Build and share an understanding of the physical elements and connection issues of renewable, clean energy technologies and coordinate investment and planning in data collection and infrastructural development [14]

SLES technology provider / LA planners / systems planners / energy systems organisation / DNO / ESO / developers

Technology & systems

Use a combination of current and novel components solutions to maintain the system and avoid undue obsolescence [15,14]

SLES technology provider / LA planners / systems planners & energy systems organisation / DNO / ESO / developers

Technology & systems

Use flexible scalable system architectures that can adapt to future needs [14]

Users & communities

Timely engagement with developers or asset owners is also important, especially before they renew assets so low carbon options can be used in replacement (Interview 2)

SLES projects / Technology provider / LA planners / systems planners / energy systems organisation / team / DNO / ESO / developers

Actor / organisations in action plan

Lead organisation in collaboration with other organisations (frequency as lead) (frequency as a co-collaborator)

- Ofgem (4)(0)
- SLES projects (3)(0)
- Govt | Department of Energy Security and Net Zero (DESNZ) (1)(5)
- SLES technology providers (6)(8)
- Local authority (LA) (1)(5)
- Educators / certification bodies (1)(3)

Aspects of the systems as lead organisation

- Business, finance & markets
- Policy & regulation
- Organisations & skills
- Technology & systems
- Users & communities
- Policy and regulation
- Business, finance & markets
- Technology & systems
- Organisations & skills
- Technology & systems
- Organisations & skills

Other co-collaborator organisations or actors (frequency in Grid technology pathway)

- Educators / academia / certification bodies (4)
- Policy makers (2)
- Developers (1)
- Catalyst community (2)
- Public funding bodies (2)
- Catalyst communities (2)
- Distributed Network Operators (DNO) (11)
- Electric Systems operator (ESO) (11)
- Academic / industry research
- Energy systems organisation (11)
- *Regional / national SLES organisations* (suggested new institutions) (3)

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- CR | Callum Rae, WP 6.2
- DE | David Elmes, Heat and Cooling Roving Champion
- JP | Jo Patterson, KMED Lead
- RB | Rachel Bray, WP 3.1
- LG | Luke Gooding, WP 4.1
- JH | Jeff Hardy, WP 3.1/3.2
- IS | Iain Soutar, WP 4.1
- BG | Bjarnedinn Gudlaugsson, WP 6.2
- JR | Jill Rymer, Management/KMED
- CM | Chris Maidment, WP 5.1
- TB-S | Tim Braunholtz-Speight, WP 2.1
- RC | Ruzanna Chitchyan, WP 6.3
- CB | Caroline Bird, WP 6.3

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- Chair of Energy Capital and the Regional Energy Systems Operator project
- Project Manager, Energy Systems Greater London Authority (Bunhill Power and Heat Network)
- Founder of Emergent Energy
- Energy, Infrastructure & Services Manager, Zero Carbon Rugeley SLES Project lead
- Project officer, Orkney Local Authority
- Consultant, Community Energy Scotland
- Consultant, Aquatera,
- Consultant, Solo Energy
- Project manager, Responsive Flexibility (REFLEX)
- Consultant, Scottish and Southern Electricity Network (SSEN) (Mull Access project)
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