EnergyREV

# Pathways for the upscaling of smart local energy systems

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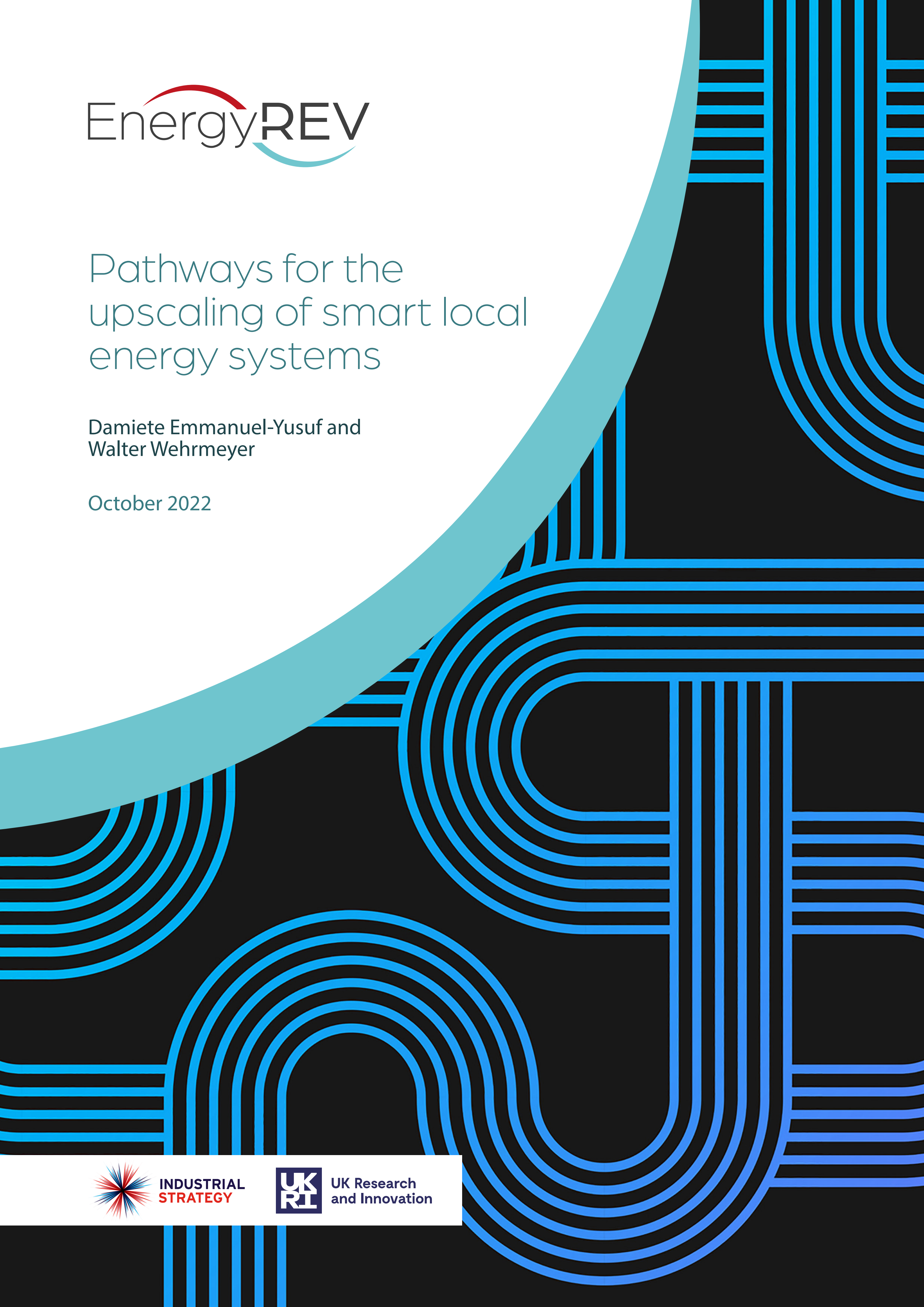
October 2022



INDUSTRIAL STRATEGY

UK Research and Innovation

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This report should be referenced as:

- Emmanuel-Yusuf, D. and Wehrmeyer, W. 2022. Pathways for the upscaling of smart local energy systems. Energy Revolution Research Centre, Strathclyde, UK. University of Strathclyde Publishing. ISBN: 978-1-914241-22-2

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## About EnergyREV

The Energy Revolution Research Consortium (EnergyREV) is part of the Government-funded Prospering from the Energy Revolution (PFER) Industrial Strategy Challenge Fund. The PFER programme is investigating opportunities and challenges around policy, regulation, user engagement and digitalisation of energy systems to unlock the benefits of SLES. The PFER programme has invested around £100 million, matched by industry, in a range of projects to help businesses, researchers and local communities develop, test and prove SLES.

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# Executive summary

Smart Local Energy Systems (SLES) are one of the key energy system components of the UK's Net Zero future (BEIS, 2021). However, their deployment levels are currently low, and their growth is slow. Given the current energy crises, with spectacular gas inflation and a global transition towards Net Zero, it has become necessary and even crucial to examine and implement avenues by which SLES can be upscaled. This report presents four key pathways to the upscaling of SLES derived from a Transition Map itself based on literature and reviewed by SLES practitioners and expert researchers. The four key pathways describe a sequence of drivers and enablers towards the setting up and upscaling of SLES. They are not mutually exclusive and some SLES growth and dissemination may well rely on more than one key pathways. The key pathways are the Local authority and Case study pathways, that have impact on the set-up phase of SLES, the Economic competitiveness and Grid technology pathways that are particularly relevant in the growth phase of SLES. The report also identifies other pathways from the contextual and framework phases of the Transition Map namely the Local community context pathway and the Policy Framework pathway.

Mapping them onto four case studies – Bunhill power and heat network; Project-Scene; Emergent Energy Systems; Mull Access Project – combined with workshops and interviews, led us to the following general recommendations for upscaling:

- The dynamics of drivers and barriers tends to be different for the set-up and the upscaling of SLES. Likewise, speaking of 'barriers' and 'drivers' as a binary choice is less helpful in understanding upscaling than a more differentiated view of barriers, hurdles, enablers and drivers
- More than local initiatives, it is national policies such as the UK Government's Net Zero Target are critical drivers for the development of low carbon systems such as SLES.
- Local authorities need statutory powers over and above local planning frameworks, much as they have for housing and transportation, to provide an incentive to meet carbon budgets.
- Regional governance is needed to promote transparency and accountability in the administration of local energy systems. In particular, regulatory review and derogations are required to drive the viability of SLES business models.
- Partnership with industry partners and commercial companies are key; not just to provide skills and competences but also because income and networks obtained from SLES projects are incentives for upscaling and increasing deployment of SLES.
- Market structures to support technology development are essential so that the sector is not heavily dependent on (temporal and selected) funding.
- Appropriate planning for new technology Infrastructure is key so that a lack of suitable infrastructure or capacity does not limit the growth of the sector.
- Communities that generate social capital to achieve local support for grid growth can be a strong catalyst for improvements. Community engagement activities such as online platforms and face to face meetings, where incentives, profits and benefits sharing can be discussed, are vital tools to encourage support.

We also derived focussed guidance for conditions needed for upscaling for the four specific key pathways:

- Local authority: local authorities need to build capability and skill in energy, maybe in collaboration with other local authorities.
- Case study: specific funding for learning and replication must be provided for demonstrator projects so that findings can be effectively disseminated.
- Grid technology: thorough documentation of lessons learned, including both failures and successes from technology improvement experiments is essential to ensure that principles, technology and experience can be transferred to succeeding projects.
- Economic competitiveness: Economic competitiveness and cost reduction with new systems are critical for the pathway. Success cannot be limited to technological innovation.

# 1 Background

Upscaling SLES is vital to fully realise their potential and benefits in a NetZero future (BEIS, 2021). SLES are defined here as local energy systems that make use of information and communication technologies (ICT) and have automation, self-regulation, and smart decision-making abilities (Ford et al, 2019). These features enhance climate change mitigation, energy security and improve access to affordable energy by increasing deployment of local renewable energy, facilitating community participation, and improving local energy systems through integration, optimisation, and management.

In the inter-related fields of socio-technical transitions, transition management and strategic niche management, 'upscaling' depicts an increase in deployment, adoption, diffusion and roll out of new technologies/innovations, which may have an impact on social practices, culture and institutions (Dijk et al, 2018; Van den Boshlt, 2010; Seiwald 2014).

Naber et al, (2017) highlight the widespread diffusion and integration of sustainable energy innovations in four upscaling patterns:

- Project growth: the project expands in size and impact on users and actors
- Project replication: the project or parts of it is adopted to other locations
- Project accumulation: the project is linked with other experiments
- Transformation: an experiment shapes wider institutional change in the regime.

These definitions and patterns of upscaling are adopted for this work.

## 1.1 Aims and objectives of research

The aim of Work Package 6.1 within the EnergyREV project at the Centre for Environment and Sustainability, University of Surrey, is to investigate the drivers and barriers that support or prevent the upscaling of SLES, 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.

Firstly, a broad literature review was undertaken to identify substantive barriers to, and drivers of, the upscaling of SLES. This revealed a general paucity of literature due to the relative youth of the issue of SLES upscaling and its multidisciplinary nature. Further, two expert workshops were used to develop causal links from literature and create a Transition Map. Subsequent workshops and interviews with SLES practitioners and other stakeholders led to the derivation and evaluation of upscaling pathways. The process gave rise to a selection of key and context pathways, which were applied to real life illustrations to gain further insights and provide guidance and recommendations on how upscaling SLES works in practice.

# 2 Literature review

The literature review aimed to provide the broadest possible trawl of available references relating to the upscaling of SLES. This was done by using a wide range of terms to find papers that deal with upscaling issues, or parts of it, but may not have used the 'correct' nomenclature to be identified in a simple search. Therefore, the project used the Web of Science with six sets of keywords:

- **Group 1**: Barriers or drivers or opportunities or challenges: 4,014296 hits
- **Group 2**: Local or smart or energy grid(s) or electricity: 6,251,103 hits
- **Group 3**: Renewable or wind or energy or thermal or heat or solar or battery or biomass or electricity: 9,799 017 hits
- **Group 4**: Upscale or transition or future or replicate or widen or growth: 10,398 948 hits
- **Group 5**: Innovation or policy or strategy or pathway or framework: 8,543,133 hits
- **Group 6**: Sustainable or eco or environment(al) or greenhouse or climate: 8,825,866 hits

All papers put together represent 45m+ references. A Boolean search was used to combine different groups, so Group 3 AND Group 4 yielded 714,644 hits etc, with a Boolean AND combining all groups yielding 5238 hits. Each paper was scanned, and some 1400 references were selected as relevant, with some 40 papers selected as being highly relevant to the upscaling of SLES. The small proportion of highly relevant papers within the wider search that yielded orders of magnitude more papers is indicative of the difficulties of finding relevant multidisciplinary papers using keywords that occur in many different disciplines.

The search results indicated that the upscaling of SLES exists within a very large field of literature: a global agenda to figure out what works and what does not work in the transition towards carbon-reduced, more sustainable energy systems. It is also topical, with 59% of all references published in the last five years and 85% in this millennium, although some papers go back as early as the 1960s, with one paper from 1927. This makes tracking the emerging literature a fluid and recursive endeavour.

Broadly, six, sometimes overlapping, types of relevant papers emerged:

- **Policy reviews**: discussions on past or proposed policy changes, reviews of specific initiatives towards the promotion of grids
- **Case studies**: reviews of specific cases, countries, or grids
- **Technology reviews**: analyses of technical changes, system improvements or technical modifications
- **Development studies**: explorations of the role of grid / upscaling / renewable energy toward regional or national sustainability
- **Framework applications**: use of existing frameworks (Multi-level Perspective, Consequential LCA, Transition Management, systems dynamics) to explain past behaviours or transitions
- **Project reports**: papers or reports on specific (typically national, but also EU and Development Agency) projects, reviewing their practice and offering alternatives in technology, policy and / or legislation

## 2.1 Limitations of literature

The literature review did not reveal one standard approach on how SLES can be upscaled. Instead, it showed that the drivers and barriers to the upscaling of SLES go beyond technological and economic issues; they also influence, and are influenced by, factors in the wider social, cultural, political and institutional context of the systems, which need to be taken into consideration.

Many papers showed material bias in their analyses of the phenomena. This can take three different forms.: The first is discussing the success rather than the failure of upscaling. This was particularly the case with end-of-project report papers, national policy reviews and case studies of good practice, where reasons for success were given, yet obstacles, barriers and failures were under-represented or framed as 'overcoming the obstacles were instrumental' without actually showing what removed the barriers. There has also been a tendency to emphasise the successful dimensions of a project at the expense of the less-successful aspects, possibly to demonstrate the success of a project to funders or other relevant parties.

Second, the upscaling of SLES is by nature multidisciplinary. However, multidisciplinary papers that integrate different approaches towards the upscaling of SLES are very rare in the literature. Most papers are monodisciplinary by design, so engineering-based papers discuss engineering-based aspects of SLES, economic papers reflect on the economic implications etc. Also, monodisciplinary papers highlighting the necessary multi-disciplinary factors that can lead towards upscaling are limited. So, policy-papers see their drivers (and barriers) in policy etc. This was compounded by a tendency to attribute the project outcome to a narrow set of factors that positively drive change, as opposed to a large variety of specific and context-setting drivers and obstacles, leaving a somewhat reduced transferability of the conclusions.

Thirdly, the underlying perception of how change happens is mirrored from other areas, where a change-conducive context is provided by things such as policy, economic factors, technology or the removal of barriers. Change then happens as a result of the enactment or actualisation of specific drivers for change. However, the obstacles and change-conducive context are neither discussed in the text nor transferable to other contexts. This is made worse where, as so often, the removal of obstacles in themselves often does not trigger change. This is akin to an implicit conflation of necessary and sufficient criteria for success.

In addition, the adjacent fields to the 'upscaling dynamics of SLES' are very substantial. These include Development Studies, Energy, Theory of Change, Engineering, Policy Efficacy, Sustainable Development, National Policy etc, so the large numbers of hits in the initial Boolean search cloud the reality that this is actually quite a small, confined and prescribed field.

Finally, several theoretical perspectives were prominent in the literature, including the Multi-level Perspective, Institutional Theory, Cultural Geography etc. This supports the general research need to conceptualise and theorise upscaling towards a wider, maybe even generic theory – developing and promulgating a Logic of Change in upscaling SLES is a central aspect of EnergyREV. However, these theoretical perspectives are coincidentally descriptive, and not equipped to offer a standard means of self -education.

All of this meant that the literature was useful as a backdrop, informing the reader generically on some aspects of upscaling, especially when seen in the context of the urgent need to improve SLES, as well as to understand how components or action points exist within the upscaling dynamics. It showed the diversity and complexity of causes that contribute to the promulgation of SLES. But it has not been possible to find one, let alone two clears, practical, standard, and easily followed models on how SLES can, or even should, be upscaled.

As a result, a new approach was developed to make sense of the body of literature on upscaling SLES.

# 3 Causal links from literature and the Transition Map

This novel approach, called the Causal Link Method, was applied in an expert workshop (see details in Appendix 1). The aim was to account for the causal relationship between specific multidisciplinary drivers or barriers within the system. To do this the literature was broken down into a large number of causal links describing the impact of changes from factors (drivers or barriers) in different aspects of the system.

For example:

- A: investment into battery technology leads to an improvement of battery performance
- B: improved battery performance leads to less load dumping and faster demand responses
- C: less load dumping leads to better economic performance
- D: better economic performance leads to greater attractiveness of the SLES
- E: greater attractiveness of the SLES leads to a growing system

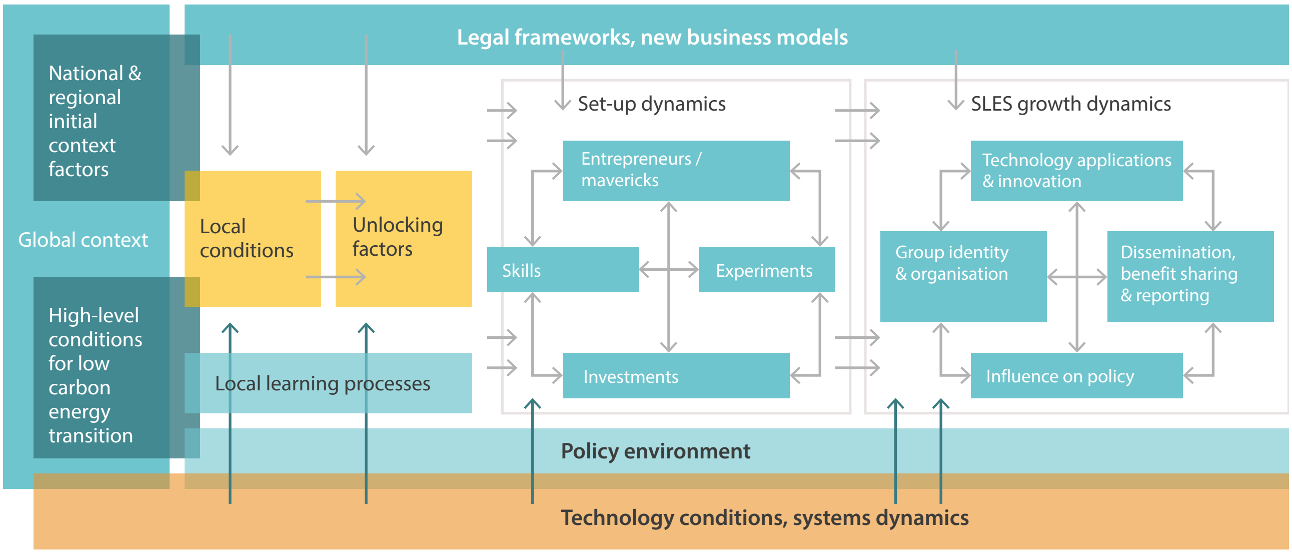
Then each of these causal links (with research evidence in the literature) can be 'stitched together:

A ➔ B ➔ C ➔ D ➔ E

This simple causal chain can be widened easily into different causal pathways by considering that each of the factors – drivers or barriers – can have several effects, which in turn have knock-on effects on the stated, as well as other, causal links. This approach to the use of literature to gain a practical understanding is novel and arguably innovative, so the workshop experimented with the heuristic process as well as the dynamics of upscaling SLES as detailed in Appendix 1.

The expert workshop yielded 267 causal links from selected references. A subsequent widening of the literature to include references with business models yielded another 200 causal links. These were sequenced and clustered to derive a map of causal links (see Appendix 2).

**Figure 1**: Transition Map.



The expert workshop group and researchers (detailed in Appendix 1) reflected on and interpreted the map and developed a conceptual flow diagram called the Transition Map to show an overall dynamic of SLES development and upscaling. Figure 1 shows the Transition Map.

## 3.1 The Transition Map

The Transition map shows that overlapping context factors and framework conditions impact on how SLES are set up and upscaled. The contextual factors form the background of the Transition Map. They include the global/national/ regional/high level conditions for low carbon energy transition, as well as local context/conditions and local learning processes. The framework conditions of the map include the legal and business model frameworks, as well as the policy environment and technology conditions and dynamics.

**The global context** includes climate change policy, international technological advancement, environmental conventions, and sustainable development goals. The national and regional context factors include the provision of local renewable energy; national and regional land use policies; and national sustainable development priorities. High-level conditions for local carbon energy transition may feature national feed-in tariffs; renewable heat subsidies; national renewable energy targets; access to renewable technologies at affordable local prices; priorities for national roll-out; legislative and policy framework suitable for SLES (i.e., no electricity supply monopoly) etc.

On the other hand, **the local context/conditions** describe local community priorities, social demographics, economic prosperity, local energy demand and supply profiles. **Local learning processes** can be demonstrated by the existence of local community institutions (social clubs, community tennis club), sense of community and track record of past community engagement.

**The legal framework** features governance for economic investments, reporting requirements, legal assurances about investments and assets, as well as the legal provisions for decisions about start up, decision-making and upscaling (or disposal) of assets. The **business models framework** comprises market and trading models. The **policy environment** features policy frameworks of SLES, local authority disposition or support. **Technology conditions and system dynamic**s relating to SLES are grid connectors, grid stability and redundancy, improved battery technology and technical links to other grids, among others.

**Global context** factors have a substantial bearing on the local context. They can help create an enabling environment towards SLES using unlocking factors, which are mostly financial and regulatory drivers. The **legal framework** matters materially in that it provides governance, legal assurances and legal advice on the start-up and upscaling of SLES. This of course has implications for emerging and established business and market models. Finally, changes in policies and technologies dynamics over time are shaping the local context.

The local context is also being shaped by two distinct evolving systems: the establishment and then upscaling of SLES. The establishment of SLES could mean the initial set up or the replication process of SLES into other local contexts; the upscaling of SLES could describe the growth of an existing SLES into additional functionality, greater capacity or different service provision. The first **setup dynamics** 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 second context field can describe upscaling where **SLES growth dynamics** represent the interplay of a functioning SLES developing its own dynamics and identity, successful economic performance and the dissemination of revenues, technology innovation and local policy.

The transition map forms the basis from which pathways to the upscaling of SLES were derived in a pathway generation workshop. The pathway generation workshop structure and process are described in Appendix 3.

# 4 Pathways generation and evaluation

The exercise yielded 24 pathways consisting of 14 driver pathways and 10 barrier pathways. The driver and barrier pathways depict sequences of factors that act as drivers (deep green) or enablers (light green) or barriers (red) and hurdles (light red) to the setting up and upscaling of SLES. The further characterisation of 'drivers' and 'barriers' to include enablers and hurdles, thereby using four sets of factors as opposed to two is to allow the strength of pressure to be reflected. In addition, some drivers are opposites to barriers (investment capital is a driver, lack of resources are a barrier) and some drivers can be turned into a barrier and vice versa. Using a four-factor categorisation can better cater for these nuances.

The four factors are:

- **Barriers**: factors that impede the evolution, transformation or growth of the SLES, usually in a way that cannot be overcome in the short-term or with local resources and ingenuity. Lack of a market, regulatory prohibitions, and local opposition in the public are examples.
- **Hurdles**: factors that act as impediments for the genesis or evolution of a SLES, but can characteristically be overcome, worked on or circumvented. Hurdles can be converted into Enablers. Examples include local lack of willingness to invest, scepticism in the quality of key components or stakeholders, past poor experiences, use of untested or unproven components etc.
- **Enablers**: factors that support, promote or nudge the evolution of a SLES. Enablers are less strong than Drivers, and for the most can revert into Hurdles. Positive attitudes towards some system components, the promise of social benefits as part of the SLES operation, an attractive distribution of the spoils of the system, opportunities to widen the desirability of a SLES to include wider objectives are examples.
- **Drivers**: factors that very likely promote the upscaling of a SLES. Without a critical mass of Drivers, a SLES is unlikely to form. A SLES with backing of an existing utility, or one that has operated for a few years successfully and is now linked to a large upscaling and demonstration grant and a local authority resolution to launch a SLES are examples.

This distinction materially aided the discussion about, and application of, the pathways.

An initial evaluation by the researchers reduced the pathways to twelve driver pathways and eight barrier pathways to remove overlapping and repetitive pathways. In subsequent evaluation workshops, six key driver pathways and four barrier pathways were selected.

The six driver pathways include:

- Local authority
- Case study
- Economic competitiveness
- Grid technology
- Local community
- Policy/learning pathways.

The barrier pathways selected were:

- Institutional and financial barriers
- Public investment and uncertainty
- Unstructured skills dissemination
- Limited citizens' engagement.

## 4.1 Conceptual limitations of barrier pathways

During the pathway generation and evaluation workshops, it became increasingly clear that that the formation and evaluation of barrier pathways, or 'pathways of doom', was conceptually difficult. This was due to limitations on how barriers are presented in the literature (as discussed in section 2.1). The number of barriers was limited because of a tendency to discuss success rather than failure, such that barriers, failures, and obstacles were underrepresented. Also, the barriers cited are mostly high-level barriers rather than barriers specific to projects. This made it harder to link the impact of the barriers to the experience and outcomes of specific projects. For instance, it was difficult to determine the impact of a barrier like 'a lack of political will' on a SLES project, or the consequential barriers that may have risen because of a 'lack of political will'. Therefore, a future research question could be to explore how the impact of such high-level barriers on project experience/outcomes can be evaluated. However, barriers to the progress of each pathway will be discussed as part of insights from the real-life illustrations. The barrier pathways are presented in Appendix 4.

## 4.2 Key driver pathways

The driver pathways were further evaluated by SLES practitioners, including practitioners at the PFER demonstration centres, and were narrowed down to four key driver pathways.

They are:

- Local authority,
- Case study
- Economic competitiveness
- Grid technology.

The Local authority pathways and the Case study pathways are the key pathways in the setting-up phase of SLES, according to the interview responses. The local authority is a major actor and decision maker because of the 'local' nature of SLES, even though it may not be the leading organisation.

For the Case study pathway, it was observed that most SLES are either demonstration/exemplar projects or were derived from such projects. As such they are also important in the setting-up phase.

The Economic competitiveness and the Grid technology pathways are key in the growth phase of SLES. This phase in the Transition Map features the interplay of technology application and innovation, group identification/organisation, dissemination and benefit sharing and influence on policy. The Economic competitive pathway is important here because as projects grow, replicate, accumulate or transform, economic considerations and benefits become more significant and are key factors for upscaling. The Grid technology pathway is also quite relevant in this 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.

The key pathways identified here are in line with other studies. For instance, Wilson et al. (2020) used cluster analysis to characterise common clusters of local energy systems in the UK by geography, scale, technology and, particularly, by institutions such as public sector, private firms and Distribution network operator (DNO) led projects. Similarly, Bridgeman et al. (2019) distinguished three main institutional configurations such as community-led, DNO led, and local authority-led projects, either directly managed or through public-private partnerships and service contracting. The following sections describe the key pathways with references to their path through areas of the transition map in italics, and map each onto a real-life illustration.

## 4.3 The Local authority pathway

The Local authority pathway typically involves the 'local authority' as a major actor. The pathway begins when policies derived from *global/national contexts* are translated to local institutional priorities and preferences. This is enabled by 'social/environmental awareness' and backed by 'government funding' which are *high level conditions for low carbon energy transitions*.

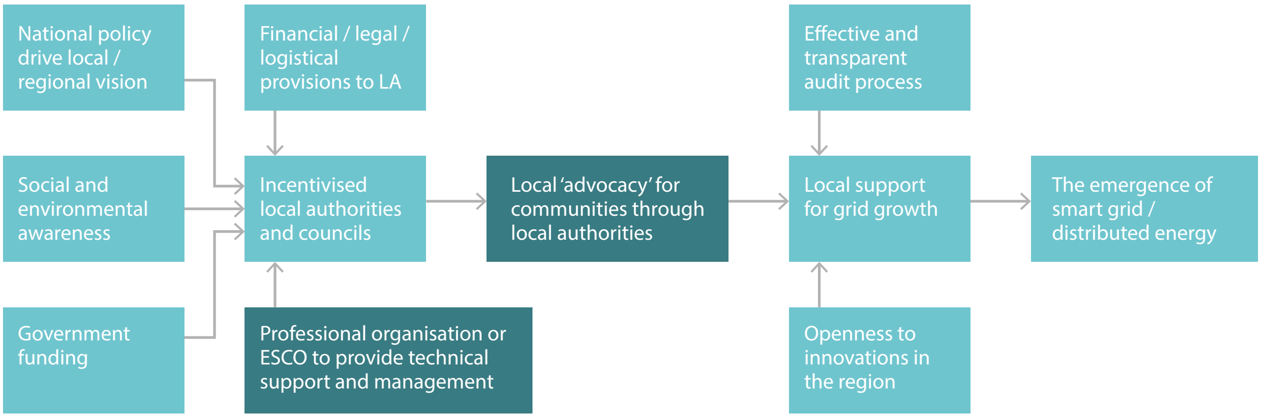
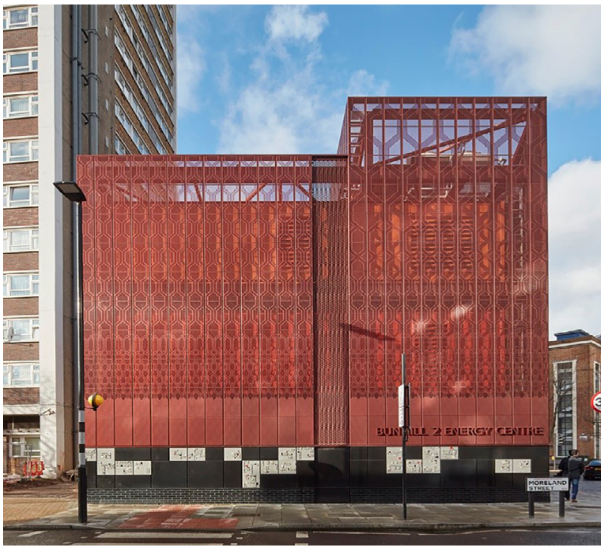


**Figure 2**: The Local authority pathway.

The preceding then helps to create a favorable *local condition* where the local authority is incentivised and supported by 'financial/legal and logistics provisions within the *legal frameworks and new business models context*. Also, a regional or local Energy Service Company (ESCO) or energy producer facilitates *local learning* by providing technical and managerial support. This leads to 'local advocacy for the community' a key driver, where community sustainability concerns are addressed, giving rise to increased local support for the grid, where the *SLES set up dynamic* is activated with an openness and willingness for systems innovations, which is further enhanced by an 'effective and transparent audit process' leading to the 'emergence of smart grid/ distributed energy'.

## Real life illustration: The Bunhill heat and power network (BHPN) Phase 2

The Bunhill heat and power network (BHPN) Phase 2 in the London Borough of Islington recycles waste heat from the London Underground to provide a low carbon, low-cost heat source. The project involved the construction of a new Energy Centre which extracts heat from the underground system and distributes it through a network of pipes with heat pumps. The network provides demand response services to the grid and serves 1,350 local homes which are largely existing council housing. It also provides heat to businesses and leisure centres built in the 1930-1980s.



Phase 2 is an extension of the original network, Bunhill Phase 1, which is powered by a Combined Heat and Power (CHP) engine that produces electricity and captures waste heat to heat buildings and provide hot water.

The upscaling of the Bunhill project from Phase 1 to 2 is an example of a project accumulation upscaling pattern. In this case, Phase I of the project was extended and linked to Phase 2, thereby increasing the number of service providers and customers and available funding, as well increased technology diversification with the innovative use of waste heat from the London Underground using heat pumps in addition to the CHP unit used in phase 1.

The following observations from practitioner interviews concerning the upscaling of the Bunhill case study, along with examples from other case studies, provide key insights into the dynamics and evolution of upscaling.

The Bunhill heat and power network is mapped to the local authority pathway.

**National policy drive local/regional vision**: The UK government's Net Zero target by 2050 has instigated various local and regional carbon neutral targets that are driving the implementations of low carbon solutions. In the Bunhill case study, Islington Council also declared a climate emergency and pledged to work towards making Islington net zero carbon by 2030, (BHPN, 2020). Similarly, local councils like Bristol have also declared climate emergencies, committing to becoming carbon neutral and climate resilient by 2030 (*Interview 2,10*). However, not all cities or councils have these stringent carbon neutral commitments, despite the UK Net zero target. Therefore, there is an imbalance in the level of commitment amongst local councils which could inhibit the drive for low carbon solutions like SLES nationwide.

For housing, it was noted that the National Planning Policy Framework is light on enforcing local authorities to use low carbon solutions. Developers are not actively encouraged to implement low-carbon solutions (*Interview 2,8*). Nonetheless, increasing requirements for carbon performance standards in housing will help to lower the regulatory bar to installing electrical heat sources, such as heat pumps. These include new standards for new builds and future home standards, which are a key part of the London plan, and the recent introduction of a lower carbon factor for grid electricity in the Standard Assessment Procedure, a key part of Building Regulations compliance (BRE GROUP 2021. These changes are set to drive institutional owners of housing like local authorities to seek cost-effective and high-performance local carbon systems to meet these requirements (*Interview 2, 6*).

**Partnership and upscaling incentives from commercial companies**: Several organisations were involved in the Bunhill case study in Islington. For example, Bunhill Heat and Power Network was partly funded by the London Borough of Islington, the EU Celsius project and the Greater London Authority, Transport for London (TfL) and UK Power Networks. Private companies and the London Southbank University also supported the project by carrying out feasibility studies, helping to increase internal capacity and analysing the real-life performance of the scheme (BHPN, 2020). Interview 1 says that there is usually a very close-knit relationship between all the companies and public authorities involved because they have done projects together and so they are able to facilitate project growth because of a successful previous experience. Likewise, some ESCOs help to facilitate SLES by building, operating, optimising and maintaining them and in some cases, bringing investment to the table to offset some capital expenditure (*Interview 2,6*). They have a revenue incentive to utilise their learning to reproduce and upscale (*Interview 1*), It is not always built into the plans for projects to talk to another local authority to establish SLES. However, commercial partners like Pivot Power in Oxford can act as a bridge to other local authorities. For instance, Pivot Power plans to build 45 SLES systems in other Local authorities. Therefore, Support from commercial partners helps to incentivise local authorities and the returns from the projects also incentivise these private companies to build other SLES systems in other locations (*Interview 1, 8*).

Commercial partners also play an important role because the setting up and upscaling of SLES needs to go beyond a champion coordinator within a local authority. Depending on the support of a council chief executive can be difficult and may get derailed by more urgent issues such as COVID 19 or school meals or social service (*Interview 10, 7*). There is the need for some sort of network or good coordination within the company or council to help implementation. Therefore, like Bunhill, there needs to be a partnership between industry, academia and government based on systems thinking from end user to policy makers to make up a low carbon future (*Interview10, 4*).

**Statutory powers for local authorities**: Local authorities need to have statutory responsibilities for energy to meet carbon budgets, just as they have for housing and transportation.

Such responsibilities will make the local authority engage with SLES proposals because they have an incentive to meet the carbon budgets and resources will be allocated towards that end (*Interview 9*). A statutory role for local authorities will also facilitate effective information sharing and decision making because the local authorise can tell the network companies what they have decided to do in their region, making information and decisions more efficient. Local energy systems need to be grounded in local realities. Ofgem's responsibility as a national economic regulator would struggle to deal with the different local issues, resources and opportunities.

**Building local authority capacity and experience**: Local authorities need to build capability in energy so that they can create integrated plans and make energy a cross cutting concern that helps them achieve goals in all the areas that are within their democratic mandate (*Interview 2*). Recruitment has been a real challenge because they are highly skilled and quite specific types of jobs (*Interview 1*).

As in the Bunhill illustration, SLES actors can work with planners at the local authority level to create a local community of skilled practitioners amongst the planners. Up until now local authority planners have mainly consented to or denied consent to solar farms and wind turbines. There is a need for a much more strategic approach about how we bring SLES actors and local authority planning teams together so that they can see how a SLES will help them to achieve their goals of economic development and place making. This will facilitate take up and development of SLES by local authorities (*Interview 9*). There is also a need for adequate planning for technology infrastructure e.g., determining vehicle availability for Vehicle to Grid infrastructure (VTG), the location of the vehicles and chargers and how many to deploy. (*Interview 1, 4*). Local authorities can also work in close partnership with the DNO to do local area energy planning. This is a new type of association to facilitate SLES which could include transport planning, managing the electricity network and, retrofitting buildings so that heat pumps work optimally. All of this requires a new level of joined up-ness (*Interview 9, 10*).

It is noted that the councils that have successful SLES roll out are mostly large cities like Manchester, London, Bristol, Birmingham, and the West Midlands; these large cities /councils can afford the human and other resources to deal with SLES on large scale. For instance, some cities like Bristol, took early advantage of solar farms when the feed-in tariffs were very large and so they managed to build a self-financing energy team (*Interview 5*).

Many details need to be sorted because this is a new sector. For example, when it comes to procurement for the components of the system: how do you engage; on what timeframes do you engage; and on what commercial basis do you engage? How do you share financial risks? Also, how do you manage changes in companies that are going bust or being bought out by bigger firms in the middle of projects? The setbacks and successes of these kind of experiences and learning processes can be recorded and applied in similar projects to help in scaling up. (*Interview 1*).

**The local authority as an effective advocate to ensure fairness**: The local authority is key to ensuring that the benefits of a SLES system are distributed fairly. This is because they have multi vector interests and can better represent residents than private companies. (*Interview 1*). The challenge from a political perspective is that there might be some vulnerable people within those dwellings with low carbon heating that may end up paying slightly more for their heating. So, the council must make sure that there are appropriate interventions to ensure that no one is paying more (*Interview 4*). In the Bunhill example, for instance, care was taken to ensure that the project was publicly owned so that it is the public who benefit (BHPN, 2020). Local engagement is critical with local businesses, communities and the public sector. The idea is to build smart and fair neighbourhoods with the local carbon hub community, network operator managing substation and communities (*Interview 9*).

**Achieving local support for grid growth**: Not everyone in the community may want to be involved in a SLES system. Some social tenants may refuse to have a heat pump and they are within their rights.

Therefore, effective strategies to engage with the local community are essential. One method is to engage with catalyst communities – these might be key groups within the community or local businesses – to generate social capital so that residents can engage with, and take up, SLES technology solutions (*Interview 9, 10*). Online platforms and face-to-face meetings can be used to engage with the end users through open discussions, and to provide the opportunity for questions to be asked about incentives, profits and benefits sharing. For example, in the Bunhill example, there was an extensive local community consultation in the densely populated urban area. Films were specially created with the local community, including a local school, to provide information and generate support for both phases of the network. In addition, Islington council tenants received a 10% discount on their heating charges, and this created further support for the network (BHPN, 2020).

**Openness to innovation in the region**: Creating a network of green technology businesses in a region will facilitate the establishment and upscaling of SLES. For example, Oxfordshire has a very good energy team. However, that kind of network and ecosystem takes decades to establish and will be very difficult to reproduce in other Local authorities. Oxfordshire Green Tech is a network of green technology experts who come together for seminars series called colloquium. It provides a focal point for the energy community in Oxfordshire (*Interview 1*). The Bunhill project also benefited from a network of local private companies and institutions in the establishment of their systems (BHPN, 2020).

**Regional governance, transparency and accountability**: There needs to be enough capacity at the combined authority or unitary authority so that they can play a public accountability role over local energy systems. Ultimately SLES will be driven by profit motive in spite of their good intents, so there needs to be an accountability structure where someone who is answerable to taxpayers and voters is able to effectively function in an oversight capacity (*Interview 5*). Regional governance models for smart local energy are required to govern this kind of SLES project and the kind of outcomes they will create (*Interview 7, 8*). Institutional change and the devolvement of powers to local authorities are key (*Interview 7, 8*). The city or local authority needs to provide a coordinating role and enforce a standardisation or technical specification across all the smart energy systems in an area. Otherwise, we're at risk of having six or seven smart energy management systems all operating across the city at the same time, all competing with each other, and all potentially unable to interact with each other. (*Interview 3*). Ofgem is too far removed from local networks and local opportunities to develop resources or provide proper oversight (*Interview 5*). If regions are given some powers so for example, to raise levies on energy bill so it could fund activity in the energy space. This will better facilitate zero carbon than leaving it to the national system.

## 4.4 The Case study pathway

The case study pathway depicts a SLES that is established from a demonstration or exemplar project by a private company or a public research project. Successful demonstrator or exemplar projects are key enablers that facilitate the development of local skills, knowledge and social capital within the *local / regional context*. This gives rise to a *SLES set up dynamic* which involves learning from experiments/ experience and creates an openness to innovation and learning by doing in the establishment of a new SLES. As the pathway evolves, the SLES growth dynamic is stimulated by enablers such as socioeconomic benefits, improved profitability and a good business case. Verified data about the grid performance also leads to increased acceptance of the feasibility and practicality of the SLES.

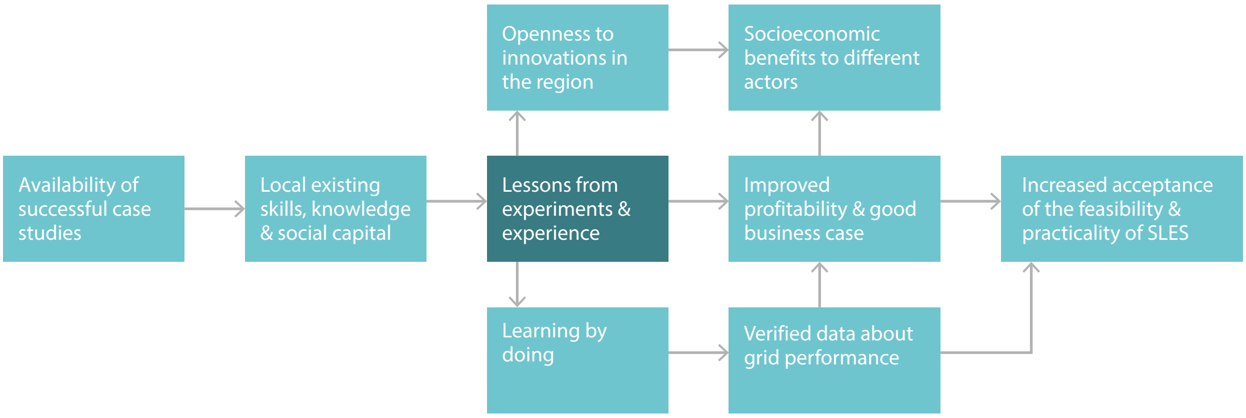


**Figure 3**: The Case study pathway.

## Real life illustration: ProjectSCENe

ProjectSCENe (Sustainable Community Energy Networks) is a new housing development in Nottingham's Trent Basin consisting of 120 new homes. It features Europe's largest community energy storage battery (lithium-ion batteries), solar photo-voltaic panels and local thermal energy production. The aim of the project was to involve all companies in the energy supply chain to generate renewable energy, support local communities, address research and policy gaps and deliver low carbon grid services to the national grid. Using novel consumer engagement tools and a focus on business model development, the projects will also develop and test business model templates that could be used by developers of housing projects.

The upscaling of ProjectSCENe from Creative Homes could be described as project growth. Creative Homes, which is a seven-house demonstration project, was extended to ProjectSCENe, a city-scale demonstration project featuring a community energy storage system.

The following observations from practitioner interviews concerning the upscaling of the ProjectSCENe illustration, along with examples from other relevant cases, provide insights into key upscaling issues.

ProjectSCENe is mapped to the case study pathway.

**Effective dissemination strategies from demonstrator projects**: Sharing learnings from case studies is essential to the upscaling of SLES. To facilitate this, there needs to be an effective partnership between industry, academia and government (*Interview 4*). This kind of collaboration was exemplified in the ProjectSCENe case study which involved Nottingham Council, University researchers and local developers. There is also the need for specific funding for learning and replication. For example, funding an exemplar project with the explicit aim to replicate the project elsewhere is important. The learning, experience and knowledge is then applied on other projects with similar potential. For example, another project, the Queens Quay model, uses heat pumps to generate energy from river water. This is being replicated in the Isle of Dogs where they're looking at a dock water solution (*Interview 2*). Appropriate venture funding can be used to further develop product-based outputs from demonstrator projects (*Interview 5*).

Sustained Energy Innovation Zones (EIZ) can be an effective step following demonstrator projects to make use of tested commercial and social models.

They can be run for the next five or ten years, ramping and scaling up to become self-sustaining (*Interview 5*). EIZ could be as big as a city such as Coventry. Within that zone you would negotiate with Ofgem for changes in regulations to support local business models (*Interview 7*).

**Local community engagement and social economic benefits**: Local engagement is critical. The idea is to create smart and fair neighbourhoods. These may involve the network operator and neighbourhood sub-stations, as well as catalyst communities such as engaged groups within communities, local businesses and public institutions. Together they can generate social capital and engage with and take up SLES technology solutions (*Interview 10*). Several lessons were learned from research projects in the ProjectSCENe case study, including effective and innovative methods for engaging residents in a community project. These included using social media, IOT devices and face-to-face meetings where fairness and distribution of social and economic benefits could be discussed (*Interview 4*).

Offering technology shares helps support the local energy system and motivate more community actors. This creates social capital that facilitates the optimal use of technologies and improves the feasibility of the SLES (*Interview 9, 10*). Communal assets also ensure fairness for people that can't afford solar PVC and electric cars etc. so that the system is inclusive (*Interview 9*). In the ProjectSCENe case study an ESCO was established to produce and manage the local delivery of energy. It offered several programmes to address energy related issues in the community and raised awareness regarding technical and behavioural aspects of sustainability, energy efficiency and debt issues in the local community. It also facilitated access to funding from large organisations and state agencies such as interest free loans for energy retrofit measures to some of the most vulnerable households in the community, as well as a grant to install wall insulation or energy efficient boilers (Rodrigues et al, 2020).

**Recruitment and participation for research**: Technology uptake for research or usage depends on the willingness of users. Effective recruitment methods should be determined and adopted, as well as good communication and marketing strategies (*Interview 2, 4*). Sometimes projects underestimate how much time and effort it will take to get these consumers and willing participants (*Interview 7, 8*). Early adopters were often driven by environmental benefits when they weren't economically viable. Currently, adopters may be driven by a desire to reduce their energy costs, while helping the environment (*Interview 5*). Since participation is purely optional, less willing participants can be encouraged by automated systems that allow each resident to choose their own level of participation. Thus, we may need to build in systems at the infrastructure level to support automation (*Interview 4*). From experience only about 15% of residents usually want full control and autonomy over the system. The rest were happy to some degree to allow the automation to happen (*Interview 3*). Finally, people need to be properly trained on how to understand and operate these SLES technologies to derive the benefits, locally and nationally (*Interview 9*).

## 4.5 The Economic competitiveness pathway

Economic competitiveness is a key pathway that is shaped by the economic opportunities the SLES system may bring to its users and the public or private institution that establishes it. The national and institutional context featuring drivers such as suitable policy targets, tax incentives and the derogation of regulation and market constraints set the scene for the creation of the SLES. This is further enhanced by unlocking factors such as the availability of capital and the cost competitiveness of renewable energy technology. These unlocking factors then stimulate the SLES set up dynamics which involve the activities of adopters and pioneers, investment in infrastructure and skills and experiments with new software and infrastructure. These factors eventually trigger SLES growth dynamics with the development of local supply business networks that provide group identity and organisation and promote benefit sharing, reporting and dissemination. These lead to profitable business models with smart grid services derived from further technology application and innovation.

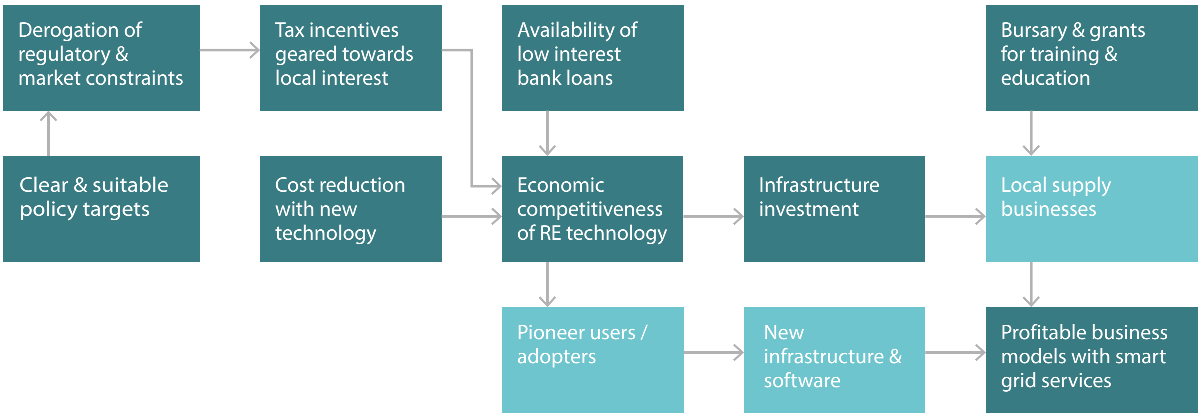


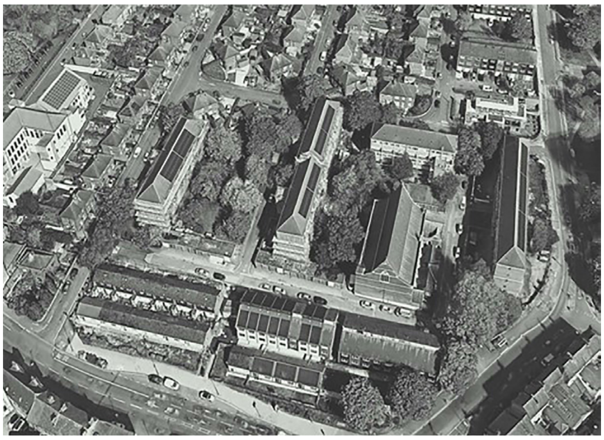
**Figure 4**: The Economic Competitiveness Pathway.

## Real life illustration: Emergent Energy Systems

Emergent Energy is an energy systems company that has developed a 'microgrid' solution that is primarily designed to achieve a profitable business model that benefits multiple parties to deliver Net Zero ambitions. Emergent currently operates nine pilot energy systems, installed in existing (retrofit) and new buildings in partnership with three city councils, serving around 250 residential customers. The systems include solar PV, private networks, smart meters and communal low carbon heating, including both combined heat and power and heat pumps. Several of the projects also include communal battery storage.

Based on this business model, housing companies and residents will not need to fund upfront capital on technologies. Residents also receive truly green energy at affordable prices, and capital funders gain reliable long term infrastructure investments returns. The microgrid system is based on the use of private wires to share the benefits of solar PV and other low carbon technologies. These technologies are intelligently integrated with battery storage, big data analytics and algorithms to create a profitable local microgrid.

Emergent Energy was able to upscale its activities by initiating and facilitating institutional and regulatory changes. These are characteristics of the transformation upscaling pattern.



The derogation of OFGEM's regulatory and market constraints was a key driver to making their projects economically competitive. The success of the projects may potentially lead to establishing these regulatory changes, which may positively impact similar upcoming projects or companies in the sector.

The following observations from practitioner interviews concerning the upscaling of the Emergent Energy case study, along with examples from other relevant cases, provide insights into key upscaling issues.

Emergent Energy Systems is mapped to the economic competitiveness pathway.

**Regulation review and derogations for SLES**: Regulation and market constraints impact the return on investment of SLES. For example, local councils do not have the power to compel people or developers to connect to their district energy schemes.

Because local authorities must participate in national competitive markets, hence potential investors do not have a guarantee for their investments (*Interview 1, 6*). Likewise, homeowners and tenants in a block of apartments that want to benefit from a local solar farm in a smart local system may have to pay distribution costs for energy because it is not directly connected to their houses. However, derogations from some of the network charging structures or environmental levies that are built into energy costs may potentially make the difference for a community scheme that wants to build shared infrastructure (*Interview 5, 6*). In the Emergent case study, aspects of the Balancing and Settlement Code (BSC) arrangements were stopping microgrids from being commercially viable in retrofit settings. Emergent engaged Ofgem on this issue and received the first Sandbox Derogation Award, which has created the opportunity for commercially viable projects in retrofit settings. The derogation makes it easier and cheaper for households on microgrid networks to switch their energy supplier. This is essential for operating microgrids fairly and cost efficiently in residential developments (*Emergent 2022, Interview 10*).

In addition to derogations for network charges, community schemes need advice to help to navigate the complex issues associated with microgrids? That would be the legitimate role for a local authority (*Interview 5*). It could be a potential trusted third party which could at least steer them in the right direction to find good advice. There need to be clear new roles for what councils, DNOs, regional local authorities, mayors and OFGEM can do to facilitate issues surrounding the establishment and upscaling of SLES (*Interview 7, 10*). Regulatory and policy arrangements are required to drive the viability of SLES business model (*Interview 9*). Currently the industry is structured with green tariffs which don't increase investment on renewables. They are unequal because the only people who can benefit from them in the household are those who can pay for them. There are no specific Government backed subsidies for SLES solutions (*Interview 6*).

**Development of new market structures**: Currently, private or Government funding is the major source of capital for these SLES systems. Developing them commercially is a challenge because there is no real pricing mechanism for them. This means long-term certainty in valuing return is a big market barrier (*Interview 3*). Market structures and policies are needed to foster the opportunities that technology provides. (*Interview 5*).

Currently most users buy energy as a commodity based on price. However, other values are emerging that people would be willing to pay more for, such as environmental benefits, ability to control their supply and generate within their community etc. The current market structure does not allow these attributes to come through. 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*). So, there is the need to build market structures and policies that can respond to changes in the system and then translate that into messages to people who generate, have storage, have flexible demand and own assets to be rewarded.

For instance, networks are in the starting point of greater flexibility, which is driven more by operating expense than capital expense. We haven't built the policy and the market infrastructure to reflect this new emerging reality (*Interview 5*). To tap into flexibility revenue streams, we need to create viability for the new types of products that will attract prosumers, consumers and small businesses into this market (*Interview 5*). Thus, we do not have a technology problem anymore. It is a market design problem (*Interview 9, 5*).

**Economic competitiveness and cost reduction with new systems**: Currently there is considerable focus on technological innovation, when the focus should be on deriving workable business models first – that is to find something profitable and commercially viable that can be scaled up. (*Interview 6, 8*).

One such system is the Smart Energy Management Systems (SEMS), an open interoperable energy management system that helps to optimise energy assets within a neighbourhood, energy system, building and network to reduce cost or CO2 emissions (*Interview 3*). The Emergent 'Microgrid' system in the Emergent example is based on the use of private wires to share the benefits of solar PV and other low carbon technologies across multiple homes through a local supply arrangement. The microgrids can be simple, including only solar PV, private wires, and smart meters. Or they can be more complex, including low carbon electrical heating technologies, electric vehicle charging and neighbourhood scale electric or heat battery storage. Integrating technologies in this way reduces operating costs, while the local supply arrangement provides a reliable income (Emergent, 2022).

Technology integration followed by roll out at scale is needed to achieve commercial viability and attract cost effective finance (*Interview 2*). Over time 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*). However, lack of long-term data on technology performance is a challenge: building a commercial model requires about 25 years of information (*Interview 2*). Finally, there is a need to optimise and operate electricity at a neighbourhood scale equivalent to local heat networks. This creates an opportunity where local electricity systems optimisation which may help to transform the economics and progress of heat decarbonisation, for instance heat pumps can be included within the local electricity system (*Interview 6*).

**Government/private funding and investment**: Research or government funding is the major source of capital for SEMS. Incentives from government can help to pay for some components of the SLES system. For example, vehicle to grid incentives help to pay some of the cost and operation of vehicles (*Interview 4*). Private funding and investments are a key source, with most SLES having some private funding to complement government funding (*Interview 1, 6*). In the Emergent example third party funding and low interest loans were two key sources of funding.

Third party investment is readily available for projects with proven returns. However, with more marginal projects, housing companies, public bodies, social housing providers and councils have access to very cheap capital, which they can use to pay for integrated and optimised SLES solutions at lower cost than individual low carbon installations.

These low interest loans also provide opportunities for residents to gain from the systems because relatively lower returns are required by the funders.

Capital providers who are electricity market specialists are useful in providing advice on regulatory, economic and commercial aspects of SLES, as well as a long-term view of electricity. For example, a very large institutional capital financier, which specialises in electricity is reported to significant funds in asset financing for dependable returns on investment projects (*Interview 6*). With time, the more systems deployed, the more the market will be sure of a return on investments. Upscaling is needed to increase confidence and attract finance because there are no specific government backed subsidies for SLES solutions (*Interview 6*).

**Pioneers, Adopters and Users**: Good communication and marketing strategies are required to encourage adoption of SLES systems because technology uptake for research or usage depends on users; there is a risk that people will not move to heat-pumps and electric vehicles. (*Interview 2*). Delays have been reported in getting resident approval to install low carbon heating system into their houses in some of Emergent Energy's projects (*Interview 3, 8*).

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 and are motivated to look for low carbon solutions because of the drive for CO2 emissions reduction (*Interview 6, 8*). Smart and fair neighbourhoods are an attempt to create smart low carbon systems that are inclusive as possible. Historically, those who don't have assets or certain capabilities cannot participate in the market. This can be solved by developing communal assets, thereby ensuring benefits from the smart system can benefit the community in some way (*Interview 4, 9*).

## 4.6 The Grid technology pathway

The Grid technology pathway often emerges as a public funded research project or a DNO-led project, set up to meet local energy demand with recognised technological opportunities. This might include local communities with insufficient connection to the grid.

Technology seems to have its own dynamics within the Transition Map. It forms a cyclical pathway that begins with the need to solve technical issues. The start point of the pathway implies that technology is not particularly influenced by the global/national context; rather it starts at the SLES set up phase, where entrepreneurs/mavericks use their skills for experimentation and learning to solve technical problems which result in technology improvements. The pathway evolves into the technology, application and innovation dynamic of the SLES growth dynamic, resulting in cost reduction with new technology and the setting up of new infrastructure and technology. This is enabled by the technical ease of installing new technologies due to suitable technological infrastructure. Finally, the new infrastructure and technology is subject to learning from experiments and then the pathway commences again. Thus, the pathway moves in a continuous improvement loop based on two distinct cycles: removal of technical barriers and improvement in technology application and implementation.

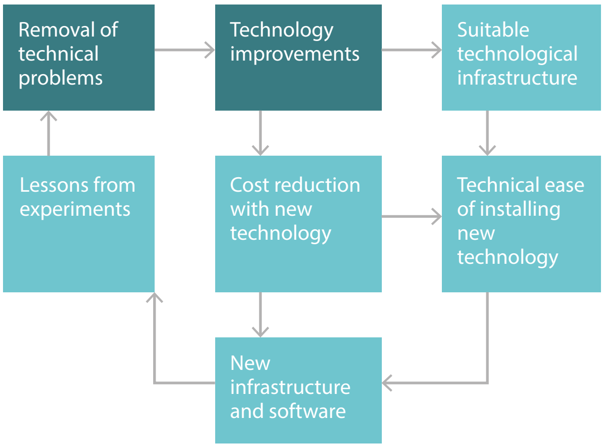


**Figure 5**: The Grid Technology Pathway.

## Real life illustration: The Mull Access Project

The Scottish and UK Governments have ambitious targets for community energy generation with 500MW planned for Scotland by 2020. Many of these are likely to be in isolated and rural areas. The Mull Access project looked to match the output from a 400kW hydro-generator with approximately 600kW of new controllable demand being installed in up to 100 homes in Mull. The project involved partners including Community Energy Scotland (CES), Mull and Iona Community Trust, SSE Energy Supply Ltd and, Element Energy. They helped to determine the feasibility of connecting locally generated intermittent renewable energy to local demand in areas where electricity export potential is constrained.

The upscaling pattern of the Mull Access project could be described as project replication because its success has led to the replication of its ideas and concept to other remote areas with similar national grid connection constraints. As a result, the flexible connection exemplified by the project is now being routinely offered.

The following observations from practitioner interviews concerning the upscaling of the Mull Access project, along with examples from other relevant cases, provide insights for upscaling.

The Mull Access Project is mapped to the grid technology pathway.

**Documenting lessons from technology improvement experiments**: 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 project. This helps to reduce risks for subsequent projects (*Interview 4*). The experience and success of the Mull Access project was well documented, with the result that the project is currently being used as a blueprint for similar network constrained areas. Likewise in the Leo project, minimal viable systems (MVS) are used to facilitate learning and dissemination. These systems capture every technical, and to a lesser extent social, dimension of a range of different technologies in different contexts. This might include the level of flexibility from a heating ventilation system, or the performance of heat pumps embedded in a local community. This is done by documenting how each of these MVS are working on multiple levels to ensure that a certain amount of energy reduction or a certain amount of energy generation is achieved (*Interview 7, 9*). This MVS approach is useful in learning more about the system and sharing lessons so they can be replicated (*Interview 9, 10*).

**Adequate planning for suitable technology infrastructure**: The Mull Access project had to install a new network monitoring system to provide a signal to export energy that was generated and transmitted locally, rather than the traditional method which would involve signals being routed via the Network Management Centre. This local signal transmission and control was easier to install than standard systems and provided increased flexibility and faster customer connection. The setting up and upscaling of SLES systems may require the planning and installation of new technology infrastructure. This is very relevant for vehicle to grid (VTG) schemes where vehicle availability; the location of the vehicles and chargers; and how many to deploy needs to be determined. Also, there is a need for flexible planning algorithms to take into account future changes in behaviour e.g., Covid-19 (*Interview 4*).

**Lack of expertise and standard procedures for SLES**: Regulation and compliance reviews force organisations and local authorities to install low-carbon technologies (*Interview 2*). However, lack of expertise and time to engage is a challenge when it comes to creating awareness of these technologies and projects at local councils (*Interview 4, 8*). A network of green technology businesses or organisations in a region will help to facilitate change. The Mull Access project was facilitated by a mix of community organisations and commercial partners. Similarly, the ESO hub project in Oxfordshire has a very good regional energy team. but that kind of network and skilled ecosystem takes decades to establish, and it will be very difficult to reproduce in other LAs. However, they can create some very transferable learning to facilitate upscaling in other locations. These might include a local authority writing a procurement guide for public charging of electric vehicles or the development of standard procedures for how to obtain permission to install a charge point in a council or tender multiple charge points (*Interview 1*).

**Cost reduction with technology integration and optimisation**: There are a several innovative ways in which technology integration and optimisation can reduce cost, improve efficiencies, and benefit the consumer. In the Mull Access project, local production and consumption were optimised by linking local controllable demand with local intermittent renewable energy generations. This avoided network reinforcement costs and reduced losses on the distribution system. Similarly, microsystems made up of Individually optimised systems which consist of integrated low carbon technologies can be built at the neighbourhood scale. A number of these systems can be connected to a piece of private wire, so they can be run as a single unit and operated as a portfolio, where they can be optimised against each other. This might involve using storage from one system to manage the solar energy in another, thus improving efficiency and creating a distributed operating architecture for an electricity market (*Interview 6*).

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*). A key aspect of these systems is that they are technology agnostic, which is an advantage so that the whole range of available or novel technologies can be utilised efficiently (*Interview 6, 8*).

**ESCOs and the supply chain**: The development of SLES needs to be underpinned by competent supply chain actors, in addition to technology providers, so that projects can be delivered effectively and meet agreed response times and guaranteed standards. (*Interview 2*). This was the case with the Mull Access project Private sector organisations such as an ESCO can provide the competences to facilitates SLES by building, operating, optimising and maintaining them and, in some cases, bringing investment to the table to offset some capital expenditure (*Interview 2, 6, 11*). 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*).

**Market structures to support technology developments**: There is the need to build market structures and policies that can respond to changes in the system. Revenue from the flexibility market can be derived through SEMS and the renewable heating incentive to make heat pumps viable in comparison to gas (*Interview 3, 8*). In addition, falling prices for key components of SLES systems such as storage batteries and electric vehicles over time will help to facilitate and improve the economics of SLES systems (*Interview 4*).

## 4.7 Context and Framework pathways

The Local community pathway is derived from the contextual phase of the Transition Map, specifically 'local conditions'. The Policy framework pathway is derived from the framework conditions phase of the map, specifically the 'policy environment'. They are examples of context and framework pathways that can influence the key pathways in the setting up and growth phases of the Transition Map. In future studies, and as the SLES sector progresses, other context and framework pathways can be described. These may include legal framework and business model pathways and technology framework pathways, which may depict specific technology pathways. The following section describes the pathways with references to their path through relevant areas of the Transition Map in *italics*.

## 4.8 The Local community context pathway

The Local community pathway describes drivers within a *local context or conditions* that can lead to the establishment of SLES. The pathway is first driven by incentives for SLES ranging from tax and financial incentives to the removal of entry barriers which are derived from the *national/regional context*. These incentives help to improve local community acceptance and promote a willingness to switch providers. This is a key driver that motivates increase in local generation, which is enabled by local investment/cooperation and a suitable local context i.e., 'favourable factors for SLES, such as available renewable energy sources and skills etc'. The preceding drivers help to build local grid management experience and eventually to result in successful SLES cases.

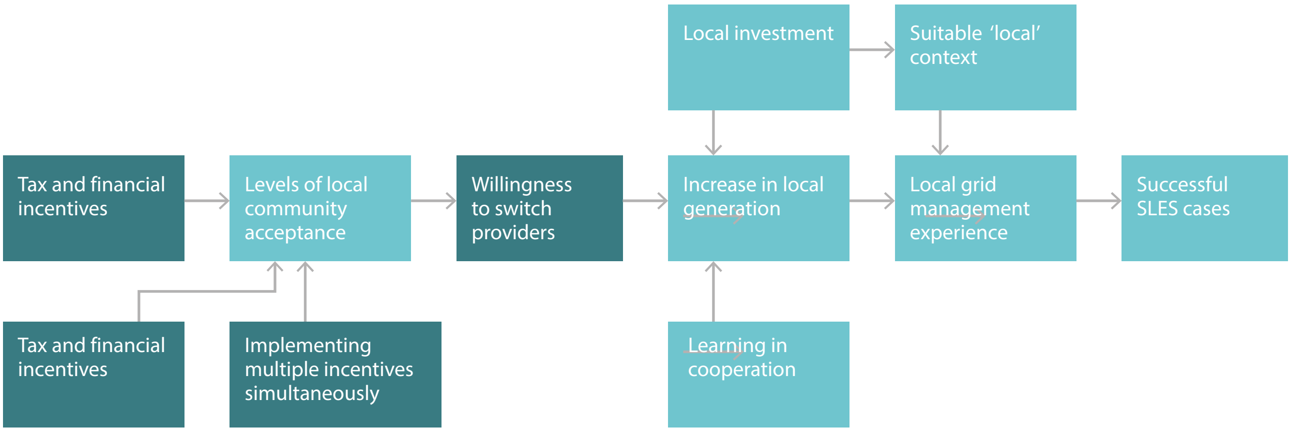


**Figure 6**: The Local Community context pathway.

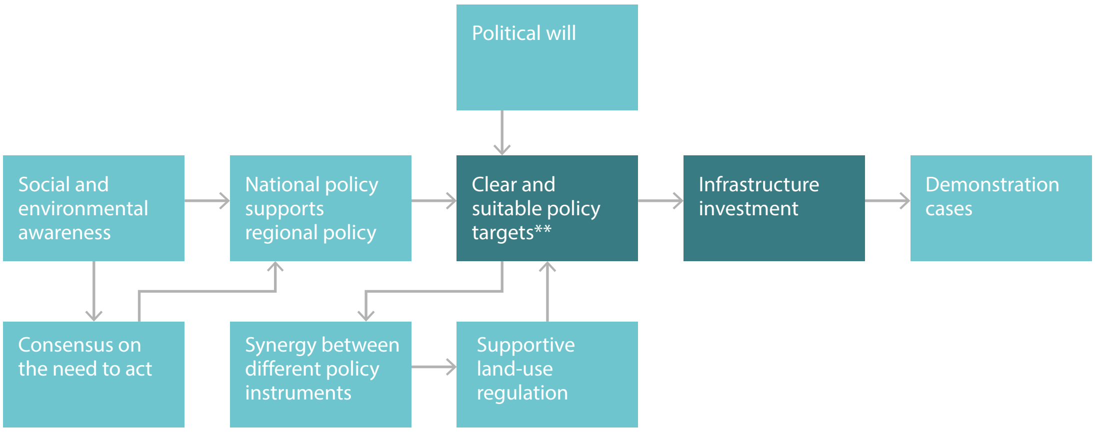


**Figure 7**: The Policy framework pathway.

## 4.9 Policy framework pathway

The Policy framework pathway describes drivers in the *policy environment* that could lead to the establishment of SLES. It commences with social and environmental awareness and the need to act in consensus from the *global and international context*. These factors facilitate the development of national policy that supports SLES regional policy. The commitment of a government to carry through a policy, synergy between different policy instruments and supportive land-use regulation all combine to help formulate clear and suitable policy targets, leading to infrastructure investment and the eventual establishment of SLES.

# 5 Summary and further analysis of pathways

In this report, we established that SLES are one of the key energy system components of the UK's Net Zero future (BEIS, 2021). However, their deployment levels are currently low, and their growth is slow. Therefore, this report presented four key pathways to the upscaling of SLES, derived from a Transition Map based on literature and reviewed by SLES practitioners and expert researchers. The four key pathways describe a sequence of drivers and enablers towards the setting up and upscaling of SLES. They are the Local authority and Case study pathways, that have particular impact on the set-up phase of SLES and the Economic competitiveness and Grid technology pathways that are particularly relevant in the growth phase of SLES.

The reported also identified other pathways from the contextual and framework phases of the Transition Map, namely the Local community context pathway and the Policy framework pathway. The following outline the results of further analysis of the pathways

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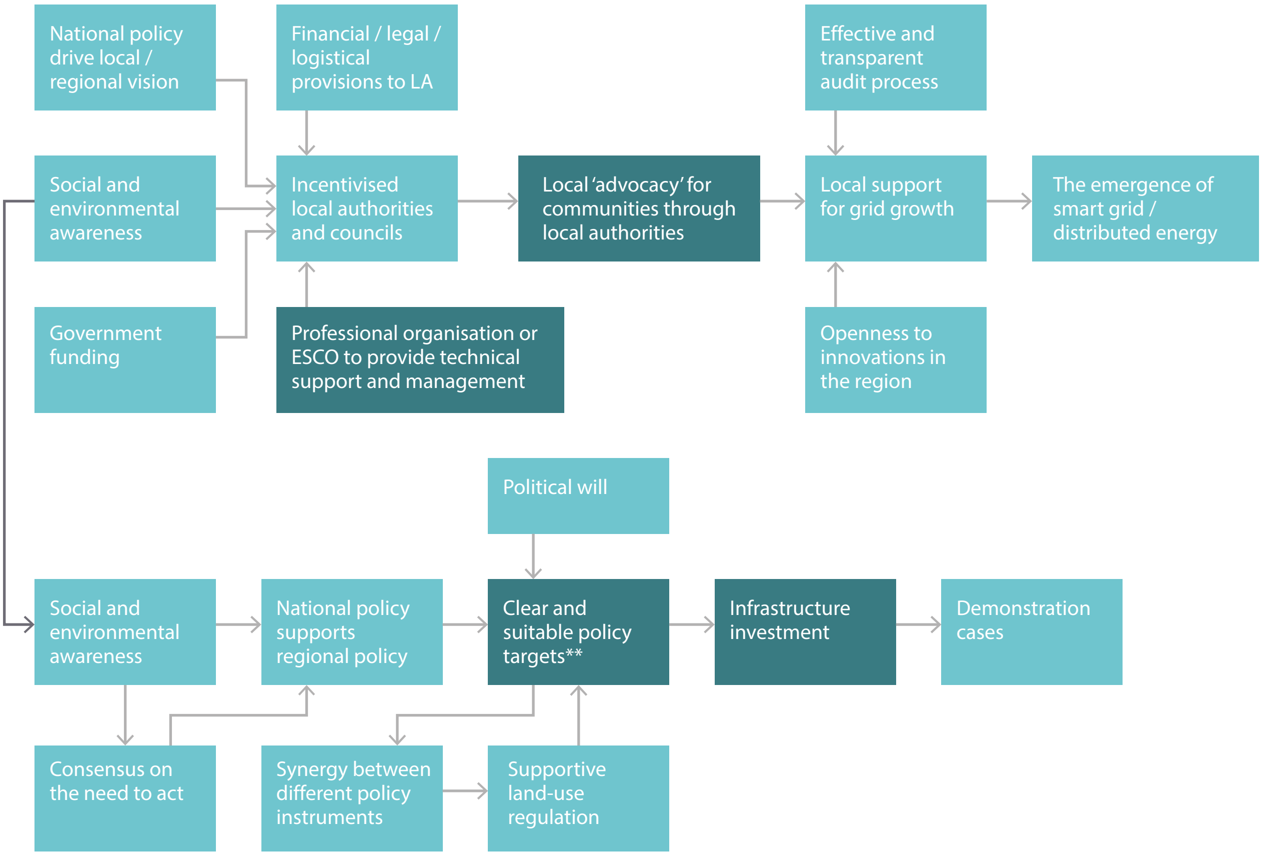
**Figure 8**: Linked key and framework pathway (Local authority key pathway and Policy framework pathway)

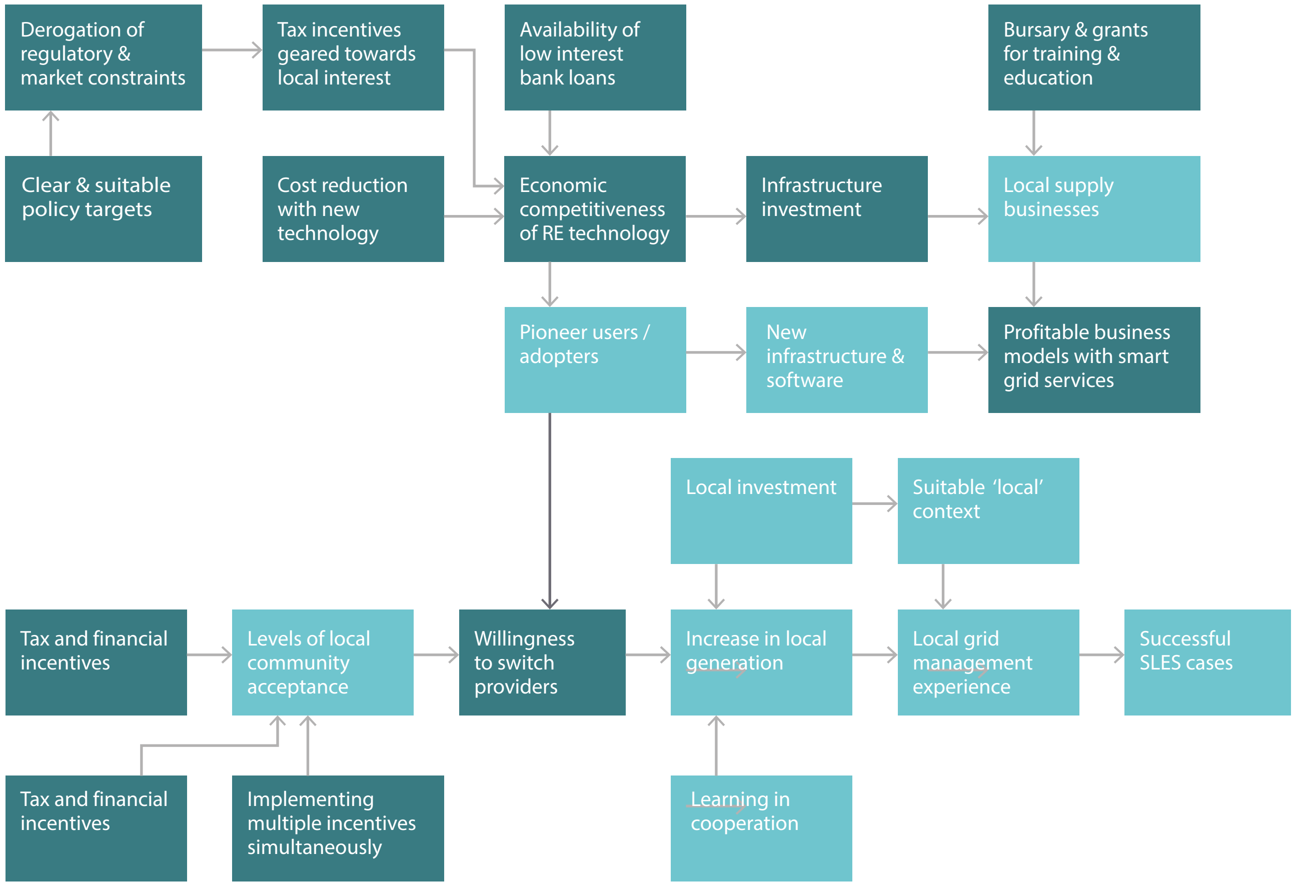


## 5.1 Linking key and framework/ context pathways

Further analysis of the pathways and real-life illustrations revealed that although the key pathways are presented as distinct, they can be linked with the context or framework pathways via drivers/enablers in the key pathway that are relevant or common to the context or framework pathways. Thus, the context and framework pathways help to represent possible underlying driver sequences relating to a policy driver or local community driver in a key pathway. For example, the Local authority pathway can be linked to the Policy framework pathway via the 'National policy driver regional/local policy' enabler and/or the 'social and environmental awareness' enablers that are common to both pathways. In this way, the policy context pathway shows a more detailed picture, featuring other important underpinning drivers such as political will, synergy between policy instruments and clear and suitable policy targets relating to the policy environment of the local authority pathway. This is shown in Fig. 8.

Similarly, the Economic competitiveness pathway can be linked to the Local community pathway through the 'willingness to switch' driver that is a key characteristic of pioneers users and adopters. It was also a key driver in the Emergent Energy case study based on the Economic competitiveness pathway. Underlying drivers or enablers in the local context that impact on the pioneer users and adopters can be revealed such as 'levels of community acceptance', 'implementing multiple incentives', 'local investment' and learning in cooperation' amongst others as shown in Figure 9.

**Figure 9**: Linked key and Context pathway (Economic competitiveness key pathway and Local community context pathway)

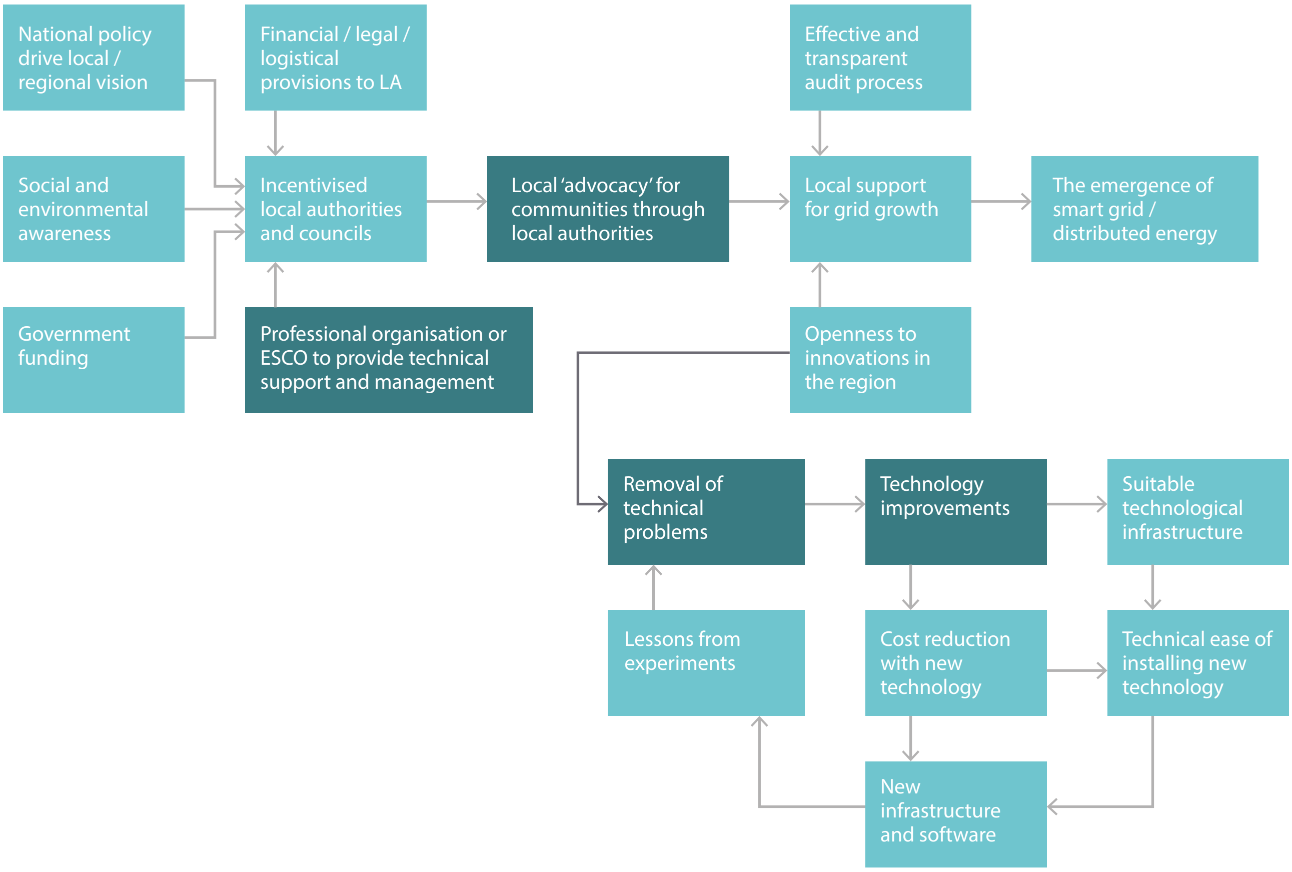


## 5.2 Hybrid key pathways

The mapping of the key pathways to the case studies also revealed that though the key pathways are presented as stand-alone, in practice they are interrelated and linked to form hybrid pathways in the set-up and growth phases of the Transition Map. For example, the Bunhill Heat and Power Network (BHPN) could be presented as a hybrid between the Local authority and the Grid technology pathways. The process of using waste heat from the underground results from an openness to innovation, and this links the Local authority pathway to the Grid technology pathway. The latter pathway is characterised by removal of technical barriers, technology improvement, application, and implementation in the use of waste heat from the underground based on the case study.

In the same way, the ProjectSCENe example which represents the Case study pathway, can be linked to aspects of the Economic competitiveness pathway via the 'improved profitability and good business case' enabler to form a hybrid Case study/Economic competitive pathway. This hybrid features drivers/ enablers such as economic competitiveness of renewable energy technology, infrastructural investment, new infrastructure/software and local supply business. These were key facilitators in the installation of the Community Energy Storage in the ProjectSCENe illustration. It can also form a hybrid 'Case study/ Grid technology' pathway via the 'lessons from experiments' driver in the Case study pathway; this is also based on the experimental development of community energy storage technology. Thus, different hybrids of the key pathways can be derived based on the evolution of a variety of case studies.

**Figure 10**: Hybrid Local authority and Grid technology pathway



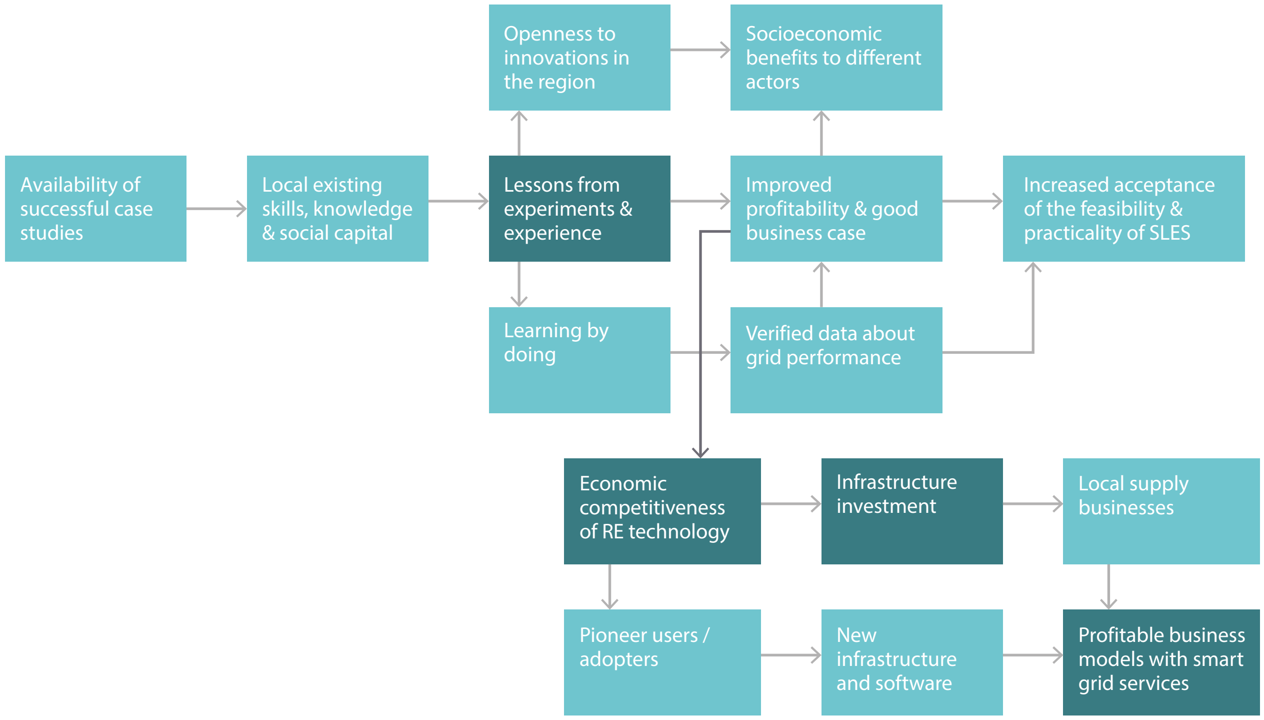


**Figure 11**: Hybrid pathway: Case study pathway and Economic competitiveness pathways

## 5.3 Future and ongoing research on the pathways

Given the diverse and emergent nature of SLES systems, future research can characterise different types of context and framework pathways such as the legal framework/ business model context pathways that describe the factors driving particular business models or legal frameworks depending on the type of SLES systems. Different technology framework pathways can also be derived based on specific technology configurations. It is possible to derive different community context and policy framework pathways as well as modified versions of the key pathways. Using the Transition Map as a base, different pathway configurations can provide templates of driver/enabler sequences for the establishment and upscaling of a variety of SLES systems. These templates can be used to map and assess SLES systems or as models for the setting up and upscaling SLES.

Research is also ongoing to create a tool in which underlying drivers and barriers of significant drivers/ enablers within the key pathways are further examined based on outputs from EnergyREV work packages and other relevant research. This will aim to provide more detailed guidance and recommendations on how to facilitate pathway progress and hence the establishment and upscaling of SLES systems.

# 6 Overarching and critical recommendations

A review of the upscaling observations of the SLES practitioners reveals that there are some overarching insights that are relevant to all the pathways and the sector in general. Other critical insights are essential to the success of each pathway or case study.

## 6.1 Overarching recommendations

- National policies such as the UK Government's Net zero target are critical drivers for the development of low carbon systems such as SLES.
- Local Authorities need statutory powers, much as they have for housing and transportation, to provide an incentive to meet carbon budgets.
- Regional governance is needed to promote transparency and accountability in the administration of the local energy systems.
- Partnership with industry partners and commercial companies are key; not just to provide skills and competences but also because income and experience obtained from SLES projects are incentives for upscaling and increasing the deployment of SLES.
- Market structures to support technology development are essential so that the sector is not heavily dependent on funding.
- Regulatory review and derogations are required to drive the viability of SLES business models.
- Adequate planning for new technology Infrastructure is key so that a lack of suitable infrastructure does not limit the growth of the sector.
- Use catalyst communities that generate social capital to achieve local support for grid growth. Community engagement activities such as online platforms and face to face meetings, where incentives, profits and benefits sharing can be discussed, are also needed to encourage support.

## 6.2 Critical Insights for each key pathway

- Local authority: local authorities need to build capability and skill in energy.
- Case study: specific funding for learning and replication must be provided for demonstrator projects so that findings can be effectively disseminated.
- Grid technology: thorough documentation of lessons learned, including both failures and successes from technology improvement experiments is essential to ensure that principles, technology and experience can be transferred to succeeding projects.
- Economic competitiveness: Economic competitiveness and cost reduction with new systems are critical for the pathway. Success cannot be limited to technological innovation.

# 7 Conclusion

This report has presented different configuration of stand-alone, linked and hybrid pathways for the upscaling of SLES. These were based on the four key pathways and two context and framework pathways derived from the Transition Map and reviewed by SLES practitioners. These configurations provide a template of possible driver/enabler sequences for the upscaling of SLES. They can serve as tools for mapping and accessing case studies or used as models for the setting-up and upscaling of SLES. Given the diverse and nascent nature of current SLES systems, future research was also proposed where different configurations of context and framework pathways, as well as modified versions of the key pathways based on the Transition Map, can be determined to provide templates for a range of viable SLES systems as the sector develops. Also, ongoing research to provide more detailed guidance and recommendations for pathway progress by examining underlying issues impacting critical drivers within the pathways was described. Finally, critical or overarching recommendations from the case studies were highlighted and discussed, so that these issues can be addressed to facilitate the deployment and upscaling of SLES.

# Appendices

## Appendix 1 Expert workshop

The workshop participants were experts and researchers from the EnergyREV consortium. The workshop was structured to implicitly follow Tuckman's earlier model of group development (Forming, Storming, Norming, Performing) with a reduced Norming stage (as the group was a one-off workshop group) and an extended reflective stage at the end. The stages were:

- Initial familiarisation with the (267) causal links
- Exploring ideas from the causal links
- Mapping the causal links into a wider set of pathways
- Review of the findings (Identification of critical nodes, subject areas and / or specific pathways)

### Expert workshop results

Overall, after a brief period of uncertainty, the group started to work on the 'stitching together' of the causal links. The initial hesitancy in trying to understand or remember the better part of 250+ causal links gave way to an initial clustering process of some of the causal links, and once the first causal links were laid on the table, it became a question of finding suitable causal links to attach, associate or filter out.

There was very little disagreement on the content of the causal links, except that a small number were not immediately understandable. This highlighted the need for extreme clarity in the descriptions in the causal links. In fact, the group had almost no disagreement on the causal links or where to place them. About three causal links were added at this stage.

The group did not really have time to discuss focal nodes, but the process was made easier after some of the causal links were collated or clustered. It seems 'where to start' was an initial issue that was reduced as time progressed, probably because it is easier to append at multiple possible places than to start an initial causal web.

The expert knowledge of the participants was probably a significant advantage at all stages, because it eased complexity during familiarisation, reduced time needed to get started and to append, and provided thoughtful reflection on the result with competence and relative speed.

The main result was a map of causal links, 150 cm high, 230 cm wide with 2/3 of the causal links being used. It is appended to this report in Appendix 2. It was subsequently reflected on and interpreted by the workshop group, as well as the researchers, who developed a more abstracted, schematic diagram of the causal links as they were placed on the workshop poster. The schematic diagram shows how the causal links coalesced into an overall dynamic of SLES development, as well as SLES upscaling.

### Interpretations and reflections

There are several sets of interpretations worth exploring, including immediate observations and the abstraction of the causal links map onto a conceptual Transition Map.

**Immediate observations**: The first set of causal links that were settled indicate a pathway where global/ regional contexts and high-level conditions for low carbon serve as initial drivers for the emergence of renewable energy (RE) at the local level as indicated below:

Knowledge and understanding of climate change ➔ Improved acceptance of Renewable Energy ➔ Growing penetration of distributed energy ➔ Opportunities for local energy management

Transitions to low carbon economy ➔ Decentralised energy generation and opportunities for community energy ➔ Regulatory stability ➔ Confidence to invest

The drive for renewable and local energy derived from the first two clusters of causal chains subject to local conditions. The two key local condition casual chains are shown below. The first set of causal links appears to be the typical benefits and economics-driven path towards SLES:

Benefits from RE ➔ Increased local investment ➔ Citizen buy in ➔ Increased local finance ➔ Greater level of community ownership ➔ Increased local RE deployment

The second set highlights local dynamics in upscaling SLES, such as local institutional frameworks that provide institutional and governance support for learning from experiences and effective dissemination, as well as developing technical expertise for maintenance and performance improvement:

Institutional support from municipality ➔ Remove barrier for RE ➔ Local /regional vision ➔ Scale up project ➔ Municipal support with resources ➔ Upscale success

Further to the drive for RE and the need for supportive local conditions the following sets of causal chains could be identified as 'unlocking chains' required to facilitate the upscaling of SLES. It is interesting to note that this consists of only financial and regulatory causal chains:

Suitable tax system ➔ Better financing of change ➔ Economic and financial incentive as part of policy package ➔ Complementary measures to reduce non-financial barriers/ mobilising private finance

Tax incentive ➔ Increased local investment ➔ Greater demand for capacity ➔ Soft loan/ small firm loans ➔ Increased local investment in low carbon

Underpinning these 'unlocking' causal chains are causal chains that indicate a favourable policy environment. It was curious to observe that there were no technology drivers in the local contexts, or the dynamics of unlocking. This implies that the role of technology is differently understood in a multidisciplinary context than in the literature. In a multidisciplinary context technology appears to have its own dynamics with subsequent loops into social, institutional or economic context, but only in a somewhat specific manner; for example, one technology change triggers economic change which then triggers social, institutional or further economic change. A pathway where a technology causal link led to, say, an economic causal link which in turn leads to another technology causal link was not found. Technology development was not an iterative reflexive process with non-technological barriers or drivers, and it seems as if technology development was not affected by local context and followed its own change logic.

By contrast, the non-technological causal links showed much greater interdependencies between domains. For instance, the 'unlocking' financial and regulatory causal chains were found to be underpinned by favourable regulatory causal chains which in turn give rise to economic or social causal chain pathways. Investments and entrepreneur casual chains were underpinned by business and legal issue casual chains. Further, investment drives skills casual chains which lead to experiments casual chains and then to innovation and benefits to technical innovation and evolution

The global/regional context and high-level conditions for low carbon deployment are preconditions and drivers for RE at the local level. These drivers are subject to local conditions which also need to go through learning processes for upscaling.

Crucially, the potential at the local level needs to be unlocked by financial (money) and regulatory factors before entrepreneurs and local investments can be activated. This also applies to skills, experiments, assets, innovation and technical evolution.

## Appendix 2 Map of Causal Links from Expert Workshop

## Appendix 3 Pathway generation workshop

The pathway generation workshop took place at the University of Surrey. Participants were recruited from the doctorate student cohort that researches the broad area of energy systems and sustainability within the Engineering Faculty of the University of Surrey. As a result, participants came from diverse disciplines, such as material engineering; systems RE systems; grid systems engineering; but also public acceptance, transition management in renewables and organisational approaches to energy sustainability.

Prior to the workshop, documents containing background information on the research, terms and definitions, as well as links to related publications, were circulated to the 16 student participants.

### Pathway generation workshop structure

The workshop took a whole day and was structured as follows:

**Research background and process presentation**: The morning session started with a presentation which provided more details on the different stages of the research so far, the workshop process and its ground rules. The participants also introduced themselves and were introduced to the EnergyREV researchers in attendance.

**Characterisation of factors**: The 16 participants were presented with a further characterisation of barriers and drivers to include hurdles and enablers as shown below:

- Barriers (Definite obstacle)
- Hurdles (Difficulty but not impossible to overcome)
- Enablers (Can, under certain conditions, support change)
- Drivers (Definite catalyst or force for change)

**Please see page 11 for the full description.**

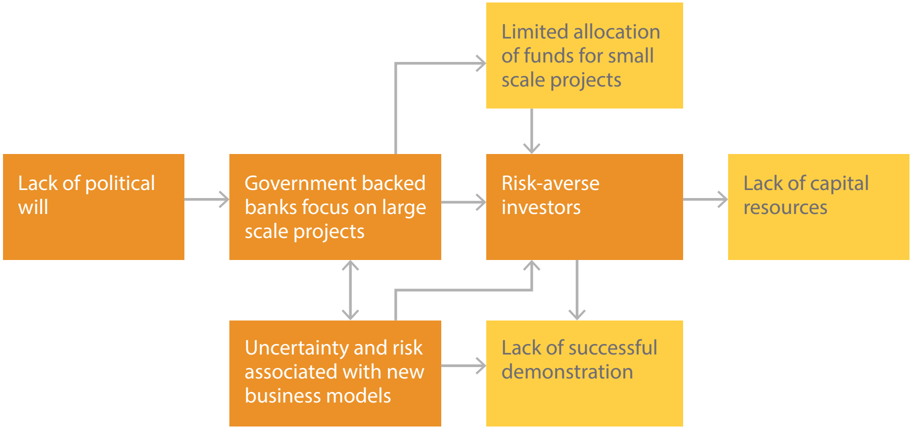
The separation of "Drivers and Barriers" into four groups followed the pre-workshop recognition that sometimes barriers can be converted into drivers and sometimes barriers are insurmountable obstacles so that a single term would not be accurate enough. A similar argument has been made about 'drivers'. The widening into four categories also allowed a language differentiation between a barrier that is simply the absence of a driver (and vice versa), which should be distinct from a barrier that is most certainly a barrier in its own right.

**Familiarisation**: The participants were divided into two groups of eight each, labelled the barrier and driver groups. Each group was presented with a total of 187 factors to familiarise themselves with. These consisted of drivers in deep green, enablers in light green, barriers in deep red and hurdles in light red. The factors were also given unique numbers to help with identification and subsequent analysis. Afterwards, the driver group were asked to identify drivers/enablers and separate them from the barriers/hurdles and the barriers group were asked to do the same i.e. identify barriers/hurdles and then separate drivers/enablers.

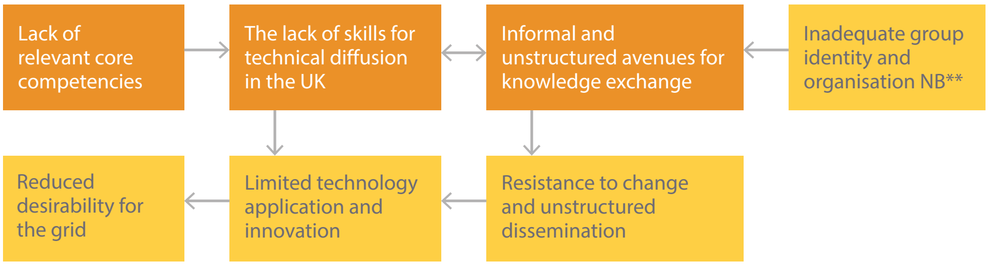
- **Placing the factors**: Each group was asked to discuss and position their factors in the phases of the Transition Map. They were also asked to identify key factors within the map. After they finished the task, they were asked to 'visit' the other group leaving one person in each group to explain their results.
- **Deriving pathways**: In the afternoon session, participants were re-grouped into four groups consisting of two barrier groups and two driver groups. Each group was provided with a print-out of the Transitions Map which showed the placement of the barriers and drivers in the morning session. They were then asked to discuss among themselves and link the factors in order to derive plausible pathways towards upscaling starting and ending from different points in the map.
- **Presenting the pathway findings**: Each group subsequently presented their pathways to the other groups and responded to questions in plenary.

# Appendix 4: Barrier pathways

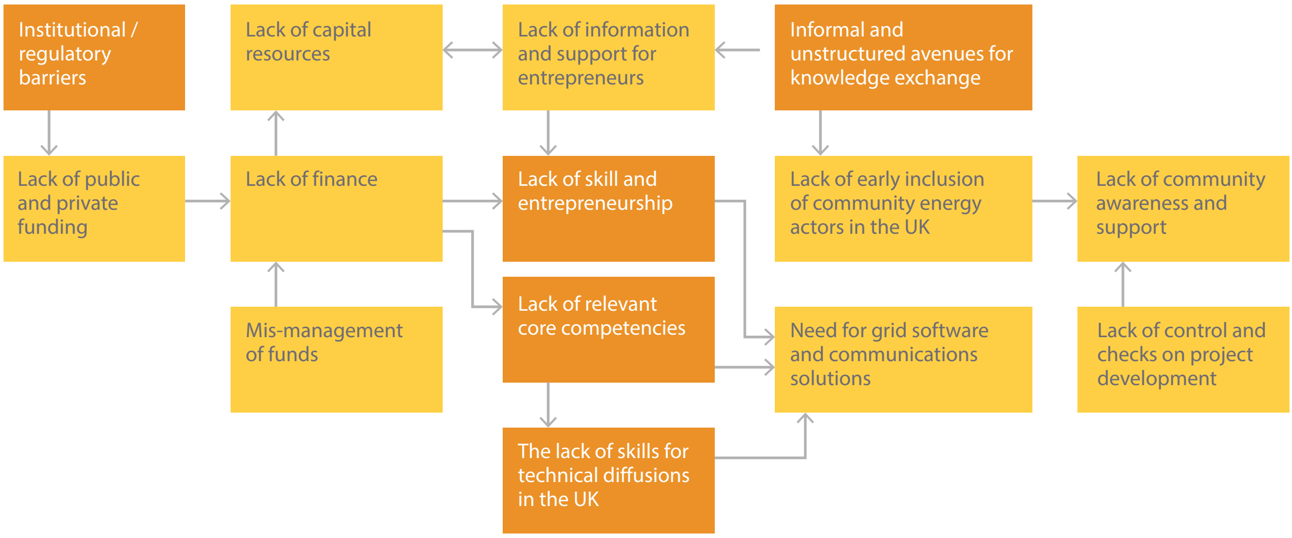
## Public investment uncertainty



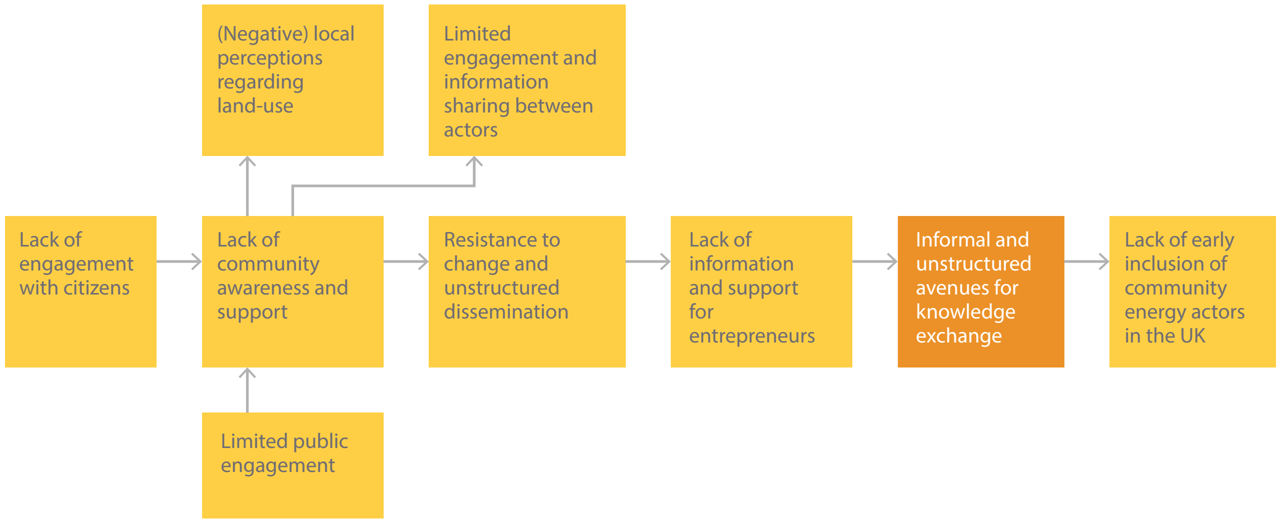
## Unstructured technical/skills dissemination



## Lack of financial pathway



Limited citizen engagement



## Appendix 5 List of Interviewees (function, organisation in alphabetical order)

- Chair of Energy Capital and the Regional Energy Systems Operator project.
- Consultant, Scottish and Southern Electricity Network (SSEN) (Mull Access project).
- Consumer Engagement Consultant; Vital Energy
- Energy, Infrastructure & Services Manager, Zero Carbon Rugeley SLES Project Lead
- Founder of an Energy System's Company and Consultant with Local Energy Oxfordshire (LEO)
- Founder of Emergent Energy
- Project Manager; Energy Systems Greater London Authority (Bunhill Power and Heat Network
- Project Officer, Orkney Local Authority; Consultant, Community Energy Scotland; Consultant Aquatera; Consultant, Solo Energy, Project Manager; Responsive Flexibility (REFLEX).
- Researcher, Creative Homes/ ProjectScene, University of Nottingham
- Researcher, Energy Superhub Oxford (ESO); Researcher, Energy Superhub Oxford (ESO).
- Researcher, Local Energy Oxfordshire (LEO); Researcher, Local Energy Oxfordshire (LEO)

## Appendix 6 Guide Interview questions

1. What is your position and function in your company in relation to local energy systems?
2. How did your system come about? Can you give a brief history of how it began and what were the significant steps to its success?

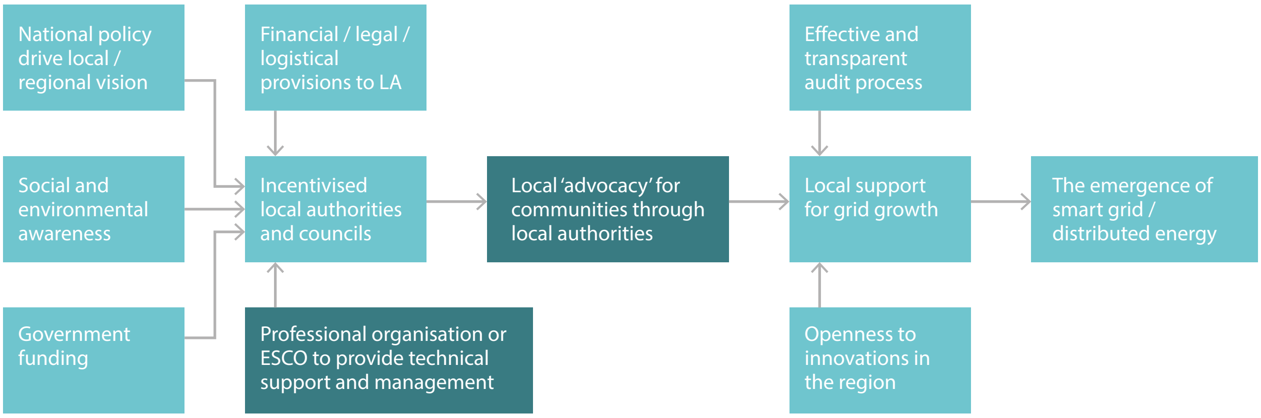
   Is your local energy system 'Smart' (i.e., using information and communication technologies (ICT) to provide real time data, or using automation and self-regulating features that are dynamic or other features adapted to provide optimal services based on customer's preferences)?

   From your experience what are the major drivers in **setting up** a (Local Energy System (LES) or a Smart Local Energy System (SLES)?
3. Which driver is the most important one?
4. What are the main barriers?
5. Who were the main actors in the establishment of your local energy system? Which actors are the most important in the decision to establish your local energy system?
6. If you have **upscaled** your system in the last three years or so, how did you do this? (*Upscaling means a growth of the SLES or LES, in output, in capability or in the range of assets. It can also mean copying of a system elsewhere*).

7. What are the critical drivers and barriers for the upscaling of your local energy system? Please indicate any contextual/case specific advantages or problems that limited or facilitated setting up and/or upscaling of your SLES or LES
8. Who are the main factors that influence upscaling and which actors can hamper progress?
9. Could you give an example on how you overcome a critical barrier or how you enhanced a particular driver when setting up and upscaling your system?
10. What lessons for the growth of SLES do you think you can pass on to others who want to set up a SLES or LES?

THANK YOU!

## Appendix 7 An example of the pathway evaluation question template



### The Local authority pathway

The pathway is typically set up by a 'local authority'. Social/environmental awareness and International/national policy translates to local institutional priorities and preferences.

Government funding, technical, management, financial and ESCO support facilitate the initial set up.

Pathway progress is facilitated by support from the local authority to meet community sustainability concerns. This in turn facilitates local community support for SLES.

Openness to innovation then gives rise to systems innovations and hence the emergence of the Smart grid.

**Do you recognise this pathway in your case study/ experience of SLES? If so, please continue with the questions. If not, please move to the next pathway.**

Please can you identify and state the drivers in this pathway that were important in your case study?

Which drivers in this pathway were not significant or completely absent from your case study?

What other drivers may be missing in this pathway that was significant in yours?

Please can you provide a brief description of the role of the important drivers you identified in the (i) setting up or (ii) upscaling the SLES in your case study?

Please indicate any contextual/case specific problems or advantages concerning each important driver or the SLES as a whole, that limited or facilitated setting up and/or upscaling.

Please can you indicate key actors and their role in this pathway based on your case study.

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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.

**ISBN: 978-1-914241-22-2**

EnergyREV is funded by UK Research and Innovation, grant number EP/S031863/1