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Prospering from the Energy Revolution

Smart local energy systems: lessons for innovators

This report collates experiences and learning from across the demonstrator and detailed design projects in the Prospering from the Energy Revolution programme.

It aims to provide a valuable resource for innovators developing new and existing smart local energy systems.

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Prospering from the Energy Revolution

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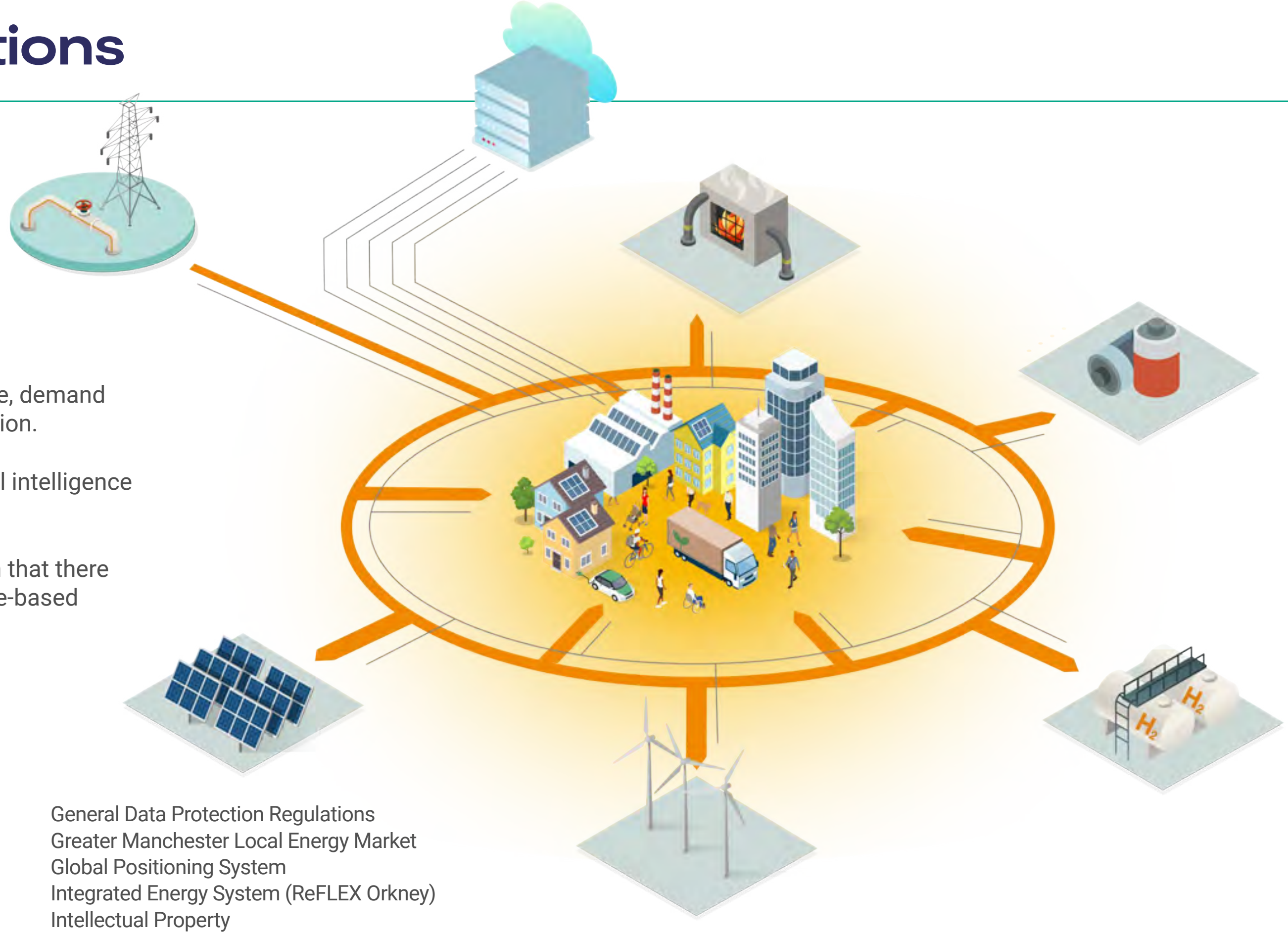
Content

Acronyms and abbreviations



Smart local energy systems

A smart local energy system brings together energy supply, storage, demand and infrastructure, at a local level such as within a town, city or region.

All these elements are connected together using software, artificial intelligence and digital energy platforms.

The Prospering from the Energy Revolution programme has shown that there are potentially major gains to be had by widely adopting such place-based approaches to energy, alongside national systems.

ANM	Active Network Management
API	Application Programming Interface
BEIS	UK Government Department for Business Energy and Industrial Strategy
BEV	Battery Electric Vehicle
CCS	Carbon Capture and Storage
CFES	Coventry Future Energy Scenarios (Project RESO)
DCR	Dynamic Containment Reserve
DER	Distributed Energy Resources
DERMS	Distributed Energy Resource Management System
DFES	Distribution Future Energy Scenarios
DNO	Distribution Network Operator
DSO	Distribution System Operator
ECO	Energy Company Obligation
EIZ	Energy Innovation Zone
EPC	Energy Performance Certificate
ESO	Energy Superhub Oxford
EV	Electric Vehicle
FCA	Financial Conduct Authority
FES	Future Energy Scenarios
FFR	Firm Frequency Response
FIT	Feed in Tariffs
FSO	Future System Operator
GDPR	General Data Protection Regulations
GM LEM	Greater Manchester Local Energy Market
GPS	Global Positioning System
IES	Integrated Energy System (ReFLEX Orkney)
IP	Intellectual Property
I-SEM	Integrated Single Electricity Market for the Island of Ireland
LAEP	Local Area Energy Plan
LEM	Local Energy Market
LEMAP	Local Energy Mapping approach (Project LEO)
LEMO	Local Energy Market Operators (GM LEM)
LEO	Local Energy Oxfordshire
LEX	Liverpool Energy Exchange (LMEX)
LMEX	Liverpool Multi-Vector Energy Exchange
LNG	Liquified Natural Gas
LPA	Local Planning Authority
MH:EK	Milford Haven Energy Kingdom
MVS	Minimum Viable System approach (Project LEO)
MW	Mega Watts
NDRHI	Non Domestic Renewable Heat Incentive
NGESO	National Grid Electricity System Operator
NMF	Neutral Market Facilitator (Project LEO)
NPV	Net Present Value
OLEV	Office for Low Emission Vehicles
PARIS	Predictable Analytical Renewable Integration System (GIRONA)
PDL	Physical Design Lab (LMEX)
PfER	Prospering from the Energy Revolution
PIRI	Peterborough Integrated Renewable Infrastructure
PV	Photovoltaic
RAG Rated	Red, Amber, Green Rated
REMeDY	Spearheading a Revolution in Energy Market Design
RESO	Regional Energy System Operator
RHI	Renewable Heat Incentive
ROC	Renewable Obligation Certificate
SLES	Smart Local Energy System
SMETS2	Smart Meter Technical Specification 2
SNC	Smart Network Controller (LMEX)
STEM	Science Technology Engineering and Mathematics
TRL	Technology Readiness Level
VPP	Virtual Power Plant
ZCR	Zero Carbon Rugeley

A summary of learnings from 14 demonstrator and detailed design projects.

Project locations

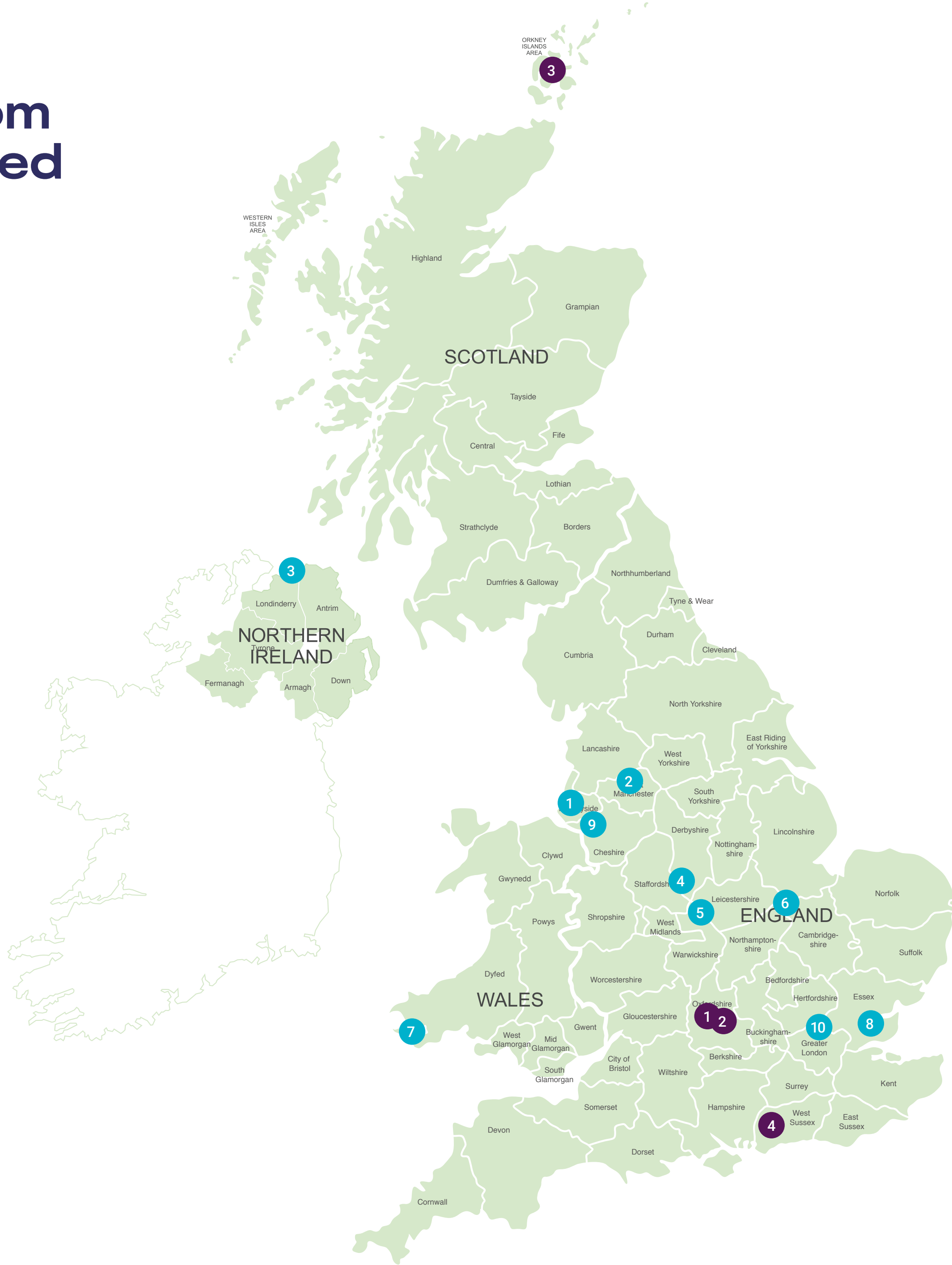
Indicative only

Demonstrators

1. Project LEO
2. Energy Superhub Oxford (ESO)
3. ReFLEX Orkney
4. SmartHubs

Detailed designs

1. Liverpool Multi-Vector Energy Exchange
2. Greater Manchester Local Energy Market
3. Project Girona
4. Zero Carbon Rugeley
5. West Midlands RESO
6. Peterborough Integrated Renewables Infrastructure (PIRI)
7. Milford Haven: Energy Kingdom
8. Project REMeDY
9. REWIRE-NW
10. GreenSCIES 2



Click a project name to go to the relevant page. Each project page has a link back to this map.

Introduction

For much of the modern history of the UK the focus on our energy system has been a national one. Decarbonisation is changing that mindset. The growth in renewable generation to supply electricity, the increasing importance of decarbonising heat and transport, and the potential for hydrogen mean that a more regional and local focus is needed to complement that national emphasis. This is also important beyond the energy system: social outcomes such as ensuring fair and affordable access to energy, and economic ones such as realising the industrial and commercial strengths of each region, require a more nuanced, place-based approach to energy.

The development of smart local energy systems, embedded in both the technicalities of modern energy and digital infrastructure and in the importance of placemaking, needs to be at the heart of the future energy system. Delivering pioneering local energy projects today is not easy. Policy, regulatory, investment models and skill bases tend to reinforce a national mindset and none are currently set up to support a move to 'local'. However, demonstrating an integrated place-based approach is important as it provides us with evidence of what can work and what might not and where the biggest benefits and the most challenging barriers are likely to be. It also shows the art of what is possible and supports the development of a wider place-based vision where smart local and smart national systems work effectively together.

This report contains summaries of learning and experience from 14 pioneering projects carried out as part of the Prospering from the Energy Revolution challenge, funded by UKRI and delivered by Innovate UK. It summarises what each of the projects has achieved, the barriers it has faced and the key points that its partners and stakeholders have learnt. It can provide a starting point for the next generation of innovation projects and act as a launch pad to help new smart local energy ventures to stand on the shoulders of those have already explored the landscape and identified some of the pathways to success.

About Prospering from the Energy Revolution

The programme was launched in 2018 with a commitment of £104 milion to demonstrate integrated intelligent local energy systems. Its objectives are:

- By 2023, to prove investable, scalable local business models using integrated approaches to deliver cleaner, cheaper energy services in more prosperous and resilient communities that also serve to benefit the energy system as a whole.
- To unlock ten times future-investment in local integrated energy systems versus business as usual in the 2020s.
- To create real world proving grounds to accelerate new products and services to full commercialisation.
- To build UK leadership in integrated energy provision.

To deliver these objectives the programme has funded over 80 projects across six streams. At the heart of the programme are ten detailed design projects and three (originally four) full-scale demonstration projects. The detailed designs have each looked at developing a smart local energy system design embedded in a particular place and in the process created investable propositions for future businesses, public investments, and community organisations.

As such, the detailed design projects have delivered three things: a kick start to local integrated energy system planning; replicable models which can be used and adapted in other towns, cities and regions; and important learning about the practicality of delivering real-world projects embedded within communities and places.

The demonstration projects have had the opportunity to go further and deliver key elements of smart local energy systems into operation. Successes include Europe's most powerful EV charging hub developed and connected to the electricity transmission network through the **ESO project** in Oxfordshire, demonstration of a local flexibility market, which facilitates local and community-level assets to support and benefit from an efficient electricity distribution network through **Project LEO**, and smart EV charging to reduce the curtailment of wind generation through the **ReFLEX Orkney** project.

Common threads

The learning from these projects highlights the complexity involved in delivering smart local energy systems. An effective, integrated local energy system will include a wide range of technologies working cooperatively across multiple energy vectors to deliver numerous outcomes. It will require significant and usually automated communication between different elements of the system and management of significant quantities of diverse data. Most importantly it will interact with a wide range of stakeholders each with their own objectives, capabilities and values.

Previous generations of energy innovation have tended to focus on technological innovation such as the development of new battery technology, or the control algorithm in a vehicle-to-grid charger to manage local network constraints. Although technical innovation have had an important place in this programme's portfolio, it is striking the degree to which innovation and learning has moved towards other elements needed for a successful smart local energy system. These include the development of novel business models, the importance of investment frameworks to leverage public and private finance, the growing importance of data, and the expansion of our concept of value.

Business models and finance

An example of business model innovation is seen in learning from projects such as **PIRI**, **REMeDY**, and **GreenSCIES** which focus on how to structure business models based around heat networks. These projects have focused on bringing together relatively mature individual technologies such as photovoltaics and heat pumps, incorporating them into original system designs. On their own we understand the engineering of each technology and we understand their economics sufficiently well that stand-alone projects can secure investment in the right circumstances. The projects have added to this evidence base by identifying the characteristics of a good integrated heat network business model. For example, they teach us about the need to consider the costs and benefits associated with investing in communal heating for each stakeholder in a building's lifecycle, from developer to tenant. They teach the limits to what is possible within the terms of today's regulatory framework, such as when to connect the electricity elements of the system behind the meter in order to fit within the rules governing distribution and supply. And we learn about the importance of designing in flexibility in terms of the source of heat, allowing the energy system to adapt and grow over an investment lifetime that can run to several decades.

Related to business models is the question of investment. Work by PWC suggests that we need £58 billion of investment in our energy system to meet the Sixth Carbon Budget using a placed based approach (£195 billion if a place agnostic approach is taken)[1]. Given the scale of investment required, and the compressed timeline associated with the challenge, this must be a joint endeavour between the public and private sectors.

Several projects have tackled the investment question directly. The **LMEX** project involves partners from the investment community and highlights that there is significant appetite for investment in local energy infrastructure but that local energy projects often don't have the characteristics needed to attract investors; they can often be too small, too bespoke and too risky.

Other projects have looked at how to overcome this challenge and to develop better investment structures which can combine public and private funding more effectively. For example, **RESO** and **Zero Carbon Rugeley** have explored a financing framework which can support the development of standardised investable propositions for the private sector. **RESO** along with **PIRI** also identify the potential to package project elements for investment in a way that combines more complex elements likely to deliver lower returns with simpler, higher return components. Packaging in this way can ensure that investors and developers don't cherry pick the easiest projects whilst leaving the hardest to others.

Modernising energy data

Another area of significant innovation is data. Building on the work of the Modernising Energy Data Taskforce, projects such as **MH:EK** and **REWIRE-NW** have identified the importance of data standardisation, both within projects and in terms of open standards applied across the sector. The challenges of data privacy and management have been keenly felt. **Project ReFLEX**, operating in the small rural Island community of Orkney, commented that personally knowing many of your data subjects made the sometime-abstract rules around data 'real'. It drove the project to go further in transparency of data processing whilst still ensuring data could be used to drive the integrated energy system they were developing.

Several projects have also identified the value of the data that local energy systems will themselves create. **GM LEM** for example has built the value of data derived from their local energy market directly into their business proposition. They pinpointed the potential to use data associated with market participants' behaviour as a source of commercial value and also as a public-sector resource supporting effective local planning.

Broadening our concept of value

Many projects have made estimates of financial value through net present value calculations. However, several have also looked to extend the concept of smart local value beyond the financial sphere. **Project LEO** places significant focus on understanding the community and social value identifying four areas: planet, people, prosperity and perception. It concludes that there is value from energy flexibility for all stakeholders, however this value is multidimensional and nuanced. Other projects identify a major part of their legacy as supporting solutions to wider social challenges. **Project Girona** for example has deployed its smart network in an area where the prevalence of fuel poverty (even before the energy price crisis) was around 30%. In realising these wider value streams it can be important to recognise the uniqueness of the community within which the system is embedded. For example, the **Zero Carbon Rugeley** project highlights the importance of understanding a community's heritage, in their case a heritage of energy innovation stretching back to at least the beginning of the industrial revolution. Understanding the importance of non-financial value streams, and finding place-specific ways to realise them, is a core part of smart local energy systems' role in delivering decarbonisation and a smooth transition.

Regulation and policy

Many of the projects have collated clear sets of recommendations for policy and regulatory change at national and local levels with UKRI has commissioned work to draw that together. A consistent and overarching point raised is the centralised, national mindset that the current UK energy policy takes and the tendency to compartmentalise energy into different vectors, sectors and scales rather than support the cross-scale and cross-vector development inherent. In addition to energy-specific regulations, projects identify the current design of consumer protection and financial service regulations as barriers to some plans.

Regarding future projects, the message of the Prospering from the Energy Revolution programme is clear: there are real, unavoidable regulatory and policy barriers to certain smart local system designs. In the short and medium-term, new projects need to start with an understanding of what is possible and what is not, and for the longer term, they need to add their voices to the call for change.

Where next for smart local energy systems?

In summary, the learning from the Prospering from the Energy Revolution programme forms a stock of knowledge and experience, developed through a do-and-learn approach, on which future projects are being developed. It shows us that the technology and investment appetite to deliver smart local energy successfully exists. However, innovation is still needed to find ways of knitting elements together with local place-based ambition in a way that supports everyone.

It isn't just innovators who need to learn these lessons; decision-makers within the institutions that frame our energy system must understand the evidence. Part of this evidence base comes from synthesising and summarising experiences that are shared across projects. Another part comes from engaging with the experiences of individual projects, such as the 129 key learning points identified in this report.

Both generalised conclusions and project-specific experience are essential in helping to ensure that frameworks evolve to become more supportive of delivering smart local energy systems in practice. Innovation funders should also reflect on the experience of individual projects. All the projects reviewed here have delivered meaningful outcomes, but in many cases, those outcomes are significantly different from those initially proposed. This is because the real barriers to delivery, and the innovative solutions to overcome them, often become apparent only when an approach is tried in practice. Funders need to take an active approach that is sufficiently flexible to enable innovation throughout a project. Funding, as well as the innovation itself, needs to evolve.

Other learning from the Prospering from the Energy Revolution programme

This deeper learning review is one part of a wider programme of capturing learning from the portfolio. Whilst this work focuses on project-by-project cataloguing of key lessons to inform future projects, other work includes:

- **Enabling Decentralised Energy Innovation:** reviewing the barriers and potential solutions that will enable decentralised energy to play a full role in decarbonisation, innovation, and delivering positive outcomes for citizens and communities. https://www.ukri.org/publications/enabling-decentralised-energy-innovation/

- **Insight briefs:** short briefings on key messages from the programme covering finance and investment (https://www.ukri.org/publications smart-local-energy-systems-finance and investment/), policy and regulation (https://www.ukri.org/publications/smart-local energy-systems-policy-and regulations/), skills and capabilities (skills and capabilities" to this address: https://www.ukri.org/publications/smart-local-energy-systems-skills-and capabilities/) and an overarching insights summary report.

- **Accelerating Net Zero Delivery:** explores local climate action's strategic and economic potential, focusing specifically on buildings and transport and estimating the social costs and benefits of adopting place-based instead of place-agnostic approaches to decarbonisation. https://www.ukri.org/publications/accelerating-net-zero-delivery/

- **Reports by ERIS, the Energy Revolution Integration Service provided by the Energy Systems Catapult:** reviewing the overarching value of smart local energy (https:/ es.catapult.org.uk/report why-smart-local-energy-systems/) including impacts on bills and greenhouse gas emissions (https://es.catapult.org.uk/report/bills-and-carbon impact-of-smart-local energy-systems/), and public awareness and appeal of smart local energy systems (https://es.catapult.org.uk/report/public-awareness-and-appeal of-smart-local-energy systems/).

- **EnergyRev:** output from a consortium of more than 60 researchers at over 22 universities working together to provide research and innovation support across the programme. https://www.energyrev.org.uk/

- **IPSOS Mori evaluations:** reports reviewing the success of the Prospering from the Energy Revolution programme at delivering its overall aims and ambitions.

- **Project Summaries:** one-page summaries of the achievements and learning from each project.

What makes up a review?

This report presents an overview of the achievements and learning from each project. It uses a standard format in order to ensure a consistent approach. The following bullets describe the main sections used for each review.

- **Project summary**
- **Objectives**
- **Key project elements**
- **What have been the successes? What has been delivered?**
- **What have been the barriers? What impacts have they had?**
- **Key learning:**

  The key learning points have been broken out into seven areas. Each review includes points in several of the areas below and each is tied to a project element.

  - Technical: covering aspects of operation and design of infrastructure including how different components physically link to the wider energy and digital systems.
  - Regulatory and policy: including national, regional and local policy making, direct energy-sector regulation and other important areas of regulation such as consumer protection and financial services.
  - Business models and business practices: including examples of viable and non viable business models, challenges around the type and level of expertise needed to deliver smart local energy projects, and the links needed between different types of organisation including public and private sector.
  - Finance and investment: learning specifically about the development of finance for smart local energy, including both public and private investment models and, importantly, the interaction of the two.
  - Social and community: includes areas of learning related to the wider social benefits and enables of smart local energy systems, how to engage communities and the value that comes from good engagement, and understanding non-financial costs and benefits.
  - Carbon: smart local energy systems will play a major part in decarbonising our energy system. This area includes important learnings about how to measure and quantify carbon savings, and how smart local energy can support decarbonisation of challenging sectors.
  - Data: learning related to how to manage data effectively, the value of good data to projects themselves, and the potential to use data to maximise the wider value of smart local energy.
- **Who is prospering?**
- **More information**

Smart local energy systems: lessons for innovators

Demonstration projects

Demonstration project

Energy Superhub Oxford (ESO)

Europe's most powerful charging hub was installed in Oxford as part of the ESO project.

Project summary

The Energy Superhub Oxford (ESO) project is a holistic, wide-ranging smart grid trial. It has explored the interface between the national and local energy systems and the value of battery storage and private wire in linking the two. ESO has connected a large scale hybrid battery and the UK's most powerful EV charging site directly to the electricity transmission network using an innovative connection design and operating model. The battery has delivered significant value by providing ancillary services to national grid whilst the EV charging hub brings together multiple charge point providers in a single integrated location.

The project has also initiated the process of electrifying the council's vehicle fleet and the city's black cab taxis and developed the network infrastructure to facilitate the electrification of a major bus fleet. Ground source heat pumps have been installed in social housing properties increasing comfort and reducing bills for tenants while trialling innovative load-shifting through smart controls and time of use tariffs.

Original objectives	1. Eliminate 10,000 tonnes of CO_2 emissions each year, rising to 25,000 tonnes by 2032. 2. Deliver a transmission connected smart local energy system project including battery storage, EV charging, and heat. 3. Demonstrate trading and optimisation of energy and services across all components.

Key project elements

- **Hybrid battery:** A 52 megawatts (MW) hybrid lithium-ion and vanadium redox flow battery connected directly to the UK transmission network.

- **EV superhub:** Europe's most powerful EV charging hub at Redbridge Park and Ride with 42 fast and ultra-rapid chargers operational and the capacity to expand to up to 10 MW of charging capacity. The superhub is directly connected to the electricity transmission network via a 7 kilometre (KM) private wire.

- **EV fleets:** Electrification of 40 of Oxford City Council's vehicle fleet including cars, vans, tippers, sweepers and a fully electric refuse vehicle. Supported the uptake of 22 electric taxis and has provided connection capacity which will enable the Oxford Bus Company to fully decarbonise up to 104 buses, with potential for a further 55.

- **Heat:** Decarbonisation of domestic heat in 57 social housing properties with shared array ground source heat pumps and exploration of flexibility and the impact on users. Installation and testing of a further five ground source heat pumps with integrated phase change heat batteries.

What have been the successes? What has been delivered?

1. Hybrid battery connected directly to the transmission network and operational.

This represents the first battery directly connected to the UK system transmission and is the first example of an innovative technical connection design known as a tertiary connection to export energy to the transmission network. This has opened up the market for this type of connection and has been strongly supported by National Grid.

2. Significant carbon savings achieved from operation of the lithium-ion battery scheduled with the trading and optimisation algorithm.

This component of the hybrid battery began operating in June 2021. We estimate it to have saved approximately 38,000 tonnes of carbon by replacing gas power stations in provision of frequency response, allowing those gas stations to operate more efficiently.

3. EV superhub completed with 11,822 charging sessions in the first five full calendar months of operation and delivery of 420 megawatt hours (MWh) of energy.

Delivering the project involved coordinating multiple, complex components, including the private wire linking the site to the transmission networks; coordinating with the wider master-plan for the park and ride facilities and developing a model of ownership and operation of electrical infrastructure across Oxford City Council; and three separate charge point providers.

4. Significant electric taxi uptake.

ESO supported the 22 taxis from Oxford's 107 black cabs fleet to transition to electric models.

5. Flexibility to capitalise on emerging opportunity and support electrification of a major bus fleet.

The project has delivered a substation at the site of the Oxford Bus Company's depot which will enable electrification of up to 104 buses in the city, with the potential for a further 55 at the Stagecoach depot.

> "Oxford has a history of being ambitious as we look to adopt new and exciting transport approaches … to achieve a Zero Carbon Oxford by 2040 we need to encourage uptake in electric vehicles, and drivers want to know that they can charge their vehicles quickly and efficiently. The completion of Energy Superhub Oxford is an exciting step for our city and the future of EV charging."
>
> **Councillor Imogen Thomas, Cabinet Member for Zero Carbon Oxford and Climate Justice, Oxford City Council**

What have been the barriers? What impacts have they had?

1. Ofgem targeted charging review.

Starting in 2017, Ofgem reviewed arrangements for how the electricity network cost would be recovered from consumers, generators and flexibility providers. Ofgem's draft decision would have significantly increased charges for smaller-scale transmission-connected projects such as ESO and would have jeopardised the continuation of the project and the broader model.

Outcome: ESO, as a pioneering project directly affected by the proposed changes, was able to provide evidence to Ofgem, BEIS and others to highlight the impact that the proposed changes would have on the ability to efficiently use transmission connections for projects on the scale of tens of megawatts. This supported wider efforts from across PfER and other SLES projects to influence Ofgem to reconsider its proposed approach. The final decision moved to a tiered approach for demand transmission charges allowing small transmission-connected demand projects to develop. Whilst not ideal, this allows the model to work at this stage.

2. Lack of clarity around EV fleets in terms of current operation and future plans.

Initial phases of the project led to a growing understanding of the current operation and structure of Oxford City Council's vehicle fleet and allowed the council to review future strategies. This led to changes in priority in the council which didn't align with other aspects of the ESO project, notably plans to connect a major vehicle depot to the private wire network.

Outcome: Connection of the council's depot to the private wire and the ability to co-optimise of charging for the council's EV fleet along with the battery through the optimisation and trading engine were de-scoped.

3. Characteristics of heat supply and heat demand.

Initial plans had been to use the optimisation and trading engine to optimise the heating aspect of the project. Due to differences in power scale and risk for tenants, this was changed at the very beginning, with Kensa providing the optimisation. The potential to use excess heat from the hybrid battery, which would have been transported to domestic customers via a heat network, was explored. Early in the project, it was identified that this would be economically challenging due to the distance between the battery and customer heat load, and costs were prohibitive. However, it would remain a possibility for future similar projects.

Outcome: Plans for a shared heat network were not progressed with heat decarbonisation focusing on shared-array ground source heat pumps and smart controls.

4. Changes to wider funding for heat decarbonisation.

Financing of the domestic heat decarbonisation elements depended significantly on other funding streams – notably the UK Government's ECO funding and Non-Domestic Renewable Heat Incentive. Changes to these funding streams, once the project had begun, led to a significant impact on the ability to deliver at the proposed scale, with the installation cost resting heavily on the social housing company. Stonewater housing accepted this burden, but the cost model became unattractive for other social housing and public-sector non-domestic users.

Outcome: Number of homes to be decarbonised reduced from 300 to 60.

What are the key lessons learned?

Technical

Hybrid battery

- **The project has demonstrated direct transmission connection via tertiary windings.**

Significant opportunities exist for projects up to around 60 MW to connect directly to the transmission network rather than, as would usually happen, to the distribution network at 33kV or 132kV voltage levels This applies to generation, demand and flexibility. Exploiting these opportunities involves making use of tertiary windings of transmission network transformers that are usually only used by network owners themselves.

The ESO project worked closely with National Grid ESO and with National Grid Electricity Transmission to connect the hybrid battery and EV superhub via a tertiary winding connection. This bypasses the distribution network allowing a cheaper, faster and more efficient connection suitable for the scope of project.

Hybrid battery

- **Optimisation of the transmission connected battery's deployment has become increasingly sophisticated through the course of this project.**

Whilst initially envisaged to be largely trading in the wholesale market, a process known as arbitrage, the battery has spent significantly more of its time in the grid ancillary services markets. These markets have become significantly more granular over the past two years (a single firm frequency response service divided now into three highly granular new services).

This has resulted in far greater sophistication in the optimising algorithms provided by Habitat and the ability to deliver far higher returns than originally expected. In addition, new approaches to optimisation for battery life are being developed. This has been supported by the development of a high-detail digital twin model of the lithium-ion component of the hybrid battery. The potential for further optimisation between lithium-ion and vanadium flow technologies is still being evaluated.

Regulatory and policy

Hybrid battery

- **Treatment of batteries as a generator remains an issue for new projects.**

To date, batteries have been classed as generators under the 1989 Electricity Act. This has consequences for connection agreements, network charges and operating licences for batteries which are designed around the characteristics of generators rather than flexibility providers. Unlike generators, batteries provide dispatchable flexibility which can be directly used to relieve network constraints or reduce the overall level of network capacity required. Treating batteries as generators fails to recognise the flexibility value that batteries provide to the overall system, and impacts geographical siting decisions. The Energy Security Bill may address this issue, however, ahead of any changes future projects need to be aware of the additional barriers and costs that current licensing arrangements create for batteries.

Hybrid battery

- **Ancillary service arrangements are constantly evolving – it is important that smart local energy system projects plan flexibly.**

The project has targeted a number of ancillary service streams with the lithium-ion component of the battery providing Firm Frequency Response (FFR) and Dynamic Containment Reserve (DCR) since its commissioning in June 2021, as well as trading in the wholesale market. Following connection of the vanadium redox flow component in late summer 2022, the project aims to demonstrate more efficient provision of FFR by co-optimising the response across both battery components. However, FFR is now being phased out and is expected to be discontinued in 2023. National Grid ESO (NGESO) has introduced a range of new response and reserve products.

The technical need for fast-acting response and reserve for the UK electricity system is likely to increase over the coming years as the system is decarbonised and the specific design of ancillary service products change further, including in terms of the technical requirements that providers have to meet. Future projects need to remain aware of this, ensuing that their design and operating model are sufficiently flexible to accommodate change over the lifetime of their assets.

What are the key lessons learned?

Regulatory and policy

EV superhub

- **Changes to network and other regulated charges can have a significant impact and should be treated as major potential risks for SLES projects.**

The experience of Ofgem's charging review has highlighted the degree to which regulatory change can have significant impact on innovation projects. Whilst Ofgem carry out substantial consultation and impact assessments as part of their process, these are likely to focus on existing market participants and well-established models and are less likely to understand or consider the potential impact on new, innovative business models.

The potential for regulatory change should be treated as a significant risk by any innovation project which rely on regulatory rules or charging arrangements. It is also important that innovation projects are proactive at engaging with Ofgem, BEIS and others when change is being considered. The engagement of the ESO project in the charging reform debate directly impacts on the final decision by Ofgem, ensuring it took account of the impact on smaller scale transmission connected demand projects.

Heat

- **Projects needs to identify risk associated with changes to government funding mechanisms, or plan to avoid reliance on other funding schemes which may be liable to change.**

Initial plans to install around 300 ground source heat pumps had to be scaled back significantly as the normal level of funding available through the ECO and Non-Domestic Renewable Heat Incentive schemes was less than expected. This change significantly reduced the number of heat pumps that could be installed to around 60.

This highlights the risk associated with reliance on revenue streams outside the main innovation fund and the lack of transparency that is often associated with government funding streams. For example, NDRHI funding was unavailable because the scheme had reached its full capacity. However, prior to closure of the scheme there was no public signposting that remaining funds were running low.

Future projects need to consider the clarity provided by government, or other funders, around support schemes that can only be claimed after the project is underway. There may be value in exploring alternative funding mechanisms where there is significant uncertainty over support schemes which will be critical to success.

Business model and business practices

Hybrid battery

- **Ancillary services make up more of the revenue and operation that expected in comparison with energy arbitrage.**

Initial estimates suggested that the battery would operate in trading-mode for around 70% of its time and provide ancillary services for the rest. Initial operation of the lithium-ion element of the battery shows that, over its first year of operation, trading accounted for only 30% of operating time with services accounting for more than 60%. The ability to provide both trading and ancillary services ensures a degree of flexibility in the operation and business case for the ESO hybrid battery. Future projects should replicate this flexibility, ensuring their operating model can respond to changes in the balance of value and revenue available from different streams.

EV Superhub

- **A clear model of asset ownership and project delivery which takes account of technical interface requirements and commercial practicalities is essential.**

The EV charging hub involves a complex set of commercial and legal arrangements influenced by the infrastructure's underlying engineering needs. Multiple charge point providers own the charger points themselves and the electrical infrastructure to link the connection point to the private wire. Oxford City Council own the land and their own electrical infrastructure, and the private wire itself is owned and operated by EDF Renewables.

There were several complications and delays in construction of the EV charging hub due to lack of early clarity as to the layout, ownership, and overall responsibility for construction on the site. The final delivery involved Oxford City Council taking overall responsibility for construction. Future projects should consider appointing a dedicated construction manager for complex multi partner projects, and detailed thought needs to be given to who owns the site itself.

The project has implemented a concession-based model with bay rental and some revenue sharing: individual charge point operators buy a long-term concession to access a certain number of bays. There is a shared electrical compound for the connections to the private wire. The decision to share one compound drove important decisions in the final layout and technical design as well as contractual relationships between parties.

What are the key lessons learned?

Business model and business practices

The overall design challenge was further complicated by council constraints imposed by the wider plan for the park and ride scheme. Coordinating the charging hub with other elements of the scheme required agreement on a park and ride master plan, a process that was complicated by a conflict in priorities for the council. Some delays could have been avoided by kicking off master-planning for the site earlier.

EV superhub

- **Developing new legal and contractual arrangements can be complex, costly and time consuming.**

  The innovative concession-based model for the EV charging hub meant new legal and contractual structures were needed. Developing this required access to specialist legal expertise and took considerable time and cost. Council resourcing constraints were also a significant issue. Future projects should consider the degree to which standard, existing contractual arrangements can be used and where they will not be appropriate. Projects should ensure that the need for legal expertise and the associated cost and time are accounted for in the project plan.

EV fleet

- **Clear long-term objectives and strategy for EV fleet electrification are critical at the early stages of project design.**

  Initial plans for electrification of Oxford City Council's vehicle fleet changed during the project. Changes included where and when EVs are expected to charge. The outcome of these changes was that the installation of planned charging infrastructure at a major vehicle depot was abandoned. This would have been connected to the private wire and transmission connection and would have allowed the trading and optimisation engine to co-optimise both the battery and EV fleet charging.

  There were several distinct drivers: firstly knowledge of how the existing vehicle fleet operated was limited by a lack of data (see below). Secondly, the project came early in Oxford City Council's fleet electrification journey and therefore, at the start of ESO, important strategic decisions had yet to be made. Finally, changes in senior management at the council and a lack of understanding around costs and impacts of electrification delayed important decisions.

  Future projects should take complete account of the current understanding of fleet behaviour and options for the electrification of a fleet. They should plan that as the fleet operator's experience develops, significant changes to the overall strategy may emerge. Senior leadership in local authorities need more training and support to understand and feel confident about the methodologies and need for decarbonisation and their role in delivery.

  A central body providing expertise to other local authorities could be a valuable resource in helping them determine EV and fleet strategies and their implementation.

Social and community

Heat

- **Ground source heat pumps are capable of delivering substantial savings to social housing tenants when replacing electric storage heaters, as well as increasing thermal comfort.**

  A pre-and post-installation monitoring programme proves that GSHPs can reduce bills while improving thermal comfort. Average indoor temperatures rose from 20.5°C to 23.4°C whilst most tenants reported saving money, some as much as 50%. Survey evidence also shows tenants found the heat pumps easy to understand and control. Overall satisfaction with heating systems rose from 2.1 out of 5 pre-trial to 4.7 out of 5 post-trial.

Heat

- **Delivery of social benefit can be dependent on availability of smart meters, time of use tariffs, and other factors which may be outside the control of an innovation project.**

  ESO has demonstrated that even in houses with moderate levels of efficiency, load shifting of two to three hours is feasible without loss of thermal comfort. However, the slow rate of installation of half-hourly Smart metering equipment technical specifications (SMETS) 2 meters and the lack of availability of time of use tariffs are major barriers to homeowners realising value from this potential flexibility. The current energy price crises has exacerbated the lack of choice in tariffs at a time when consumers are more in need of ways to manage their bills.

  Future projects should carefully consider the current state of the energy supply market and the availability of SMETS 2 meters across their potential customer base. They may also wish to look at ways to support delivery of these elements, for example by partnering with a supplier willing to ensure installation of appropriate metering and to commit to offering time of use tariffs.

What are the key lessons learned?

Social and community

Heat

- **Learning from ESO automated control trials emphasizes the importance of householders understanding their heating system and retaining choice.**

  Across a small trial, ESO has reinforced existing understanding of the importance of choice for customers. Evidence from five houses shows that some householders used manual overrides of the heating system, or opened windows, to control their internal temperature.

Carbon

Hybrid battery

- **Estimating the carbon impact of the battery when providing ancillary services depends on difficult-to-define counterfactuals.**

  The lithium-ion battery has largely operated to provide response and reserves services to National Grid, reflecting the greater value available from these services in comparison with wholesale market trading. However, identifying the carbon saving associated with provision of response and reserve involves quantifying an appropriate counterfactual against which to compare the savings.

  The counterfactual chosen by ESO is the use of gas power stations to provide response services. This involves reducing the output of gas power stations below their optimally efficient output level. Using efficiency curves, ESO has estimated that deloading gas power stations may reduce their efficiency to 95% of its level when operating at full output. The ESO battery therefore allows gas generation units to operate closer to their most efficient output level leading to lower overall emissions per unit of electricity generated.

  Against this counterfactual, carbon savings from providing ancillary services during the first year of operation has been estimated at 25,000 tonnes CO_2. This is higher than the original, overall, objective for the battery of 15,000 tonnes CO_2/year.

  It is important to note that these findings are preliminary, and that the academic team involved has secured further research funding to develop their modelling. Future battery projects aiming to reduce carbon emissions should review the ESO work and consider both the mode of operation of their battery and the appropriate counterfactual against which to benchmark carbon savings. Carbon impact assessment associated with providing ancillary services is an evolving area and does not yet have standard processes.

Finance and investment

EV fleet

- **SLES projects can spark new opportunities. For example, the opportunity to support the Oxford Bus Company in getting government funding to electrify 104 buses.**

  The development of the private wire network as part of the superhub, and early design decisions which ensured that network capacity could be used flexibly in future, opened up the opportunity to partner with the Oxford Bus Company after the ESO project had started. The ability to capitalise on opportunities demonstrates and reflects the flip side of the risk associated with existing elements of a project falling away.

  Working with the bus company, ESO installed a substation at the bus depot with sufficient capacity to service the planned electric bus fleet. This allowed Oxford Bus Company to bid successfully on the Zero Emissions Bus Regional Area Scheme and, together with Oxfordshire County Council and other bus operators, secure just over £80 million of investment.

  This highlights the importance of building flexibility into innovation projects to allow them to take advantage of new opportunities.

Data

EV fleet

- **Existing levels of data availability for vehicle fleets may not be sufficient to develop a full electrification strategy.**

  Data collection for existing fleets will be based on current needs, but GPS data as a minimum is essential for understanding how fleets operate. Fleet telematics for electric vehicles differ to those for petrol or diesel fleets. Enhanced monitoring is often needed to identify appropriate battery capacity for electric vehicles and to make optimal investment decisions in charging infrastructure.

  For example, monitoring of the Oxford City Council fleet showed that typical daily vehicle millage was around 50 miles, meaning that requirements for battery capacity may be significantly less than initially thought.

  Learning from ESO shows that it is important to identify current levels of data capture and understand any gaps between this and future needs. The project also shows that as data availability increases this may lead to changes in understanding of fleet needs with implications for the wider project. As with many elements of SLES projects, flexibility is critical.

How does this help solve whole system challenges?

Smart

ESO's contribution to smart includes the development of the optimisation algorithm, the learning about the relative value streams for the operation of a battery, and the delivery of infrastructure needed to bring multiple elements of the energy system together physically (in this case, electricity transmission, EV charging and EV fleet management). It has also reinforced existing knowledge about the role of 'smart' in decarbonising domestic heat.

The project could not integrate all its components into a fully optimised local energy system. This was due to practical project constraints such as changes to the strategy for charging Oxford City Council's EV fleet and the decision to drop the link between heat decarbonisation and excess heat from the battery.

Local

ESO has directly supported local decarbonisation through the electrification of energy demand (heat and EV fleets) and the provision of new capacity capable of serving growing demand for EVs in the future, and support for other energy users in the city, particularly taxi drivers and buses.

The loss of ability to leverage government funding streams for heat decarbonisation resulted in the project delivering fewer heat pump installations than initially envisaged and therefore having a smaller than anticipated impact on local domestic carbon emissions.

Whole energy system

A key area of value that ESO has delivered is the linkage between local energy demand and the national energy system in the guise of the electricity transmission network. The innovative connection design for the battery and EV charging hub, combined with the set-up in scale of EV charging capacity has opened up new models for linking local demand with national supply. And the development and learning around operating of the hybrid battery, in conjunction with EV charging demand has allowed the project to look both ways – inwards towards local demand and outwards to supporting the national electricity system.

More information:

- ESO project website
- Email: Tim Rose, Tim.Rose@edf-re.uk

Who is prospering?

✓ **Oxford City Council:** through ESO's funding for EV vehicles and charging infrastructure. This has provided a significant step towards full decarbonisation of the fleet, although challenges remain around the higher capital cost of electric vehicles in the next phase unless new funding streams become available.

✓ **Project commercial partners:** EDF Renewables has now proven the superhub model and is now in the process of constructing two more with a future 38 connections agreements with National Grid across the country. Kensa has productised its shoe box heat pump and patented a new integrated heat pump and heat battery design.

✓ **EV drivers (existing and future):** now have access to world leading charging facilities including ultra fast chargers of up to 300 kW resulting in 11,800 individual charges were delivered during the first full five calendar months of operation.

✓ **Social housing residents:** have benefited from the installation of ground source heat pumps in 62 properties with clear evidence of significant bill reductions.

✓ **Taxi drivers:** who took advantage of a try-before-you-buy scheme and a grant towards a fully electric taxi leading to 26 electric black-cabs operating in the Oxford taxi fleet.

✓ **Oxford bus operators: and bus passengers** who will soon benefit from access to a substantial number of electric buses.

✓ **Oxford city residents:** through reduced vehicle emissions.

✓ **Users of the national electricity system:** who will benefit from cheaper and lower carbon provision of critical ancillary services.

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Demonstration project

Local Energy Oxfordshire (LEO)

Project LEO has supported the development of a wide range of local energy projects at the grid edge and a new local market platform for electricity system flexibility.

Project summary

Project LEO is running trials in Oxfordshire to build a broad range of reliable evidence of the technological, market and social conditions needed for a greener, more flexible, and fair electricity system. It combines two approaches: bottom-up support for local energy projects operating at the grid edge and top-down development of local DSO flexibility markets by SSEN, the local distribution network operator. The project has a wide range of individual plug-in projects and community based smart-fair neighbourhood trials covering a diverse range of technologies including solar, heat networks, EV and vehicle-to-grid, and buildings acting as flexible demands. Many of these have participated in market trials bidding to provide DSO procured services and trading flexibility peer-to-peer (P2P) through DSO enabled markets. LEO has been undertaken in parallel with project TRANSITION, a DSO project funded by Ofgem.

The project has also explored the wider value that a large scale shift in philosophy towards SLES can deliver for local communities. It has taken a no-one-left behind approach, developed new ways to engage local communities and to understand the opportunities and barriers that different groups in society face when engaging with the energy system.

Original objectives	1. Achieve a local, balanced energy system. 2. Deliver benefits across the local energy ecosystem. 3. Ensure equitable access to energy services.

Key project elements

- **Plug in projects:** Enable a portfolio of Distributed Energy resources operating at the grid edge capable of providing flexibility through local and national markets.
- **Smart fair neighbourhoods:** A series of community projects focused on exploring local value and demonstrating how smart technology and new commercial models can create opportunities within local communities and do so in an equitable and fair way for everyone.
- **Minimum Viable System (MVS) approach:** The MVS approach provides a fast learning loop to develop, test and integrate essential LEO processes and assets.
- **Demonstrate an integrated DSO and local energy approach to flexibility:** Deliver market trials for local flexibility markets with SSEN acting as a Neutral Market Facilitator (NMF) for procurement of DSO services and enablement of wider flexibility trading.
- **Future system learning and planning:** Set up processes to monitor, collect, store and assess information relating to energy services. Develop spatial and temporal datasets and synthesise these to produce insights that enable the planning of a fully integrated energy and transport system across Oxfordshire.

What have been the successes? What has been delivered?

1. LEO has supported many demonstration and trial local energy projects, which have participated in delivering local flexibility.

These include technology specific projects such as PV, hydro, battery, vehicle-to-grid EV charging and building demand-side management plus a number of smart fair network. Such trails will demonstrate how flexibility services can deliver opportunities through a local energy market place in an equitable and fair way for everyone.

2. Development of DSO market framework and trading platforms.

In conjunction with the TRANSITION project, LEO has supported the development of a neutral market framework for the procurement of DSO services and the enablement of trading of P2P services. This includes the NMF platform developed by TRANSITION and Piclo Flex, a satellite platform for flexibility trading.

3. Delivery of DSO market trials to procure network services and enable peer to peer network capacity trading.

Two sets of DSO market trials have been run, which involved LEO's portfolio of local energy projects providing a range of services such as peak management, and fast, dynamic response following a network fault. This has provided invaluable learning for both the DSO and the participating projects about the technical challenges and opportunities of delivering flexibility services.

4. Regional and local mapping tools bringing together dozens of data layers to provide a geographical visualisation of energy use, constraining factors, and opportunities for SLES.

This includes local community energy mapping, which acts as a local energy development tool and a route to engagement with local citizens. A regional mapping tool brings together multiple land-use and energy data sets to support strategic planning of the Oxfordshire energy system.

5. Improved understanding of the barriers and opportunities for local communities and others on the grid edge to participate and benefit from SLES.

Developed through a learn-by-doing approached and captured in detail across multiple published reports.

What have been the barriers? What impacts have they had?

1. Delivering flexibility services remains technically complex for grid edge assets and local energy projects. There is a need for greater expertise to support non-specialist community and local providers to participate.

Enabling flexibility can be particularly difficult for small projects where the assets involved are not primarily designed for flexible operation. Technical requirements include the ability to share data, be controlled remotely, and for operation to be scheduled in advance. The bespoke nature of many local energy projects means that plug and play is a long way from being a reality.

Outcome: LEO has overcome these limitations by directly supporting local energy projects to meet the costs and access the expertise needed to participate. In other cases a greater reliance on manual operation has been used to test principles. A key conclusion is the importance of standardising and simplifying in a range of domains, including technical, digital and contractual. The project also identifies the significant value that would come from developing the aggregator sector to provide functional expertise to support non-specialist flex providers to participate in flexibility markets.

2. There is value in optimising the electricity system through local flexibility, particularly behind the secondary substation, but the value of DSO procured flexibility is currently relatively low.

This, combined with the technical challenges of preparing and delivering flex from assets that were often not designed with this purpose in mind as limited participation in market trials.

Outcome: Project partners are better informed on the relative scale of value streams for grid edge assets and future market trials are expected to focus on supporting assets to develop flexibility provision as an addition to other revenue streams.

3. Markets structures reward economic value but struggle to support wider social goals and ensure that no one is left behind.

Operation of many electricity markets is based on lowest overall cost, defining value in overall economic terms only, whilst value to local energy schemes is likely to include a range of non-financial factors, such as environmental, social, and equality based benefits. The difficulty in valuing non-financial outcomes can be a barrier to delivering LEO's social objectives.

Outcome: the project has explored and articulated financial and non-financial benefits and explored these with stakeholders identifying the importance of wider impact.

> **"LEO is a project that begins to tell us how you run an energy system, when it is completely different from the ones we have now."**
>
> **Councillor Dr. Pete Sudbury, Oxfordshire County Council**

What are the key lessons learned?

Technical

Demonstrate an integrated DSO and local energy approach to flexibility

- **The project has produced substantial value through working closely with the TRANSITION project, a network-funded innovation project developing DSO markets.**

TRANSITION and LEO are partner projects. TRANSITION focuses on developing the market and associated platforms that allow SSEN to act as an NMF, procuring flexibility services that support its role in efficiently operating the distribution network. LEO is a socio-technical innovation project aiming to demonstrate that SLES can maximise economic, environmental and social prosperity.

The two projects are complementary, with TRANSITION helping develop flexibility markets and LEO supporting the development of market participants. The two projects also benefit from a greater understanding of each others' needs, motivations and limitations. There is value in future projects looking for opportunities to replicate the synergies of developing complementary projects.

Plug in projects/ minimum viable system approach

- **The ability to baseline the operation of assets participating in flexibility services is an important part of quantifying the level of service delivered. This is a significant challenge for some types of DER.**

Baselining means estimating how a device would have behaved if it wasn't delivering a flexibility service. For example, for a demand side response provider participating in demand turn down, it involves estimating the demand profile had it not been delivering the service.

LEO has explored both historic baselining – using previous metered data provided by the market participant from similar days over the past eight weeks – and nomination where a participant defines their own baseline. Experience from market trials shows that baselining is a challenge for some grid edge assets: historic baselines for weather dependent renewables require a same-day adjustment to reflect current weather conditions, whilst assets effected by external factors that are difficult to predict struggle to provide nomination baselines. An example is flexibility from V2G chargers, where the baseline would depend on whether an EV was plugged in, the state of charge of its battery, and whether or not the owner needed to use the vehicle during the period contracted.

Baselining is a critical part of a well-functioning flexibility market and LEO shows that further development of how to work with grid edge assets to appropriately baseline their activity is needed.

Plug in projects

- **LEO has developed a clear understanding of the technical requirements needed for assets to participate in flexibility service provision. It has also identified that the barriers to participation for the grid edge remains high.**

The market trials delivered in conjunction with TRANSMIT have defined a clear set of DSO flexibility products against which LEO projects have been able to assess their ability to deliver. For example, Low Carbon Hub have RAG rated their assets against the ability to provide four DSO procured services. As an example, the service sustain peak management requires reduction in offtake of electricity (demand) or increased injection of electricity (generation) at predefined peak periods. Low Carbon Hub identified that:

- Solar capacity cannot deliver this service as it will already be generating at the level dictated by current sun and cloud conditions;
- A 15kW / 50 kWh battery which is currently used to time-shift solar generation to match demand at a local school can technically provide this service. The price needs to be sufficiently high to offset the value of holding the energy to supply at a later time to meet the school's demand.
- A 440 kW hydro plant on the river Thames can technically provide the service but may be unavailable at peak times in winter due to high river flow rates.

Future projects looking at DSO procured services and considering the technical ability of grid edge assets to deliver flexibility services at all levels (P2P, DSO or ESO) should review the detailed learning available from LEO.

What are the key lessons learned?

Regulatory and policy

Demonstrate an integrated DSO and local energy approach to flexibility

- **Local energy systems need policy and regulatory certainty in order to thrive; without it, necessary investments in physical assets, infrastructure, skills and organisational capability will not be made.**

This includes arrangements across the spectrum of electricity regulation including connection agreements, network charging approaches and national support for the development of local flexibility procurement.

For example, delivering flexibility in a way that supports efficient use of network infrastructure can only be sustained if there are corresponding changes to the structure and functioning of the electricity market which allows the value of flexibility at different locations and times at or near the grid edge to be clearly signalled and tradeable.

Whilst LEO and a number of the other PfER projects have demonstrated pathways to making these changes a reality, it is important that future projects continue to challenge national institutions to put in place appropriate frameworks, and in particular to make use of the opportunities that may come about through the UK Government's Review of Electricity Markets.

Business model and business practices

Minimum viable system (MVS) approach

- **The agile approach to energy system innovation demonstrated through the MVS methodology has supported more flexible project development.**

MVS is based on the minimum viable product approach used as part of the lean start-up concept in the digital sector. It involves starting with a basic system that allows a hypothesis, adaption, or business model to be tested.

The MVS approach allows local energy asset owners to develop an understanding of the requirements needed to deliver flexibility. This has enabled those assets to be prepared for participation in the DSO markets through an iterative build-measure-learn approach. An agile approach has significant advantages over traditional planning and design, particularly fr innovation projects where the design requirements and the constraints on delivery may be poorly understood at the start of the project.

The concept has been expanded to include MVS+ and pre-trial stages which have built on the basic approach, for example, to increase the level of automation and flow between delivery stages. A commercial MVS trial was also carried out focused on the ability to forecast and baseline the behaviour of some grid edge assets which provided useful pre-trial evidence on the likely value that would be derived from different assets. Origami energy worked with individual asset owners to determine what could be done to improve forecasting and baselining.

The assets that have benefitted from this approach include a hydro generator, co-located rooftop PV and battery, vehicle-to-grid charging, and the Oxfordshire County Library acting as a demand response asset.

Demonstrate an integrated DSO and local energy approach to flexibility

- **A DSO framework provides the opportunity to deliver valuable services directly to the network operator, but it also provides an opportunity to enable a wider range of P2P network capacity trading.**

The local flexibility services trialled by LEO can be split into two groups: DSO procured services such as Sustain Peak Management which procures demand reduction over periods of peak demand on the network; and DSO enabled services such as Maximum Export Trading where market participants trade a portion of their normally fixed network capacity for an agreed period with a counterparty behind the same network constraint. Trading DSO enabled services needs agreement from the DSO but doesn't impact on the network.

The development of DSO-procured services was identified by local energy projects as being of potentially significant value. Where there are a number of assets in the same area (and behind the same network constraints) it would allow the optimisation of the network capacity across that local portfolio. Compared with DSO-procured services, these services could be more within the control of the local project and would support the creation of long term partnerships.

However, at this stage of development there are challenges to delivering successful DSO-enabled trading, in large part due to the very limited number of projects looking to trade and the need for counterparties to be connected behind the limiting network constraint. Even where this is the case, technical factors can still be a barrier. A number of potential capacity trades were identified as part of the trials, but several had to be abandoned due to network effects such as voltage constraints.

What are the key lessons learned?

Business model and business practices

Demonstrate an integrated DSO and local energy approach to flexibility

- **Whilst DSO procured services can provide useful value to some grid edge assets, evidence from market trials suggests that commercial benefits of participating in the trials are low for many at the grid edge, with high upfront costs required to enable participation.**

Although the trials have successfully demonstrated the participation of grid edge assets in delivering flexibility services to the DSO, the trial auctions have seen relatively limited participation and bids at or close to administrative price ceilings. For example, the Sustain Peak Management service had a price ceiling of £300/MWh during the first trial period, raised to £600/MWh during the second. Even after moving to the higher ceiling there was only one auction where the offered capacity equalled that requested; remaining auctions were illiquid with less capacity offered than required.

It is common for innovation projects to see revenue streams that do not support the investment required, whether that is a financial investment or investment in time or expertise. Developing more automated systems will help make participation cheaper and more accessible. However, it is vital to consider the relative scale of flexibility benefits against the broader business of the energy assets themselves. For example, Low Carbon Hub, in reviewing the potential of its portfolio of generation and storage, identified that it might expect a maximum 10% upside on expected income from flexibility services depending on the asset type.

Social and community

Future system learning and planning

- **The capability lens has allowed the project to explore the barriers to participating in SLES projects.**

Capabilities are the ability to act. They are related to what people are able to do as well as what they have and it takes social arrangements into account. LEO has developed a capability framework to consider how households, business, communities and the local energy system itself can adopt and integrate flexibility technologies and practices. This framework allows LEO to identify barriers to engagement for particular groups in society and to better deliver its no-one left behind objective.

The project has carried out a detailed assessment of the capabilities required to benefit from vehicle-to-grid technology. It helps identify opportunities to create business models and value propositions that will work for people with and without the physical, financial, social and knowledge capabilities to participate fully. For example, in its detailed analysis, the work identifies a set of digital capabilities as requirements for vehicle-to-grid. In analysing capabilities across age groups, it notes that only 65% of those over 65 have a smartphone. This lack of digital capacity will limit the ability of older people to participate and benefit from V2G without support.

Smart Fair Neighbourhoods

- **Value analysis for flexibility and other energy system developments tends to be based primarily on economic benefit. It is important to identify, quantify and consider other sources of value including social and environmental value.**

LEO has articulated four areas of value: planet, people, prosperity, and perception. The experience of LEO suggests there is value in a flex offer for all LEO stakeholders. This value is multidimensional and can vary significantly across stakeholders. Financial benefits are not the only, or even the primary motivation, of many SLES stakeholders.

LEO recommends that environmental and citizenship benefits be prominent in future SLES value propositions. For example, SMEs embedded in the local community may be keen to show that they act as good energy citizens and support the local energy ecosystem. These value propositions should be tuned and adapted to different groups and respond to potential users' needs, priorities and capabilities if grid edge involvement in flexibility provision is to be scaled up.

This approach has also been identified as important in delivering LEO's equality objective and ensuring no one is left behind. The focus on economic efficiency in the design of competitive energy markets makes it challenging to deliver equality of outcomes, particularly across vulnerable groups. There is a risk that introducing local flexibility markets under existing rationales used at national level might perpetuate and exacerbate existing inequalities.

What are the key lessons learned?

Data

Future system learning and planning

- **Data needs to be managed effectively and flexibly in order to support innovation success.**

In common with many PfER projects, LEO has needed to make use of a wide range of external data and has produced significant quantities of new data. Data management is a major project activity, and the process of standardising data formats along with ensuring and maintaining its quality has taken significant resource.

The project has implemented a series of data management tools: data principles covering aspects such as production, use, confidentiality, integrity and provenance of data; development of standard formats; data certificates and data standards. For example, LEO has developed an online health scan tool that provides a dashboard highlighting the level of missing data in a data set and identifies outliers in a data set that follows LEO's standardised format for time-series data.

Whilst the LEO data management tools have improved sharing and use of data within the project, interfaces with data outside the LEO remit could be controlled differently. Even engagement with the TRANSITION partner project, which has its own data platform developed by a third party limited the degree to which LEO's internal processes could be used.

Data sharing agreements are necessary to ensure appropriate privacy and security of the data, and these agreements often dictate specifically how, where, and by whom data can be used. Whilst compatible with well-defined processes and activities, this can cause challenges for innovation projects. The LEO data management team has had to revise data sharing agreements, and how data is used in the project has evolved.

Future System learning and planning

- **Mapping is a useful and accessible way to combine multiple data sets and enable them to be used widely for identifying potential opportunities.**

LEO has developed two data mapping tools: the local area energy mapping approach (LEMAP), which visualises local energy flows at a community level, and Oxfordshire's integrated land use mapping tool.

The development of LEMAP has formed an important part of two smart fair neighbourhood trials. It provides three engagement routes: participatory mapping, where local residents help build the local energy map by providing information on their energy use; a story map approach which can visualise key energy outcomes; and chat forums. The process has been successful in growing engagement and helping non-expert participants to understand the current shape of their local energy system and identify opportunities for interventions.

The integrated land use map combines 79 layers of detailed information across the planning and environmental constraints and designations domains, energy data including electricity networks, aerial photography and renewable generation potential. It aims to provide the spatial intelligence required to support energy system planning in LEO and broader strategic planning to deliver the Oxfordshire Energy Strategy. The design has been informed by three key recommendations from a review of existing local energy mapping.

Firstly, in addition to bringing datasets together in a way that works for the moment, it is crucial to ensure that these can be maintained after the initial project finishes. Secondly, electricity, heat and transport should be considered holistically. And thirdly, where possible, publicly accessible datasets should be used to avoid access restrictions and costly licences.

How does this help solve whole system challenges?

Smart

LEO highlights the importance of embedding smartness at the grid edge to ensure that costs are reduced and opportunities maximised. It demonstrates the value of local energy projects having the smart capabilities needed to participate in providing flexibility to the wider energy system.

Local

LEO brings a bottom-up approach, starting at the grid edge and moving inwards, to meet the top-down approaches being developed by electricity network companies to manage local network constraints. It shows that these two approaches are complimentary and that, when stakeholders at all levels work together, a range of financial and non-financial benefits can be created that support local energy projects to ensure that no one is left behind.

Whole energy system

LEO's focus on electricity has tackled many of the challenges associated with electrification of heat and transport, whilst the Smart Fair Neighbourhoods approach and mapping activities are supporting a holistic view of energy. LEO's philosophy, which focuses on equality, capacity and non-financial and traditional economic benefits, demonstrates that a whole-system approach is about more than just energy.

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Who is prospering?

✓ **Local residents:** through the development of new local energy schemes under LEO and the Smart Fair Neighbourhood trials.

✓ **Local Authority buildings and their users:** through their participation in LEOs local flexibility markets.

✓ **Private / public-sector EV charge point owners:** through the revenue and benefits generated from the provision of flexibility via V2G flexibility.

✓ **The DNO and its customers:** internally to SSEN, lead project partner and local DNO, LEO has drawn significant interest and has raised awareness of the role of a DSO in supporting wider societal ambitions. Other DNOs across the UK are benefitting through knowledge sharing to support their own DSO transition.

✓ **Local energy schemes and the communities that support them:** including the new value streams developed by Low Carbon Hub across its community owned renewable energy portfolio and the end energy users those assets support.

✓ **LEO commercial partners:** including Nuvve's increased understanding of market opportunities for vehicle-to-grid flexibility offering in the UK, Piclo through its increased understanding of the role of flexibility trading platforms, and Equiwatt through an improved understanding of aggregation of domestic demand response.

More information:

- Project LEO home page
- TRANSITION project home page
- LEO YEar 3 synthesis report
- Project LEO and TRANSITION Market Trials Report (Period 2)

- Email: futurenetworks@sse.com

Demonstration project

ReFLEX Orkney

ReFLEX Orkney set out to pioneer an integrated, affordable, low-carbon energy system using a disruptive, progressive and all-encompassing approach.

Project summary

ReFLEX Orkney set out to pioneer an integrated, affordable, low-carbon energy system. The project aimed to create a smart local energy system in Orkney, Scotland, interlinking local electricity, transport and heat networks into one controllable, overarching system, digitally connecting distributed and variable renewable generation to flexible storage and demand. This whole systems approach requires disruptive, progressive and all-encompassing systems spanning technical innovations, new financial models, changes to consumer behaviour, and the way energy companies and regulators operate. ReFLEX has uncovered critical interdependencies between different aspects of the system. Progress has been slower than anticipated due to inertia within the current energy system and the need to accommodate radical and disruptive change in a real-life setting.

Key project elements

- **The ReFLEX concept and approach:** The project has developed fundamental principles to accelerate a just carbon transition for whole energy systems, based on a localised but widely replicable basis. This is facilitated through progressive technology and business models. It introduces revolutionary system flexibility and control, pre-financing capital, and face-to-face local customer support through the membership scheme.

- **Integrated Energy System (IES):** the project has integrated elements of electricity, heat and mobility across Orkney. This has been achieved through creating a framework for bundling electricity, transport and heating services in ways that will help enable energy efficiency, flexibility and resilience. The IES is supported by FlexiGrid, a digital smart grid control and coordination platform, and other digital tools to help increase demand flexibility.

- **ReFLEX Orkney Ltd:** the project has set up an ongoing organisation aiming to expand delivery of the IES over the coming years and includes the ReFLEX Experience Centre, a customer hub bringing together advice and support across all elements of ReFLEX.

- **Technology business models**: This involves delivery of smart EV charging within the market flexibility platform, exploration of a no-upfront-cost model for behind-the-meter PV and battery, flexible electric storage heating and hydrogen.

- **Orkney Tariff:** A one-year tariff delivered by Shell Energy, the tariff provided 100% renewable electricity at an affordable price reflecting the availability of local electricity generation.

- **A focus on just transition:** By focusing on a just transition, we ensure that ReFLEX helps deliver an affordable and democratised energy system, providing equality of access and utility for all, locally and nationally.

- **Data:** Development of data analytics to support the efficient operation of the IES and help Orkney residents and businesses to access the benefits of a coordinated approach to energy, including the Orkney carbon calculator.

What have been the successes? What has been delivered?

1. Articulation and demonstration of a robust and part tested energy system business model that can deliver an accelerated just transition at a localised level.

This includes the integration of heat, transport and electricity vectors, novel and coordinated finance options and business models for multiple infrastructure elements. It also involves aligning the operation of the broader Orkney energy system with the area's renewable wind resource availability.

2. Exceptional levels of engagement and participation.

With a householder energy survey returning more than 2,000 responses, ReFLEX Orkney membership having grown to circa 1,000 by the end of 2022, equal to around 5% of the total Orkney population and 10% of households, and active participation by around 350 of those members in ReFLEX services.

3. Significant uptake of decarbonised transport.

ReFLEX has supported an increase of over 200 in the number of EVs on Orkney, over 140 domestic EV charge points, enrolled over 180 people in the local Co-Wheels car club and delivered five community electric vehicles.

4. Improved understanding of carbon emissions and energy use across Orkney.

Delivered through 300 carbon footprint calculations completed using the ReFLEX carbon calculator and the mass deployment of energy monitors across 115 properties. This was supplemented by questionnaires and data-gathering from live ReFLEX assets throughout the project.

5. ReFLEX outreach.

The Reflex team have made more than 100 presentations on the project with local, national and international events and global agencies such as the United Nations Office for Project Services, the Arctic Circle Assembly, UK and Scottish Governments and multi-national corporations.

6. Expansion of expertise from sector specific to 'whole system'.

The ReFLEX project has engaged around 70 different specialist participants. Many of these people were already experts in certain parts of the energy stream. ReFLEX has both broadened and deepened their knowledge and understanding at an individual and collective level. The cluster of experts based in Orkney now has a unique critical mass of experience and expertise upon which to draw with an expectation that this will support new innovations and solutions. The team has already been engaged in around 20 projects following on from ReFLEX Orkney.

7. Orkney is now ready to step onwards towards decarbonisation.

This may be achieved through the increased commitment for change in the community and an increased understanding of the challenges and opportunities associated with integrating different elements of the energy system on Orkney.

What have been the barriers? What impacts have they had?

1. Muddled and inconsistent analysis, advice and energy policies at UK, regional and local levels which seek to characterise and deal with the average situation.

This fails to recognise diverse and differentiated energy system issues which exist at an individual consumer, community and location level and reduces the challenge to a non-existent typical situation.

Outcome: Lack of focus and commitment on the imperatives of: universal access to and affordability of energy system services; rapid transition to decarbonisation; system reliability and security; role of energy system solutions as a driver for community, economic and industrial development. This in turn reduces momentum and levels of financial backing for change. It also fails to unleash the capacity and talent of progressive and disruptive innovation which will be necessary to put a just and meaningful carbon transition into effect.

2. Existing regulatory arrangements limit the ability of SLES to deliver benefit to customers particularly in generation constrained areas like Orkney.

In particular, consumers do not have a right to supply their own demand from renewable generation behind their own meter and there is no requirement for DNOs to procure flexibility in generation constrained zones. In addition to specific limitations, ReFLEX faced a lack of flexibility around how existing frameworks are applied which has limited its ability to demonstrate potentially important new models.

Outcome: Through discussion with Ofgem and the local DNO this issue is now clearly defined and identified as an important barrier to the delivery of SLES within a generation-constrained area. In combination with other barriers this leads to exclusion of disadvantaged consumers from the potential benefits of SLES

3. A focus on bilateral arrangements between consumers and technology/service providers in a SLES.

Most organisations involved in delivering a SLES require a direct relationship with end-users. This includes manufacturers, service providers, financing companies, and operators. The result is a complex customer experience where users themselves have to line up the full range of products and services needed to benefit from participating in ReFLEX.

Outcome: Original plans for a one-stop shop model for the ReFLEX Engagement Centre had to be adapted with the project providing customers with support to engage with multiple organisations rather than acting as a single point of contact for all ReFLEX related activities. It also highlights the unsuitability of existing regulations for the development of SLES.

4. Long payback periods of 15 years or more combined with significant debt risk for investors affected the financial viability of the no-upfront-cost model for domestic PV and battery systems.

In addition to the challenges, the project initially expected for this element of ReFLEX, risk to investors was increased due to the lack of right to self supply for customers (see above). This meant that behind-the-meter generation and storage could be curtailed by the DNO regardless of the customer’s current demand and introduces significant uncertainty around the likely output of the PV system and therefore revenues to repay investment.

Outcome: Delivery of domestic PV and battery systems were descoped from the delivery but ReFLEX has developed a clear understanding of the factors affecting financial and regulatory viability of future projects.

What are the key lessons learned?

Technical

Integrated Energy System

- **Connection to an active network management scheme (ANM) via an API and an electricity aggregator could be a feasible and cost effective way for small scale (less than 50 kW) generators and batteries to access non-firm connections.**

  Orkney was Britain's first ANM scheme with distribution connected renewable generators able to connect under new non-firm ANM rules since 2009. This allowed generators to connect without upgrades of the local distribution network, in particular the highly expensive undersea cables linking Orkney's outlying islands and Orkney's mainland itself to Scotland. However, this meant that those generators could be curtailed by SSEN, the DNO, when needed to keep the network secure. Some generators have faced higher levels of congestion than expected, for example the 900 kW Rousay, Egilsay and Wyre community turbine was estimated to have had 60% of its potential generation curtailed.

  Connecting to the ANM scheme requires complex and expensive communication and control equipment which links to the ANM control hub. This equipment is appropriate for large scale generators but the costs are beyond what is feasible for smaller scale installations.

  ReFLEX has helped to identify an alternative route to the full ANM connection for small scale generation of below 50 kW through an API based integration with an electricity aggregator. This is important for the future development of ANM and smart grid architecture as it will lower the threshold to participation by smaller generators and flexibility providers, a critical step for the realisation of SLES models. ReFLEX was unable to implement the new approach due to uncertainties over the level of curtailment that small scale generation would face (see below). There is an opportunity for future innovation projects to take this forward.

Regulatory and policy

Integrated Energy System / ReFLEX concept and approach

- **Under existing regulations, DNOs have the right to limit self-supply of renewable electricity generated behind the meter.**

  There is currently 57.10 MW of network-scale generation operating across the Orkney distribution network. The level of curtailment experienced by this capacity is a function of the overall electricity demand seen by the Orkney distribution network. To protect this capacity from further curtailment, SSEN has taken the decision to limit the connection of micro-generation behind the meter. Very small scale generation and battery storage, less than 3.68 kW for a typical domestic or small business connection, or 11kW for a three phase connection, can still connect and notify the DNO. However, anything larger needs to connect via the ANM and will be subject to its output being curtailed.

  Engagement with Ofgem through the sandbox approach has clarified that SSEN has the right to apply this curtailment at the level of the individual asset rather than at the property's electricity meter. This means that the generator or battery will not be able to produce electricity even if it is fully used behind the property's meter with no export onto the electricity network.

  The implication is that consumers on Orkney no longer have the right to supply their own demand from their own generation. Their expected demand has already been factored into the calculation of curtailment faced by generators connected directly to the network.

  The reduction in scope of the ReFLEX project is, in part, a consequence which has reduced the ability to connect PV and battery systems and support a significant reduction in consumers' bills. This element of the project was designed as a root for those who cannot afford the upfront expense to receive the benefits of flexible behind-the-meter systems.

What are the key lessons learned?

Business model and business practices

ReFLEX Orkney Ltd / ReFLEX concept and approach

- **The business model for an integrated energy system operating in a local context represents a major departure from any existing energy business model.**

  It requires a reimagining of all aspects of the energy system and operating models. In addition to changes to regulation and legislation, delivering SLES involves setting up new business entities along the lines of those developed in ReFLEX.

  An example of the new ways of working is the need for the project to set up ReFLEX Global – an entity which holds access to IP building blocks owned by individual organisations but required in order to deliver the IES. ReFLEX Global then makes IP available to individual applications on an as required basis through appropriate pre-agreed licence mechanisms that provide benefits to the originators whilst supporting the implementation team.

  The project has estimated that setting up a ReFLEX model requires an initial budget of £1M for set-up and £0.5M per year to operate.

Technology business models

- **EV charging can support reduced curtailment where EVs are co-located behind the same network constraint with potential to deliver revenues to customers.**

  Analysis shows that an EV with an average Orkney usage of 7,700 miles-per-year could deliver an additional revenue into Orkney of around £100 a year by reducing curtailment of Orkney's generation capacity, assuming that wholesale electricity and associated low carbon support is valued at £150/MWh for generators. This reflects the subsidy support received for Orkney wind farms through the ROC and FIT schemes.

  Whilst this is potentially a significant value stream, it is important to note that the revenue would need to be split between three partners: the generator whose curtailment is reduced, the operator of the smart management scheme, and the EV owners. In addition, these values assume that a third of the EVs charging can be met from otherwise curtailed generation, a fraction that may be tricky to achieve in the major settlements on Orkney as these are in a network zone with relatively low levels of curtailment (circa 5%). More opportunities would exist in the outlying zones where curtailment can rise to 30% or higher.

Technology business models

- **The proposed 'no-upfront-cost' model for PV and battery installations requires private investment of up to £8,000 per home with payback periods of 15 years or more and significant investment risk.**

  The model planned to use the external investment to fund the initial capital cost of the PV and battery system and repay that investment from savings on the purchase of electricity and from providing flexibility services such as Firm Frequency Response, Balancing Mechanism trading and local curtailment avoidance over the lifetime of the system.

  ReFLEX scoped out a system with upfront spending funded by SMS through a combination of the Innovate UK grant and debt funding. The customer would sign up for a specific tariff with a partnering energy supplier and pays a discounted rate for PV generation that is self-consumed in the property. The supplier passes this revenue to SMS to support repaying the initial investment.

  Modelling estimates that the payback period for the initial investment could be fifteen years or longer. This would require both investors comfortable with long-term financing and end-users prepared to enter contracts of that length.

What are the key lessons learned?

Business model and business practices

The long payback period accentuates several risks that are challenging to mitigate for the investor. These include managing the risk of technical faults, customers who default on payments, issues where properties are sold or rented, uncertainty over the future of the flexibility service market, and concerns over whether partner organisations such as the energy supplier will remain committed to the model throughout its lifetime. Mitigation measures for managing debt risk, such as applying a cancellation charge or removing the equipment from the premises, have been explored and, on the whole, found unviable under current arrangements.

Future projects must remain aware of these challenges and note the outcomes of the ReFLEX financial modelling. However, had the scheme been confident in the ability to access significant curtailment reduction revenue (see above), this may have changed the economics for Orkney.

It would be valuable for future ANM scheme designs, such as those that will likely be brought forward as part of broader DSO reforms, to build in the expectation of domestic and small-scale commercial flexibility directly into the rationale and design of the initial smart grid schemes themselves.

Social and community

ReFLEX Orkney Ltd

- **Data protection law, warranty terms and conditions, and Financial Conduct Authority (FCA) regulations limit the ability of ReFLEX's Experience Centre to act as a single point of contact for ReFLEX members.**

ReFLEX's initial objective had been to create a one-stop shop where ReFLEX members were able to arrange all elements of their experience despite these being delivered through multiple businesses behind the scenes. It would have joined up commercial products with grant funding or affordable finance. This would simplify the customer journey allowing ReFLEX Ltd. to coordinate the multiple business links needed and provide the seamless and easy customer experience required for a successful SLES.

For example, a ReFLEX customer who leases an EV, purchases a Smart EV ChargePoint and participates in flexibility provision might need to engage with eight organisations (EV retailer, EV broker, and EV finance company; Smart EV ChargePoint providers, Smart EV ChargePoint installer, Energy Saving Trust and OLEV for grant funding, and ReFLEX Orkney Ltd).

However, the project discovered several limitations to what is possible. Warranty conditions form a contract between product owners and manufacturers and standard terms and conditions require the owner to engage directly with the manufacturer. For smart EV chargers, the owner was the ReFLEX member who had to engage directly with the manufacturer over any faults. For EVs themselves, the owner was the finance company with whom the ReFLEX member had to engage over any warranty issues.

Data

Data

- **The highly local context of ReFLEX in a small community on Orkney combined with the use of multiple data sets across a complex, multi-partnered project needs detailed planning and resource from the start.**

Delivering a data-driven project in a small community made data privacy, security and governance 'real' for ReFLEX. ReFLEX members and participants are often friends, family members or acquaintances of the ReFLEX team. The project wanted to go beyond simply meeting the formal requirements of GDPR and other regulations to ensure that the data approach was as transparent and accountable as possible.

This was particularly important when combining data sets, each one of which maintained anonymity, but when combined could lead to the identification of individuals. This meant the project had to instigate more rigorous reviews of combined data sets.

What are the key lessons learned?

Data

As with many PfER projects, the experience of ReFLEX suggests the need for future projects to allocate greater resource to data management and to ensure that suitable expertise are available to the project. For example, ReFLEX recommends that data scientists are involved early in the project to ensure greatest value can be derived from the data, and a data protection specialist is involved to support early creation of a data strategy. This would support a consortium-wide approach to data governance, for instance, licensing data sets for all consortium members rather than individual partners.

Carbon

Data

- **The carbon savings from interventions in the energy system vary significantly across the country, it is important that carbon calculators reflect local conditions.**

Many organisations provide carbon calculators for businesses and households to benchmark their existing carbon footprint and to estimate the likely impact of changes to the way they use energy. However, the majority of these are built using national estimates of the impact of each intervention. ReFLEX Orkney shows the value of constructing carbon calculators to reflect local conditions. For example, the carbon value of reducing renewable curtailment is significant in a grid-constrained area such as Orkney. Moving energy demand, including heat and transport, to flexible electric demand and aligning with periods of curtailment can have a larger carbon impact compared with similar actions elsewhere in the country.

There are challenges in accessing good quality data to support local carbon calculations and future projects, as well as aiming to ensure that carbon calculations truly reflect the local impact on carbon emissions, need to be aware that access to data from third parties may be limited and data quality variable.

> “ReFLEX was very helpful and sent all the relevant forms and instructions to apply … I am thoroughly enjoying the EV experience and with a home charger, it is easy and economical.”
>
> **Charles Groundwater, new EV owner and ReFLEX Orkney member.**

How does this help solve whole system challenges?

Smart

Developing the IES control platform and delivering the curtailment reduction methodology and trial are key elements and examples of the smart systems needed to make integrated energy systems a reality. ReFLEX shows the importance of people-centric 'smart'.

Local

ReFLEX is strongly based in Orkney and draws together the community from across the islands to help solve important energy system challenges and maximise the use of Orkney's renewable resources within the community. The ReFLEX approach provides an improved way of approaching energy challenges at the grid edge and in remote rural areas.

Whole energy system

The IES represents a truly whole-system approach which builds on Orkney's history of developing innovative ways to integrate electricity, heat and transport and integrate hydrogen into a rural energy system.

Who is prospering?

✓ **Orkney residents:** Through improved access to EVs, smart charging and supporting flexible electricity tariffs and through the ReFLEX Orkney Ltd organisation which aims to developed the islands' Integrated Energy System over the coming years.

✓ **Local renewable generators:** Through reduced curtailment in the demonstration phase and the potential for the future curtailment -reduction schemes.

✓ **Orkney Island Council:** Through a significantly increased understanding of Orkney's energy system and opportunities for delivering a net zero Orkney.

✓ **UK citizens:** Through the identification of key regulatory barriers which currently limit the ability of SLES projects to support social inclusivity, and a growing national debate on what needs to change.

✓ **ReFLEX commercial partners:** Through improved understanding of market opportunities, barriers and risks. The advancement of technologies, business models and networks which can be exploited outside of the project.

✓ **The national economy and energy system:** Through the ability to replicate the ReFLEX approach quickly and at reduced costs and through understanding of a more sustainable pathway to a zero carbon energy system. National stakeholders benefit from improved understanding delivered through more than 100 presentations at local, national and international events.

More information:

- ReFLEX homepage
- Email: John Thoules, info@reflexorkney.co.uk

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Demonstration project

SmartHubs

SmartHubs, focused on the West Sussex region, aimed to use an intelligent virtual power plant concept to help shape the way energy is generated, stored, and supplied to homes and businesses.

Project summary

SmartHubs aimed to use a an intelligent virtual power plant (VPP) concept to help shape the way energy is generated, stored and supplied to homes and businesses. The VPP aimed to combine generation and demand of energy across electricity, heat and mobility. The project, based in West Sussex, planned grid connected and behind-the-meter energy storage, a hydrogen electrolyser, PV generation, and a large scale marine source heat pump along with air source heat-pumps in individual buildings. A smart VPP platform aimed to dispatch and optimise the low-carbon energy fleet to deliver cheaper energy, the provision of flexibility services and support a stronger, cheaper, cleaner network.

Key project elements

- **Virtual power plant platform:** The development of a VPP platform, which optimised the dispatch of resources and communicates with and controls the individual assets which form the VPP.
- **Energy storage:** Development of a 12 MW/14.4 MWh grid-connected battery energy storage system, nine 400 kW behind-the-meter batteries, and 250 smart photovoltaic battery systems.
- **Hydrogen:** A 2 MW electrolyser to enable onsite generation of hydrogen for a bus and passenger car refuelling station.
- **Low carbon heat:** 250 air source heat pumps in domestic social and private housing and a large scale marine source heat pump, plus interseasonal heat storage system for the Shoreham Port Authority building.

What was the outcome?

- Shortly after the project was funded the partners identified significant barriers to delivery. This was related to incompatible requirements of the project as initially planned and the public procurement processes that West Sussex County Council is required to use. This led to the project being restructured and restarted in December 2019.
- Despite the restructure, it did not prove possible to deliver the complex, innovative VPP model within the constraints imposed by the public procurement process and project funding. Public funding for the project was stopped early in March 2021.
- There were some successes, including improvements to heat pump flexibility forecasting and the development of data management processes suitable for agile SLES projects.
- Work on several aspects of SmartHubs has been taken forward since project closure. This includes: the grid scale battery where investment of £23 million has been secured for a 24MW/20 MWh installation, twice the capacity of the original proposal; development of a £5 million PV behind-the-meter solar and storage programme across schools and corporate buildings; and the set up of a Future Energy Transition Hub to harness the skills, knowledge and resources of local organisations.

What have been the barriers? What impacts have they had?

1. Public procurement processes are designed to ensure efficient spending of public money. They require significant resource and time and can place significant constraints on delivery which need to be factored into the design of any local energy project from the start.

The SmartHubs project underestimated the challenges posed by procurement and failed to design a project that fitted within the constraints imposed.

Outcome: Identification of the scale of procurement challenge soon after funding was awarded led to the project being paused and restructured. However, ultimately the project was unable to find a procurement model that matched with the timescale and requirements of innovation funding and closed early.

2. Lack of early engagement with stakeholders:

The project lacked implementation of a detailed stakeholder engagement plan or a consortium wide strategy for working with key stakeholders.

Outcome: Additional challenges were created as the needs and potential roles of key stakeholders were not fully understood. The project also faced a lack of support from some stakeholders, such as local councils, early in the project.

3. The objectives and required functionality of the VPP changed through the early exploratory phases of the project leading to a misalignment of expectations across the project:

The VPP had to be rescoped three times and the final design differed significantly from the one proposed in the original application.

Outcome: Significant divergence in expectation between project partners and stakeholders, including Innovate UK, as to the role and functionality of the VPP.

4. There was a tension between the commercial and innovation drivers for the project:

The consortium included four SME organisation with UKRI funding at 35% and private finance at 65%. Although the Technology Readiness Levels (TRL) for individual technologies was high, readiness of the commercial, smart control and integrated-system elements were lower

Outcomes: Project partners needed to operate within constraints imposed by their commercial funding and the need to ensure a return to investors. This sometimes conflicted with the innovation need to demonstrate and trial new solutions, which could reduce commercial returns.

What are the key lessons learned?

Technical

Virtual power plant platform

- **The nature of the diverse range of technologies considered under SmartHubs, each with different cost and revenue streams, means that their control and aggregation was difficult to align within the overall objective of the VPP.**

The specification of the VPP at the start of the project was at a relatively high level reflecting the uncertainty, at that point, around the final technology and services mix that the project would deliver and the final objectives for operation and dispatch.

Having a dedicated partner who understood each of the technologies and their markets, and led VPP development, would remove some of the issues faced by SmartHubs, allowing other partners to focus on delivering and installing their assets. The VPP plan should also have included the DNO from the beginning to support the development of the virtual market and ensure planning was in line with the DNO capacities and strategy, helping to target grid constraints effectively.

Low carbon heat

- **Although off-gas grid homes provide the clearest benefit of any housing groups for heat decarbonisation, the project identified that off-gas grid homes can also represent one of the hardest part of the market to decarbonise.**

The technical challenges faced included the age and configuration of homes, construction type, the prevalence of microbore piping (not suitable for hybrid heat pumps), wet underfloor heating (not compatible with the smart controls), listed homes (requiring planning permission), a lack of insulation (needed to be eligible for RHI); and DNO limitations (primarily due to the presence of an EV charger). The project noted a comparison with the Freedom Project delivered by Wales and West Utilities, which surveyed 78 on-gas-grid homes, with only six deemed as unsuitable to proceed.

This is essential learning for future heat decarbonisation projects, which, for good reasons, aim to focus on off-gas-grid areas. There may be substantial benefits in theory regarding bill reductions, more investable propositions and reduction in fuel poverty. However, it will be vital to carry out detailed surveys early in the process and avoid undue optimism bias.

Business model and business practices

All elements

- **The public-sector procurement process was fundamental to the successful delivery of the SmartHubs programme. However, there was a lack of understanding across the consortium and the limitations that procurement places on the project were not fully recognised.**

A key challenge for SLES is the need to combine multiple individual elements to deliver the final project. Generic versions of many elements are available in the competitive market, but innovative SLES demonstration project often involves adapting existing products to integrate with the broader system. This may be achieved by the SLES project procuring all of its products and services from consortium partners without going through a standard public procurement process.

The learning from SmartHubs is that this approach does not fit public-sector procurement needs.

Early discussions with legal experts can highlight the concerns with appointing consortium partners to install the technology on public buildings without going through an appropriate public-sector procurement route.

However, even with earlier awareness of the needs of the procurement process, it is still likely to be challenging to attempt to define the procurement scope early on, as the innovation challenge and potential solutions still need to be fully understood. SmartHubs would have benefited from a model where, before the procurement, there was a project development phase where the technology scope and site recruitment could be completed.

However, this would need greater flexibility in the use of innovation funding as the project's spending has the potential to change significantly between the initial award and the start of procurement.

What are the key lessons learned?

Business model and business practices

All elements

- **There was a divergence in the requirements and preferences from different stakeholders regarding the Special Purpose Vehicles (SPV) needed to deliver the commercial elements of the project.**

  SPVs are commonly used to manage the finance arrangements of multi-party investments and form part of many SLES demonstration projects. A range of SPV models includes simple joint ventures and more complex relationships involving site ownership, capital investment, and project revenue flows. As with other project elements, the design of SPVs needs to consider public bodies' procurement obligations and limitations. A local authority may need to procure the services of the SPV to deliver all or part of the project.

  One of the SPV models explored by SmartHubs involved commercial partners and a local authority. The most streamlined and flexible SPV form would have had the local authority as a direct signatory providing long term security for investment and more straightforward project expansion in the future. However, this model would have created additional procurement processes for the local authority.

  One potential model identified would involve a local authority procuring one body, such as an SPV, to deliver all the technologies within the programme, with one revenue stream back to them via a power purchase agreement, energy service agreement or similar agreement.

  Technology partners would then work within that SPV to deliver the simplified end service to the local authority. However, this could be challenging within current innovation funding frameworks due to the need for substantial time and resources to scope and agree with an appropriate consortium and bring funders on board.

  SmartHubs' experience suggests that there is value in developing a greater understanding of SPV options and limitations within the public sector.

Virtual power plant platform

- **A VPP project involves significant interaction with the local DNO's network. It is important to involve the DNO early, in a strategic way, and ideally consider asking them to become a project partner.**

  Within SmartHubs, engagement with UK Power Networks (UKPN), the local DNO, was carried out separately by each consortium partner without an integrated approach. During one project element, there was also a challenge when UKPN was directly contracted by West Sussex County Council and so was unable to speak to commercial SmartHub partners.

  As UKPN is a primary stakeholder in this project, it would have been beneficial to have them involved earlier in the project and throughout, perhaps even as a partner. This reinforces learning from several previous local energy projects, including Centrica's Cornwall Local Energy Market project.

  Any SLES looking at the electricity vector should ensure that a strategic approach to DNO engagement is embedded from the start. The SLES should consider directly involving the DNO as a project partner and identify opportunities to align their project with DNO innovation activity.

What are the key lessons learned?

Social and community

All elements

- **Early and well planned engagement with stakeholders and the wider community ahead of the application and early in the project would have helped build support and identified constraints.**

  Stakeholder engagement, including with the public, is important throughout a SLES project. Early on, it helps build momentum and support for a project. It helps frame the challenges and solutions and identify opportunities and barriers to the proposed approach. Later in the project lifecycle, it ensures a strong takeup of products and services, allows delivery to be refined, supports effective dissemination of learning and identifies follow-on opportunities.

  SmartHubs identified the importance of developing a fully thought through strategic engagement plan and carrying out detailed and specific engagement with critical stakeholders, such as social landlords likely to be the end-customer, ahead of the final VPP concept.

  Since the closure, West Sussex County Council has developed a Future Energy Transition Hub to harness partners' skills, knowledge and resources to support local energy communities to take ownership of their local energy transition. It will own resources such as the Local Area Energy Plan/Pathway and can fill one of the main missing links between national policy and local ambition.

  One of the challenges faced was the coordination of public awareness campaigns and critical project decisions. West Sussex County Council was reluctant to promote the SmartHubs project too early as they could be seen as endorsing a product that had yet to go through a compliance process.

Finance and investment

All elements

- **A feasibility period at the start of any future grant funded innovation project could ensure that the project is shovel ready at kick off and capable of delivering the technical work packages.**

  Innovate UK made public-sector funding for SmartHubs available via a single funding decision. This was based on a detailed proposal submitted in July 2018, including a complete project plan from inception to completion and well-defined milestone and work packages. This funding was conditional on match funding from project partners and defined against specific costs.

  Many of the challenges faced by SmartHubs relate to the fact that once started, it was clear that key elements of the scope, project plan, milestones and costs needed to change to deliver the project's overall objective. In reviewing its experience, the SmartHubs consortium suggests that there would be value in a more flexible model for public-sector funding based on an initial feasibility stage leading to a 'Stage Gate 0'. During this period, the scope may be changed from the original application, assuming changes are well justified, to increase its likelihood of success.

  During a feasibility period, SmartHubs would have been able to develop a detailed stakeholder engagement plan, including, for example: agreeing on formal memoranda of understanding; seeking legal and financial assistance to provide advice on specialist issues such as procurement; carrying out high-level master planning; and firming up technical designs to account for the more detailed project understanding.

Who is prospering?

✓ **Future SLES projects:** Through access to the experience of SmartHubs and greater understanding of the barriers that will face any SLES project. In particular the challenges associated with delivering complex integrated systems in partnership between the public and private sectors.

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Smart local energy systems: lessons for innovators

Detailed design projects

Detailed design project

Project Girona

The project has installed batteries and solar panels in 62 properties in Coleraine, Northern Ireland, including households and community centres.

Project summary

The project has installed batteries and solar panels in 60 properties in Coleraine, Northern Ireland, including households and community centres. These are operated to reduce bills for customers through maximizing the use of energy from the solar panels in the property, storing excess energy in the batteries, trading in the wholesale electricity energy market, and providing services to the local Distribution Network Operator.

The project has developed software that optimises and dispatches the resources across four value streams: use it within the property, store it in the battery, trade it on the wholesale energy market, or deliver network flexibility services.

Original objectives	1. Help reduce emissions and have cleaner air. 2. Collect data to build local clean energy community. 3. Build a business case for Northern Ireland. 4. Reward customers. 5. Save customers 25% to 40% on energy bills. 6. Reduce fuel poverty and increase electric heating. 7. Test, learn and revolutionise.

Key project elements

- **PARIS platform:** A smart optimisation and dispatch engine that brings together forecasts of energy production, energy forecasts, network constraints and market prices and dispatches resources to maximise the benefits to the end-consumer through highly efficient purchasing, storage and recycling of electricity in the local market.
- **Solar panel and batteries:** Installation typically of 3.3 kWp solar panels and 3.68kW/11kWh batteries in 62 domestic, social housing properties, two farms and two community centres communicating via APIs to the PARIS platform.
- **Grid integration:** The project has supported the DNO and the electricity system operator by using the flexible components to reduce power flows through a constrained primary substation at times of peak demand and generation and by providing frequency response to the all-Ireland electricity system.

What have been the successes? What has been delivered?

1. Significant reduction in electricity bills for 62 households including social housing, a significant number of whom were in fuel poverty.

Savings are estimated at £27,000 over the period of 18 months, equating to an average of £450 per property. Savings for individual households have been between 40% and 60% of the total bill and this has been delivered in an area where around 30% of households are in fuel poverty.

2. Generation of 172 MWh of renewable electricity in an area where with limited network capacity under traditional connection arrangements.

Solar panels generated, on average, around 2,800 kWh per installation, equivalent to more than a full year's electricity demand for a typical domestic property. The batteries meant much of this generation could be used within the property with only 18% being exported.

3. Delivery of grid services to NI Electricity Networks to manage loading on the network.

Batteries were managed to minimise loading on the local distribution network ensuring that the heavily loaded local primary substation was not strained. Project Girona has also won contracts to deliver voltage support to the DNO providing an additional income stream and adding further resilience to the network.

4. Early success in commercialisation of the PARIS platform with two major contracts agreed and wider investment to project partners.

Girona has led to PARIS being ready for deployment. It has been sold on a white label basis to an electricity retailer in the Republic of Ireland. In addition, a PARIS is being used by a major agricultural food producer to design the optimum deployment of renewables and storage across five factories, 22 retail stores and hundreds of farms, again in the Republic of Ireland.

What have been the barriers? What impacts have they had?

1. COVID-19 led to significant issues including customer recruitment, the ability to install batteries inside houses, and the ability to deliver heat electrification elements of the project.

COVID-19 was an extreme example of the need for resilience within a project and led to wholesale changes to key parts of the plan. The ability of the project to respond in an agile way was an important component of keeping the project delivering.

Outcome: Significant reorganisation of the project including moving recruitment of participants later and relocating many of the battery installations to the outside of properties to reduce contact between trades people and householders. In turn this led to the need to design, certify, and manufacture a waterproof cabinet for external battery installations. The heat electrification elements of the project had to be de-scoped as COVID-19 meant the project missed the summer season for installation of heating systems.

2. Lack of existing expertise within housing associations.

This included a lack of pre-existing contracts and legal agreements for delivering this type of project with tenants.

Outcome: This led to delays in starting the participant recruitment. In response, the project made more resource available, including legal expertise, to draw up bespoke documents which were agreed with housing associations.

3. Tenants were initially sceptical about installations despite no personal financial commitment and a clear benefits case.

This was largely due to a lack of understanding of the projects and nervousness about whether benefits would be delivered.

Outcome: The project pivoted to deliver early demonstrator installations in two community centres, leading to clear visibility of the solution and community organisations becoming trusted advocates to encourage early adopters.

What are the key lessons learned?

Technical

PARIS platform

- **The combination of the PARIS platform's four operating modes – use it, store it, trade it and network services – in a single optimiser creates significant value and allows it to be applied to a wide range of applications.**

  Many smart-energy-management systems offer a subset of these modes of operation. By developing a platform that can optimise across all four, PARIS is able to support:
  - Suppliers wishing to plan their energy purchasing in the day ahead and intraday wholesale energy markets.
  - End consumers with multiple behind-the-meter assets wishing to minimise their bill against a supplier's
    retail tariff and maximise the value of their onsite assets.
  - A DNO (or future DSO) in delivering through a local flexibility scheme.

- **The use of high-end software products such as high-speed real-time databases and a product build that considers the technical interface needs of clients and stakeholders is valuable.**

  The PARIS product is built with high-specification components. It is designed to provide data interfaces compatible with industry systems such as SCADA, typically used by network companies, generators and large users. These two features increase the appeal of the products to potential clients and promote flexible and well-managed data and technical interfaces between the systems. In addition, the project invested in NEPLAN, a technical power flow software solution used by the local DNO. It used this to plan the electrical infrastructure associated with its connection resulting in outputs familiar to the DNO.

  Project Girona shows value in future projects considering the build quality of their digital products and investing in ways to support the interface with key stakeholders, both to support communication of complex challenges and to automate data transfer.

Regulatory and policy

PARIS platform / grid integration

- **Northern Ireland offers an alternative set of regulatory, legislative and market structures useful for comparison with the Great Britain system.**

  Northern Ireland is part of Ireland's Integrated Single Electricity Market (I-SEM), which has several critical structural differences from the GB electricity market and has a higher penetration of variable renewable generation. The Utility Regulator, rather than Ofgem, regulates the electricity sector in Northern Ireland.

  These differences provide an alternative set of arrangements to trial SLES projects, providing an experience that UK innovators, regulators and policymakers may find helpful when considering reforming innovation models. SLES designs could be validated and stretched using the higher level of variable renewables on the Irish system with learning adapted and scaled up to serve the GB model.

  However, there is a risk that the differences between Northern Ireland and the rest of the UK limit the flow of learning back and forth between the two systems.

> "We couldn't recommend this technology highly enough; we store our own energy and our family has benefited. We used to pay £25 a week in a pay-as-you-go meter, now we pay less than £10. We don't have to do anything. The battery and solar panels work; we are now aware of our contribution to carbon as well, which we never thought about before."
>
> **Gerard Deeny – residential customer**

What are the key lessons learned?

Business model and business practices

All elements

- **The project stakeholder group has supported smooth delivery and expanded impact.**

  Prior to the project receiving funding from PfER, Project Girona set up a project steering group including the DNO for Northern Ireland, the Electricity System Operator, the regulator, a customer advocacy body, Northern Ireland Housing Executive, local authority and NI Government. The group advised the project and provided a sounding board as it evolved. An important role of the steering group was to ensure that key stakeholders were aware of what was happening and therefore ready to respond. It also ensured that key strategic challenges were identified as early as possible and that the project's impact, for example on regulatory reform, was high.

All elements

- **Resilience should be made a cornerstone of any SLES project.**

  Project Girona faced some challenges which had the potential to end it early or drastically reduce scope. Although COVID-19 caused many of these, several had implications which would have likely affected the project even without the pandemic. For example, initial plans for battery installations were changed from internal to external locations. This was partly to reduce the level of work which had to be undertaken within properties and reduce COVID-19-related risks. It also reflected a growing recognition that many target homes had limited space. Delivering external installations required designing and manufacturing an external battery cabinet and IP66 certification (waterproof, outdoor protection suitable for electrical equipment).

  Within innovation projects such as those required to deliver SLES, significant adaption to the original plans is likely to be needed to overcome unexpected challenges or exploit unanticipated opportunities.

Solar panels and batteries

- **Significant time, cost and expertise need to be allocated to developing legal agreements and contracts for innovative smart grid approaches to energy.**

  An early stage of the project was to formalise agreements with social housing providers to allow Project Girona to approach tenants. Although there was agreement in principle before the project started, converting this into legal agreements and contracts with which to approach tenants was challenging. The innovative nature of the offer meant that no existing templates were available, and new documents had to be drawn up from scratch.

  Future projects should consider the contractual and legal agreements their project is likely to need and identify if current documents exist that can be used.

Grid integration

- **There is value in focusing significant effort on understanding the issues faced by the DNO and learning to speak their language.**

  Several of the Project Girona team had previously worked for NIE, the local DNO, and understood their challenges and the traditional way in which the network is managed. The engagement started well before the project. Project Girona treated the DNO as a direct client, identifying areas where the project could support the DNO in delivering its objectives. This approach resulted in significant goodwill, which helped progress the project.

  An example is revision of the G99 grid connection process. This details how small-scale generation of more than 16 amps per phase should be connected to the distribution network and was required to connect PV panels and batteries under Project Girona. The project worked with NIE to improve the application process and incorporate more detailed modelling. NIE application success rate rose from 90% to 100% under the new process, and the turnaround time for NIE to approve applications reduced from 12 to 14 weeks, to 2 to 3 weeks.

  The experience of Project Girona suggests that there is value in making time to fully understand the challenges faced by key stakeholders, such as DNOs, and aim to work with them to support their outcomes rather than focusing solely on the project deliverables.

What are the key lessons learned?

Social and community

All elements

- **It is important to find ways to build trust and demonstrate benefits to tenants and homeowners who may be sceptical about a new technology or passing control of their energy use over to a third party.**

  Tenants were initially reluctant to sign up to the project despite a clear financial benefit and no cost of participating. This reluctance may have been due to a lack of understanding of the system, nervousness about whether it would really deliver the benefit, and a lack of value-perception, which came from the fact that there was no cost to the end-user.

  To overcome this, the project installed Project Girona systems in two community centres in the local area. This provided an opportunity for residents to see the scheme in action and the cost savings being released in practice. The community centres and the organisations that operated in them were able to become trusted advocates for the scheme supporting a growing positive local narrative around Project Girona.

  Future projects need to consider how the early adopters on a scheme will be encouraged to sign up, particularly in areas where fuel poverty is prevalent, and householders may be nervous of moving to what appears to them to be a complex system.

All elements

- **Pre-payment customers start seeing bill impacts from day one.**

  Project Girona had initially assumed that the reductions in bills would be seen by residents when monthly or quarterly bills were delivered. However where payments were managed through a pre-payment meter with householders topping up weekly or even daily, the bill savings created by the solar panels and batteries were evident even during the first few days following commissioning. This had value in further advertising the scheme via word-of-mouth.

How does this help solve whole system challenges?

Smart

Project Girona has demonstrated Northern Ireland's first smart grid system through controlling PV and batteries via an innovative smart grid optimisation and dispatch platform. By developing and demonstrating the PARIS platform, the project has delivered a commercial product and operating model for future smart grids on the all-Ireland electricity system and beyond.

Local

The project has been able to overcome local network constraints which would otherwise have significantly limited the ability of the DNO to connect new capacity, showing the value of managing electricity supply, demand and flexibility on a local basis.

Whole energy system

The project has focused primarily on electricity with options for decarbonising heat and transport de-scoped primarily due to delays caused by COVID-19.

More information:

- Girona project website
- Project Girona - Northern Ireland's first smart electricity grid – YouTube

- Email: Anne Marie McGoldrick, annemarie@theelectricstoragecompany.com

Who is prospering?

✓ **Social housing tenants:** Across 58 households who are seeing savings in the range of 40% to 60% on their annual bills in an area where fuel poverty was already in excess of 30% before the current energy crisis.

✓ **The local community:** Through installation of Project Girona products at 2 community centres, which now benefit from zero-carbon generation and lower electricity bills.

✓ **NIE, the local DNO, and its customers:** Who have seen improved business processes developed in collaboration with the project, and increased flexibility available to manage local network constraints.

✓ **Electricity consumers across Northern Ireland and the Republic of Ireland:** Who benefit from cheaper and more automated provision of grid services such as frequency and voltage support.

✓ **Commercial partners:** Who are developing the Project Girona model into business as usual and are commercialising key products such as the PARIS platform.

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Detailed design project

GreenSCIES(Green Smart Community Integrated Energy Systems)

GreenSCIES has designed a smart energy system based around a fifth generation heat network, capable of decarbonising heat, power and mobility across the London Borough of Islington.

Project summary

The GreenSCIES consortium has designed a smart energy system based around a fifth generation heat network and capable of decarbonising heat, power and mobility across the London Borough of Islington. The design draws low-grade heat from local data centres and from the London Underground which is distributed between buildings through ambient temperature pipelines. Heat pumps are used to adjust the temperature in buildings, heating them in winter and cooling them in summer. There is also a link to the London Aquifer which can store heat between summer and winter. Distributed energy centres connect PV, EV chargers and energy storage at electricity hubs which can supply energy to run the heat pumps, act as hubs to support low carbon transport, and deliver demand side response to the electricity system.

Key project elements

- **Built around a fifth generation heat network:** The GreenSCIES model integrates mobility and electricity vectors with a heat network distributing water at close to ambient temperatures combined with highly efficient heat pumps at individual buildings providing heating and cooling.
- **Community engagement:** The GreenSCIES model has been developed through detailed engagement and co-design with the local community and stakeholders to ensuring that SLES supports the broadest possible set of local ambitions, including energy, improvement of the local environment and community benefits.
- **Centre of excellence:** A hub providing the skills, knowledge and services needed by local authorities and other organisations across the UK to deliver smart local energy in their own regions.
- **Decarbonisation case studies:** Developed through the centre of excellence and showing the applicability of the GreenSCIES model to other areas across the UK. This includes the use of an automated feasibility tool to identify new opportunities.
- **Policy and regulatory review:** Covers current energy system policies and regulatory barriers relevant to SLES, which identifies blockers to the delivery of SLES in general and the GreenSCIES approach specifically.

What have been the successes? What has been delivered?

1. Detailed design of GreenSCIES for a third of the London Borough of Islington.

This has the potential to meet the energy needs of around 62,000 residents and 45 business/other organisations. The design could deliver 132 GWh of low carbon energy and mitigate fuel poverty for up to 1,700 households.

2. Investment and site secured to deliver the New River Scheme in Islington.

This will act as a demonstration of the GreenSCIES concept and deliver decarbonisation for around 9,000 people and 10 businesses. The scheme includes 6 large scale heat pumps with a combined capacity of 9 MW, 610kW of PV, and 39 EV chargers, all connected through a GreenSCIES 5th generation heat network and distributed energy hubs.

3. Case studies completed for seven schemes using the GreenSCIES model including opportunities in Greater London, Bristol, the West Midlands and South Yorkshire.

These identified heat recovery opportunities across manufacturing industries, hospitals and supermarkets and inter-seasonal heat storage opportunities in aquifers and mine water. All 7 show significant carbon savings and have the potential to be taken forward to development.

4. Successful development of GreenSCIES business plan.

This shows an internal rate of return around 10% and can deliver an 80% reduction in carbon emissions. The plan is based around a shared approach to funding, multiple value streams across mobility, power and heat, co-designed with the local community and delivery of a shared vision across multiple stakeholders.

5. The centre of excellence has begun working to replicate the GreenSCIES approach, deliver learning opportunities and share learning on a global stage.

For example, the GreenSCIES centre of excellence presented at COP 27 in Egypt sharing learning with those tackling the challenges faces cities in Africa. The centre has also developed training courses for those interested in developing SLES models and covering heat network development, domestic heat pump applications and a Green Skills Boot Camp.

What have been the barriers? What impacts have they had?

1. Institutional and consumer inertia can act as a barrier to developing and then engaging with new, innovative models for energy.

The project had to imagine a very different form of energy system and, critically, to overcome convention to ensure users embraced the opportunity of GreenSCIES.

Outcome: The GreenSCIES concept embodies this more creative approach to energy. Through collaboration and co-design at all levels, the project has ensured that, whilst novel, the model reflects the needs and values of each of its stakeholders. The result is an approach model that is now being delivered into operation.

2. Investors are unfamiliar with the complexity and business models involved in GreenSCIES.

This creates a nervousness which the project scope and structure needs to overcome.

Outcome: Whilst the project has shown that there is strong interest in investment and development in SLES, a key area of learning is how to structure a project to ensure that investors are comfortable with risk, timescales and level of returns. This can include combining financial and non-financial considerations such as local reputational impacts. For example, a local data-centre owner is keen to build its reputation for supporting the community through the use of otherwise waste heat.

What are the key lessons learned?

Regulatory and policy

Policy and regulatory review

- **To drive the uptake of SLES, more certainty in terms of roles and responsibilities for SLES is needed, along with greater coordination between national and local electricity markets.**

SLES schemes will need to combine multiple revenue streams across several energy vectors in order to deliver investable business cases. GreenSCIES has identified 14 potential SLES revenues streams relevant to its own business model and has RAG rated these in terms of accessibility under current policy and regulations.

The analysis highlights two revenues streams as red: optimisation of network access rights and peer-to-peer trading. Network access is normally offered at a fixed, flat capacity (the same capacity at all times) and there are limited opportunities for consumers or generators to optimise when they use their network capacity. Peer-to-peer trading does not fit with the current philosophy of a supplier-hub model for electricity retail meaning that a licensed supplier is required.

Four revenue streams are identified as green, meaning there are no policy related blockers (although delivering these through an SLES is still likely to face other types of barrier). Three relate to heat: inter seasonal storage of heat using an aquifer, sales of heat, and sales of cooling. The fourth involves providing electricity ancillary services, although there are no general policy barriers to GreenSCIES's distributed energy hubs providing these, it is important to note that each individual ancillary service has a set of technical requirements which need to meet. Ancillary service products and markets are evolving rapidly and future projects will need to become familiar with different markets and keep track of upcoming changes on a regular basis.

A further eight revenue streams are rated as amber and cover areas including wholesale electricity market trading, provision of flexibility to the DNO, and access to the capacity market and balancing mechanism.

SLES built around a fifth generation heat network

- **Heating and cooling are the most significant revenue streams for GreenSCIES and policy changes that affect the relative prices of gas and electricity will be material for GreenSCIES.**

Current arrangements for recovering the cost of support for renewable energy and energy efficiency involves collecting levies largely from electricity bills. In August 2021, environmental and social levies accounted for around 25% of an electricity bill compared with just 2.5% for gas.

Heat pumps, whether used as part of a heat network or on their own, use electricity as an input and compete against natural gas in the provision of heat. Moving the cost of decarbonisation policies away from electricity and onto gas will make heat pumps cheaper to operate and inherently more competitive.

The UK Government is expected to look at options to shift levies away from electricity and towards gas over the coming decade. Future SLES projects looking at ways to decarbonise heat should monitor consultations and decisions in this area and consider regular updates to its financial models to test the impact of emerging or proposed changes to these and other policies.

> **"GreenSCIES's approach is about sharing resources between building and applications. In doing so it's possible to deliver a cost-effective, near zero carbon local smart energy system. It is applicable to pretty much every urban area with a demand for low-carbon heat, power and mobility."**
>
> **Prof. Graeme Maidment,**
> **Director of the GreenSCIES projects**

What are the key lessons learned?

Business model and business practices

Community engagement

- **Successful delivery of SLES needs coordination across the community, stakeholders, and delivery partners.**

To be successful, SLES needs to balance multiple objectives. Projects need to be investable, deliverable, create value within the energy system and support wider aims and ambitions for the communities in which they are based.

GreenSCIES has developed an innovative co-design process which, following an initial stakeholder mapping exercise, involves an iterative process where design options are shared with stakeholders and are tested against each other. This ensures that, alongside engineering value, the project took a holistic view of Islington's existing infrastructure, considering how the energy system would fit into the wider public realm. Co-design enhanced the final model in three ways:

- Identifying important design features of the SLES itself: This included pinpointing the importance of ensuring flexibility in access to heat from the network. Local stakeholders identified limits on the times during which heat could be accessed under some existing heat network operating models; there was a strong desire to avoid this in the GreenSCIES design.
- Identifying potential areas of wider value: For example, local residents highlighted that upgrading infrastructure could increase the pride and sense-of-place that they experience, supporting initiatives to improve the local environment.
- Identifying areas of concern which the model could mitigate, for example, concerns about the degree of intrusion that might be associated with upgrading infrastructure within homes.

One particular group of stakeholders who need to be enabled to lead on SLES are local authority officials and elected representatives. Islington Council has been at the heart of the GreenSCIES project throughout and has integrated the vision of the project into its wider 10-year net zero carbon strategy. This involvement is an important part of the project's success, with the local authority driving forward a vision, acting as a convener to draw stakeholders together, driving innovation into practice through the planning system, and shaping potential projects.

Policy and regulatory review

- **The use of heat as the main network vector combined with the hub-architecture for electricity assets allowed many of the regulatory challenges associated with the electricity sector to be bypassed.**

GreenSCIES uses heat pipes to distribute energy around the SLES linking sources (data centres and the London Underground) with heat storage and heat pumps located in the hubs. Regulations for heat network reflect their characteristics as local infrastructures and ones in which ownership and operation will often link closely with the production, consumption and sale of heat.

By contrast electricity regulations are based on the historical assumption of a national system and are designed for a framework where network ownership is decoupled from generation and supply. This makes the development of electricity-based SLES challenging. Schemes need to comply with ownership separation rules or fit within limited exemptions which place significant limitations on the size and design of the SLES.

GreenSCIES integrates electricity by connecting multiple components behind the meter of a hub, where each hub has a single interface to the wider electricity system and can buy and sell electricity and flexibility in the same way as any other customer.

As SLES concepts mature, regulation and policy may change in a way that better supports electricity-based architectures. However, future projects may find it valuable to consider the learning from GreenSCIES and the relatively easy regulatory pathway it lays out.

What are the key lessons learned?

Social and community

Centre of Excellence

- **The upskilling of the local workforce will be essential for the successful rollout of SLES.**

Whilst the raft of national and local government net zero targets will drive demand for low-carbon goods and services over the coming years, it is crucial that there is a workforce in place to deliver the change needed. GreenSCIES highly recommends the establishment of nationwide educational and training centres that can support local authorities in building skills and creating local green jobs in energy efficiency, housing retrofit, low carbon mobility and other SLES related subject areas.

Central government has recently made several announcements which could help to stimulate green growth in these areas. A network of SLES training centres could support local areas to capitalise on these opportunities. In addition, SLES training centres should deliver a package of training, resources and guidance, to support the development of localised action plans.

Future projects need to remain aware of the potential for shortages in key skills and should actively work to support up skilling in the sector.

Finance and investment

SLES built around a fifth generation heat network

- **The investability of SLES can be increased by looking at opportunities to conflate opportunities and bring together value streams.**

GreenSCIES, along with many SLES projects, is about drawing together multiple elements into a coordinated, integrated whole to deliver greater value together. Some of those elements may be investable in isolation whilst others may not. SLES provides the opportunity to look for synergies in the delivery of different elements of the scheme, including sharing costs and bringing together diverse revenue streams in a self reinforcing way.

GreenSCIES identified the example of sharing elements of the civil works between the heat and electricity elements of the project which, it estimated, increases the internal rate of return for the project by 1%. This is a significant increase which, combined with the multiple revenue streams associated with heat, EV charging and electricity sales, makes a significant difference to the investability of the project.

Decarbonisation case studies

- **Soft market testing identified significant appetite from energy service companies and infrastructure developers to invest in and develop SLES concepts.**

The soft investment prospectus identified investment opportunities across the retailing of heating and cooling; electricity market opportunities including demand side response, decentralised generation and storage; and investment in EV charging infrastructure. It also asked for responses from organisations interested in delivery of the network infrastructure across heat, electricity, communications, and IT.

The soft market test received 10 expressions of interest from a range of energy service and energy infrastructure companies. The feedback received by Islington Council showed significant appetite, expertise and willingness to engage with the innovative concept of GreenSCIES. The process has supported the transition of the model from detailed design to procurement in the New River development where learning from the soft market test is informing the technical design, procurement and business models being put into practice.

Decarbonisation case studies

- **The model is replicable: GreenSCIES style energy systems are being built into developments across the country.**

The seven case studies show the replicability of the GreenSCIES model. In each location a source of waste heat has been identified, which enables the high efficiencies of fifth generation heat network technology to be realised and combines this with opportunities involving other renewable infrastructure.

An example in Yorkshire aims to use the significant quantity of waste heat associated with a glass factory to sustainably heat a new housing development. There is also a large PV farm in the vicinity whose output could power the heat pumps as well as supplying some of the wider energy needs of the factory. The GreenSCIES model provides a framework to develop these distinct elements into an effective SLES for the area.

A second example involves working with a UK supermarket chain to look at capture of waste heat from their refrigeration system. Opportunities also exist to use other elements of the supermarket infrastructure for mobility and electricity generation, such as the car park for overnight community EV charging, and PV generation on the building’s roof.

How does this help solve whole system challenges?

Smart

GreenSCIES delivers an opportunity to optimise the sourcing and flow of energy across different sources and end uses using an ambient temperature heat network.

Local

GreenSCIES case studies are based around the concept of capturing and using waste heat from industrial, commercial and transport activity and using it efficiently within the local area. A core part of the model is the process of community and stakeholder engagement which shapes the project in order to deliver value.

Whole energy system

By integrating supply and demand across electricity, mobility and heat, GreenSCIES fulfils the ambition of a fully integrated energy system. It also goes further identifying values such as neighbourhood pride and the local environment. The centrality of the local authority and the development of the model around wider local ambition extends the model from whole energy to whole community.

More information:

- GreenSCIES overview video
- Project Website
- Report by Islington Council: Vision 2030: building a net Zero Carbon Islington By 2030
- Policy challenges and future changes for smart local energy systems – Report by Energy System Catapult

- Email: Graeme Maidment, maidmegg@lsbu.ac.uk

Who is prospering?

✓ **Islington residents:** Through access to affordable local energy with the project providing a framework that could draw thousands of residents out of fuel poverty.

✓ **EV drivers:** Through access to low cost, accessible EV charging.

✓ **Waste heat providers:** Organisations who create waste heat through their main activities, such as Transport for London and data centre owners, can derive additional revenue streams and wider non-financial benefits through the GreenSCIES model.

✓ **Islington Council:** Through a new model to support delivery against its 2019 declaration of a Climate Emergency and through a framework which can draw investment into the borough.

✓ **Wider UK projects:** Including developments looking to replicate the GreenSCIES model across the country, including the 7 case studies developed.

✓ **DNOs:** Through access to new flexibility providers to manage network constraints.

✓ **Industry:** Through new models for managing energy producing and meeting demand along with a better understanding of how to manage their energy portfolio.

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Detailed design project

Greater Manchester Local Energy Market (GM LEM)

The core of the project is the development of a detailed design for a market platform, which included public engagement.

Project summary

The GM LEM aims to change the way the electricity market currently works by developing a platform that increases visibility of energy activity and transactions, suitable for the challenges of the mid-2020s. The project is based on an ambitious whole system vision for how energy is generated, traded, transported, supplied, and used across the city region. It envisions localising energy systems, reducing the distance energy travels to its point of use and optimising consumption.

The GM LEM helps to deliver Greater Manchester's objective to fully decarbonise the region by 2038. To support this, the project has developed detailed Local area energy plans (LAEPS) for each of the 10 boroughs within the city. These form the basis for analysis of the potential value of GM LEM.

The project's core is designing a Local Energy Market (LEM) platform. LEM is a market maker that will support local energy and flexibility trading across Greater Manchester. The platform has been designed to evolve over three phases, the first of which can be implemented within existing GB electricity market arrangements. Later phases rely on increasingly significant levels of regulatory and policy change. The project has put considerable effort into understanding the current regulatory barriers and options for change. It has kicked off a programme of detailed engagement with Ofgem, Department for Business, Energy and Industrial Strategy (BEIS) and others to ensure that these reforms are considered as part of the broader national debate on electricity market reform.

The project has also explored several value sharing propositions which can allow end consumers to benefit from the value provided by GM LEM in early stages where direct participation is likely to be limited to suppliers and generators.

Original objectives	1. Inform: Delivery of Local area energy plans for each of the 10 Greater Manchester boroughs. 2. Validate: Present investment ready-business models through the design of value sharing propositions. 3. Optimise: Design, test and evaluate evolution of a Local Energy Market platform.

Key project elements

- **Local area energy plans:** The production of 10 LAEPS, one for each borough of Greater Manchester together with a region-wide synthesis.
- **Market maker platform:** A detailed and phased plan for implementation of a LEM Platform with phase 1 deliverable within current GB market arrangements; a technical design document and working prototype.
- **Value sharing propositions (VSPs):** design of three business ready VSPs including one for domestic heat pump customers and two for commercial customers: a heat as a service model for commercial buildings, and a vehicle-to-grid offer for electric van fleet operators.
- **Policy and regulatory analysis:** which identifies the detailed options for regulatory and policy change required to deliver each phase of the GM LEM.

What have been the successes? What has been delivered?

1. Identification of the potential for £40 million energy system savings per year through the GM LEM and demonstration that implementing a market maker platform represents a viable business case.

Analysis based on the Greater Manchester LAEPs and on projections in ENWL's Distribution Future Energy Scenarios shows significant value from reduced wholesale energy costs and avoided network investment within regions. The business case for implementing the market maker platform could achieve a positive cash flow by 2027 and be delivering £1 million/year surplus by 2033 for the Local Energy Market Operator (LEMO).

2. An initial model for GM LEM is deliverable within today's regulatory and market rules as an initial phase of a longer-term project.

A market-seeding approach to early development will allow suppliers, aggregators, and generators to match supply and demand within the GM LEM area and demonstrate the potential for local markets. End-consumers can benefit through innovative valuing sharing propositions designed to pass the GM LEM contribution from direct early participants to the final customers.

3. Value sharing options have been developed and shown capable of delivering end-user value both as stand-along products and in conjunction with the GM LEM.

These include commercial models for Heat as a Service (HaaS) for commercial buildings, smart charging and vehicle to grid in the context of hospital van fleets; and domestic type of use tariffs for heat pump customers.

> "Exciting to see Manchester taking positive steps to using more renewables."
>
> "Cleaner air and less traffic noise with more EVs."
>
> **Local residents, participants in GM LEM's user engagement programme**

What have been the barriers? What impacts have they had?

1. Current regulatory arrangements limit the ability of a LEM to deliver local value in the short term.

For critical areas of local value, such as local network capacity, no routes are currently available to release value and create revenue streams for local participants. At the same time, realising other elements of local value would require the GM LEM to take on national energy system roles, which are currently costly, complex, and poorly designed for the needs of local energy systems.

Outcome: The phased approach to developing the GM LEM and the market maker platform has been used to design a minimal phase 1 proposition, which demonstrates functionality and allows some organisations already directly involved in wholesale electricity and flexibility markets to begin trading locally.

2. The need for significant regulatory change in order to implement more advanced phases of GM LEM.

The more advanced GM LEM models are not possible within today's structure. Delivering more advanced elements of the GM LEM will require regulatory sandbox approaches or enduring regulatory change. Whilst sandbox approaches would be the most likely way to facilitate the evolution of GM LEM over the next few years, existing derogation schemes are not designed for region-wide whole system projects.

Outcome: The project has developed a number of options for each phase of the GM LEM along with the regulatory arrangements needed for each option. Participants have begun a programme of engagement with Ofgem to consider regulatory reform, and the project has identified the potential of an emerging model for facilitating region-wide innovative models: Energy Innovation Zones.

What are the key lessons learned?

Regulatory and policy

Market maker platform / regulatory analysis

- **Key areas of local value cannot be easily realised or turned into revenue streams under today's market conditions. Maximising the value from later phases of the GM LEM will require significant regulatory and policy change.**

Under existing rules, users of electricity networks have either an implicitly (domestic and small commercial customers) or explicitly (larger users) defined quantity of network capacity available to them. Trading that network capacity is not possible within the current market rules and has been de-scoped from the network access reforms considered by Ofgem over the past few years on the grounds that the setup cost would be high and the level of uptake and benefits uncertain.

In the past, several local energy projects have considered ways to reduce their exposure to certain elements of network charges including those that cover Transmission (TNUoS) and Distribution (DUoS). Those projects have argued that by balancing more locally they avoid putting strain on the wider network and should be rewarded for doing so. More recently, Ofgem has expressed concern about parties being able to avoid costs, and through its recent charging approaches has to recover sunk network costs across all users fairly arguing that reducing the number of customers paying them increases the charges remaining customers have to pay.

Future projects aiming for commercial viability need to think carefully about whether regulation allows areas of theoretical (and real) system value to flow through into revenue streams for their project. The electricity sector has been debating these issues for more than a decade and it is important the future projects review the experience of GM LEM, similar local energy projects, and the arguments made for and against change across the sector over that period.

Market maker platform / regulatory analysis

- **Whilst several options exist for developing later phases of the GM LEM, these will require a combination of regulatory change or the need to take on potentially costly and complex roles within existing market structures.**

There are several models that could deliver the full process of trading energy which GM LEM wishes to achieve in its later phases. All models involve a significant level of complexity. The first group of options involves the LEMO either becoming, or partnering with, an active wholesale market participant such as a supplier. The second involves setting up a trading exchange which would require approval from the Financial Conduct Authority and compliance with all relevant financial regulation.

For later phases of GM LEM, assuming existing market arrangements persist, there will also be significant value in the LEMO formally becoming, or partnering with, an aggregator and a virtual lead party (required for trades in the balancing mechanism). It may be advantageous for the GM LEM to become a direct partner with the Electricity North West in its role as a DSO.

Future projects should be aware of the complexity of operating in the more advanced modes of LEM, but they should also maintain a close awareness of market reforms which are increasingly likely to lead to substantial changes in legislation and regulatory rules by the second half of the 2020s.

Regulatory analysis

- **The ability to trial and demonstrate phase 2 and 3 elements of the GM LEM would benefit from new innovation support mechanisms, particularly the ability to gain derogations for region-wide whole-energy system projects, for example by using a proposed Energy Innovation Zone approach.**

Delivering energy and flexibility trading, the core of phase 2 of the GM LEM, may be best demonstrated as part of a region-wide whole-energy-system demonstrator. The Energy Innovation Zone (EIZ) concept is being pioneered in the West Midlands and will allow for geographically defined areas to apply for regulatory derogations to tackle a specific energy place-based challenge, in turn allowing innovators to deploy clean energy solutions under bespoke rules and conditions agreed between local authorities and national regulators.

The EIZ approach will require UK Government legislation, and should this be implemented, future projects looking at region wide LEM approaches should consider the use of an EIZ to gain region-wide integrated derogations to relevant industry codes and regulatory rules.

Market maker platform

- **There are potential tradeoffs between developing a LEM using a single, mandatory, trading platform compared with allowing trading to evolve more naturally across multiple, voluntary, local and national platforms.**

Operation of a local energy market across Greater Manchester could develop using either model. The first is likely to give greatest value in terms of acting as a one-stop-shop for local trading and maximising the information and the flexibility available to the DNO to manage network constraint. However, it may be perceived to go against the principle of open and competitive markets.

What are the key lessons learned?

Business model and business practices

Market maker platform

- **A significant fraction of value associated with savings on network investment comes through embedded rather than explicit flexibly provision.**

  Through modelling, the project has estimated the likely reduction in peak demand seen by moving from a low-flex to a high-flex scenario whilst maintaining the same underlying mix of generation and demand. The high-flex scenario assumes that generation, demand, and flexibility providers can shift demand away from peak periods through tariffs, peer-to-peer trading, or demand turndown.

  This provides an embedded flexibility benefit for networks by reducing peak electricity flows without the need to explicitly contract for it. For example, the project estimates that peak network usage in a high-flex scenario based on delivery of the primary LAEP pathway will remain within the overall capacity of the current electricity distribution network out to 2038. By comparison, a low-flex system could exceed that network capacity as early as 2026. It also suggests that embedded flexibility accounts for over 80% of the revenue to the GM LEM in 2038.

  Future projects need to consider the embedded flexibility benefits that development of a LEM can facilitate. These embedded benefits should be identified and quantified, and it is also critical that projects consider how these benefits can result in revenue stream and cost savings for consumers and businesses in a region.

Value sharing propositions

- **In the context of commercial building tenancies, the project has shown that a truly fixed price Heat as a Service (HaaS) offering can be commercially viable in return for a modest risk premium.**

  Truly fixed-cost heating means charging a fixed price for provision of a service, such as meeting a pre-defined temperature within certain areas of a building. This moves significantly the risk associated with the quantity of fuel needed (for example, due to whether a winter is cold or mild) from the consumer to the HaaS providers. Key to delivering a commercial HaaS produce is to understand and price that risk.

  The project has shown that for commercial properties, charging risk premium of approximately 1% of cost allows a HaaS provider to manage a risk of a 5% to 10% variation in weather-dependent electricity volumes, assuming appropriate controls in place.

  Future projects should build on the cost-fixing methodology developed by this project. They should also look at evolving the stand-alone HaaS model developed here to one that integrates into a more advanced LEM where energy can be explicitly traded. This will provide a different set of options for the HaaS provider which may allow further re-risking of the fixed cost offers.

Value sharing propositions

- **Heat-based 'type-of-use' tariffs can deliver cheaper electricity prices to consumers either as stand-alone products or as part of a LEM**

  The demand profile for electricity to run domestic heat pumps differs significantly from other types of electricity demand. This means that a larger fraction of heat pump demand comes from off-peak periods in comparison with other uses of electricity. If a supplier can separate out the heat pump component of their overall demand portfolio, they can purchase energy to meet that component at prices that are, on average, lower than the price they must pay for component of their portfolio. The project has demonstrated that a heat-pump type-of-use tariff could reduce electricity bills for a typical household with a heat pump by around £159 or 10% based on an indicative standard unit rate of 26p/kWh.

  As LEM projects expand, future projects should look to build on this understanding which has been developed based on national market price variations. As with the HaaS product discussed above, the additional local trading and flexibility option available through a LEM may provide more options for locking in lower average prices for a supplier trading heat-pump demand profiles.

What are the key lessons learned?

Social and community

Market maker platform

- **Local citizens are supportive of local energy markets, would expect high levels of transparency and scrutiny, and the majority would expect local renewable energy to be cheaper than equivalent national tariffs.**

Research for the project highlighted the low levels of trust that citizens currently have for the energy market. Well managed, LEMs have the potential to rebuild that trust. It also identified a split on price expectations. Highly engaged participants are willing to pay a price premium for locally renewable energy. By contrast the majority felt that locally sourced electricity should be cheaper, believing that it will place lower costs on the wider system.

Finance and investment

Market maker platform / Local area energy plans

- **By facilitating a local energy market, the market maker platform can deliver significant benefit for the local area and operation of the platform itself can be made into a viable business by charging a modest fee on each kWh of trading activity.**

Analysis based on the LAEP scenario estimates that by 2038 the GM LEM could deliver over £40 million of overall local benefit per year through a combination of local wholesale energy trading, flexibility services and data sales.

By charging a fee of between 5% and 10% on wholesale energy trading, network flexibility trading and the sale of energy from local solar panels the platform operator is able to cover its operating costs, recoup its start-up costs and receive a small surplus, potentially £1 milion/year by the early 2030s.

Data

Market maker platform

- **A LEM platform will produce valuable data that can be incorporated into products to support the scheme's objectives.**

The market maker platform will produce a significant quantity of valuable data and bring together a range of existing data into one location. These data streams are hugely valuable and give the LEM an opportunity to curate data packages for different types of users. For example, public authorities might have free or low-cost access to data streams on the LEM that will aid place-based decision making and inform investment.

Modelling of the revenue flows for the market maker platform suggests that data sales could account for around £90,000 per year in a mature LEM.

> “A LEM would make use of renewables, that's a good thing no matter how I am involved with it.”
>
> “Everything feels out of my hands, but a LEM would change that.”
>
> **Local residents, participants in GM LEM's user engagement programme**

How does this help solve whole system challenges?

Smart

GM LEM will rely on much of the local electricity system being smart-enabled. Trading on the LEM will require half-hourly settlement, smart meters and automation of demand control in order to work effectively. In return it will provide data, transparency and lower system costs.

Local

At the core of the GM LEM is local market trading of energy and flexibility across the Greater Manchester area. It has shown that such a system is both desirable and valuable and can be partially delivered within existing market arrangements whilst later elements depend on (potentially significant) changes to market structures.

Whole energy system

Whilst focused on the electricity system, the project expects to support decarbonisation of heat and transport as those sectors make greater use of electricity. In the process it has further developed proposals for value sharing through heat as a service and flexible EV charging. It also highlights the wider societal value of whole-energy-system data to local organisations including local authorities, businesses, and communities.

Who is prospering?

✓ **Local domestic and business energy consumers:** initially through the value realised by energy suppliers in the LEM and passed to consumers via value sharing propositions such as OVOs Heat Pump Pro tariff.

✓ **Local generators:** including rooftop solar who can trade their energy through the LEM and derive value from its traceable provenance.

✓ **Commercial property tenant:** through the Heat as a Service and smart charging mobility offering developed by Bruntwood.

✓ **Public sector:** through the availability of new data streams that can support better place-based decision making.

✓ **Electricity network companies and their customers:** through access to a functioning local energy market platform through which they can procure flexibility to manage their network. This will result in lower overall network charges for consumers and other network users.

✓ **Local citizens:** through the support that GM LEM will give to delivery of wider local objectives including a net zero Greater Manchester by 2038.

More information:

- Greater Manchester Combined Authority Local Energy Market homepage
- Final project summary report
- GM LEM citizens' jury
- Local Area Energy Plan for the Bury area of Greater Manchester
- GM LEM local energy markets video

- Email: Sean Owen, Sean.Owen@greatermanchester-ca.gov.uk

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Detailed design project

Liverpool Multi-vector Energy Exchange (LMEX)

The LMEX Project is creating a detailed design for a city-wide, smart local energy system that will facilitate the local trading of energy and flexibility.

Project summary

The LMEX project is creating a detailed design for a city-wide, smart, local energy system that will facilitate the local trading of energy and flexibility from local renewable generation, electric vehicles, energy storage, and low-carbon heating and cooling. The project has created designs for the key technologies needed to make a successful local energy exchange. The Flexibility Exchange Platform provides an advanced market trading environment and user interface which draws together bids and offers for energy and flexibility and clears to provide a single price and dispatch instructions for each settlement period. The Smart Network Controller (SNC) then communicates with, controls and optimises local energy assets in real-time to deliver the market outcome. LMEX has also developed the business model for a commercially viable exchange operator and is stimulating the development of investable local energy projects which could trade on the exchange.

Original objectives	1. A local trading pool design to accommodate many generation, storage and load-side assets. 2. Compelling business models that attract investment, and drive early market liquidity. 3. A city-wide design for a local energy and flexibility services market: the Liverpool Energy Exchange (LEX).

Key project elements

- **LMEX architecture:** The LMEX architecture includes both hardware and software layers. The SNC physically monitors all assets participating in the LMEX and receives real time data on network conditions from the DNO. It interfaces with the software layer, the market platform, to dispatch local energy assets based on market results. Through monitoring of energy flows, the system confirms delivery of services and provides the data required for settlement of market trades.

- **LMEX business model:** The project has identified a commercially feasible business model for a local exchange operator which combines revenue from energy and flexibility trading on the platform, joining fees reflecting the value and opportunity that participants will get from access to the LEX, and value created through data mining.

- **Physical Design Lab (PDL):** A network of physical assets located in buildings across Liverpool and connected to the SNC, used to test and demonstrate the LMEX market architecture and benefits to local energy users.

What have been the successes? What has been delivered?

1. A city-wide local energy exchange model.

The model developed is based on a trading pool where buyers and sellers trade directly with the exchange operator who clears the markets for energy and flexibility for each settlement period with participants receiving a single price for their product. The model mirrors national electricity market structures used in other countries, particularly in the US, Australia, and Scandinavia.

2. Design and initial demonstration of key technologies.

Two key products have been developed: the SMPnet Omega controller which integrates participants' hardware with the exchange; and the market platform including user interfaces. These have been demonstrated in shadow mode and are ready to be tested in control mode in conjunction with assets in the developing Physical Design Lab. Follow-on funding through the Innovate UK Impact Acceleration fund has been won to deliver control mode demonstration.

3. Analysis showing indicative value of the LMEX.

Analysis based on 600 city buildings shows that the LMEX could deliver revenues in excess of £10 million/year this decade and could lead to the Liverpool area retaining between 10% and 20% of all local spending on electricity.

What have been the barriers? What impacts have they had?

1. The need for a supply licence to trade electrical energy.

The initial objective of LMEX was to deliver peer-to-peer trading without the need for a profit making intermediatory. However, engagement with Ofgem through their Innovation Link service identified the need for a supply licence to facilitate any trading of electricity. Early exploration of business models also identified the need to focus on a commercially viable exchange operator.

Outcome: The project has focused on developing a supplier partner business model and the development of a business model which provides sufficient commercial revenues to enable an exchange operator to cover its costs and achieve a return on investment.

2. Great Britain's national-focused electricity market combined with the lack of good quality data on local constraints.

Current GB electricity market arrangements are based on the assumption of national wholesale energy trading. Whilst these arrangements do not preclude local trading, they are not designed to support projects like LMEX in developing a local market. There needs to be more data on local electricity system operation and network constraints; this hampers visibility of the need for local flexibility.

Outcome: Whilst LMEX has found a route to navigating the complexities of the national market structure, direct energy-bill cost savings delivered through a future LMEX are likely to be limited to the wholesale energy component of bills under current market arrangements. This was also a factor in the project's decision to focus on a supplier-partner model with a national supply company fulfilling many of the complex requirements on wholesale trading. The lack of local constraint data limited the level of confidence in estimates of future flexibility revenue

3. Challenges delaying the roll of the physical design lab due to Covid.

The COVID-19 pandemic and the associated lockdowns limited the ability for the team to engage with potential participants in the design lab or to carry out installation work that was considered non-critical.

Outcome: This significantly delayed the setup of the physical design lab and meant the project was unable to physically demonstrate the operation of the market and SNC in practice during the original project. However, this is now in operation and is being taken forward due to follow-on funding, The Watson Building, a multi-tenanted commercial building, is now connected to the physical design lab and LMEX is exploring connection to a wide range of other public and private buildings in Liverpool.

What are the key lessons learned?

Technical

Business models

- **The process of aggregating multiple small-scale providers to provide a megawatt of flexibility or a megawatt hour of energy poses different challenges from delivering those same outcomes from a single, large asset.**

  Small-scale projects involve different investment characteristics compared to large projects. There may be significant value in combining multiple small scale assets across varying ownership structures, with different individual objectives, into portfolios. Risk management will be different. Managing operating and balancing risk for large projects can revolve around maintaining reliability through good operation and maintenance practices for a single asset.

  By contrast, when operating a portfolio of small projects, the overall risk will depend on the combined operation of individual assets, each facing its own constraints, limitations and uncertainties.

  SLES developers need to be aware of the organisational and technical challenges of working with an extensive portfolio of small projects and the need to manage risk associated with the delivery of each participant's objectives and the overall aims of the SLES itself.

LMEX architecture

- **Delivering the LMEX involves the co-design of both software and hardware control that enables market trades to be automatically enacted and settled whilst reliably maintaining system limits.**

  Current software and hardware architectures for local energy lack standardisation of protocols, products, and services: do not focus sufficiently on the physical execution of decisions made by the market software.

  The result was that LMEX needed to develop a more detailed architectural structure. This included introducing innovative new capabilities, such as defining new services that could be traded on the LMEX and controlling and coordinating action across LMEX-connected devices with sub-second resolution using clearly defined standards and protocols.

  The key to success is in the planning, in detail, of the exact processes by which actions will be instigated and controlled. This takes considerable time and resource.

Regulatory and policy

Business models

- **A supplier licence is a requirement for any trading of energy**

  Engagement with Ofgem confirmed evidence from other projects that there is a need for a supply licence to trade electrical energy. Whilst licence exempt routes do exist for smaller projects, this is not suitable for city-wide designs due to a size limit of 5MW.

  Options for meeting the supply licence obligations include the LMEX market operator becoming a licensed supplier, which is a complex and potentially process. An alternative is for the LMEX to partner with a licensed supplier who can undertake the tasks for which a supply licence is required such as responsibility for imbalance on traded energy in the national market.

Business models

- **The current market and regulatory arrangements do not suit the development of LMEX.**

  The national focus of current GB electricity market arrangements is not well designed to support local energy projects. Whilst this may change, future SLES projects must not underestimate the complexity and multiple barriers this creates.

  For example, wholesale electricity trading and the regulation of retail tariffs assume that energy requirements can be met from any part of the country with limited impact from either distribution or transmission network constraints. In addition, the coordination between the national system operator and local distribution system operators is still at an early stage, and many of the products required to deliver flexibility services that LMEX can support are in flux. These include DSO services, such as local peak avoidance, and national services such as response and reserve.

Business models

- **Current costs-saving options for local energy trading are limited to the wholesale energy component of the end-user bill**.

  Prior to the current energy price crisis, wholesale energy accounted was around 30% of typical domestic consumers total electricity bill, with network costs, environmental and social policy costs, taxes, and operating costs making up the rest. Whilst trading energy locally may reduce the burden on both the local distribution and national transmission networks, under current arrangements it is only the wholesale energy component which LMEX can directly influence.

What are the key lessons learned?

Regulatory and policy

Modelling carried out by the project shows that across 600 representative buildings in the city it is possible to realise savings of the order of several million pounds on the wholesale energy element of electricity bills. This can be achieved when the price of local energy generation is less than the prevailing national wholesale price. It is important to note that wholesale bill savings delivered through LMEX would reduce when national prices fall. In addition to savings, asset owners can generate revenue from flexibility services, which also reflects the impact that the operation of LMEX is expected to have on reduced need for distribution network reinforcement.

Any SLES project looking to identify potential electricity bill savings needs to ensure it appropriately considers the different elements of the electricity bill.

Social and community

LMEX architecture

- **Developing the user interface for the LMEX is a major undertaking, worthy of a project in its own right.**

The project undertook significant user interface design activity involving user surveys, participatory workshops and user testing. This was conducted in parallel with other activities, such as development of the market model itself. The project has identified that there would be value in delivering these activities sequentially once the range of options for interaction between users and the market were better defined. Future projects should also consider how a user interface can flex to the needs of different user types, for example, with more sophisticated users able to access greater functionality.

Data

Business models

- **Access to and effective use of data available through the LMEX is an area where it adds value and could represent a significant revenue stream to the exchange operator.**

The data available to the LMEX operator allows it to identify opportunities for existing or future local energy asset owners; for example, where there is network headroom, or where there is a potential match between profiles for local demand and new generation capacity or the opportunity to better balance supply and demand through investment in flexibility. These insights are enabled through LMEX's role in bringing together significant levels of data from across the city.

The value of data mining activity can support the LMEX operator itself, either through the provision of paid-for consultancy or by charging a percentage fee on capital investment or future trading revenue realised because of the data insights provided.

Future projects should be aware of the value of data created and curated by local energy exchanges. This, along with the whole-system understanding that exchange operators will themselves develop from their privileged position at the heart of SLES, can represent a significant value stream.

Business models

- **There is a major mismatch between local energy project ambitions to provide flexibility to support local network constraints and the availability of granular, locational data on where those network constraints are today and where they could be.**

The project has identified that LMEX can create significant value through provision of flexibility services to the local DNO. Doing so requires a clear understanding of where network constraints occur along with the scale timing and duration of those constraints. To support development of flexibility assets it is also important to understand how these constraints may evolve over time considering demand, local generation, and DNO investment plans.

Today there is limited data available to support this understanding. As local network companies continue to evolve from DNOs into DSOs, it is important that more data is made available to potential providers of flexibility to support investment and ensure that the availability of flexibility evolves in the places and the forms that it is needed.

Any SLES project aiming to support the development of flexibility and to engage with emerging DSO markets needs to acknowledge that sufficient data is unlikely to be available today. They should engage and support the DNO in making data on network constraints more widely available. It also highlights the importance of DNOs continuing to increase the data they collect and the amount that is made public.

What are the key lessons learned?

Finance and investment

Business models

- **A key conclusion of the project is that whilst technology is now capable of delivering SLES projects, and there is an appetite in the investment community to invest in local energy, the characteristics of many local energy projects do not align with the needs of investors.**

  Although there is significant interest in local energy across Liverpool, LMEX has found that individual projects are often small scale, differ widely in design, and have highly varied objectives.

  Developing an investable proposition is likely to involve bringing those projects together into a well-managed portfolio able to identify place-based synergies between projects with similar objectives and maximise the combined benefit and associated revenue streams of projects within the portfolio.

  LMEX has shown that the development of a self-supporting SLES ecosystem will need to draw local energy projects together giving an overall sense of place-based scale and ambition. Synergies between projects and opportunities for collaborations should be identified. It will also be important to facilitate discussions between projects and investors and support the creation of a coherent and investable portfolio.

Business models

- **Successfully rolling out SLES across the country will require a hybrid investment model leveraging both public and private funding.**

  The scale of investment in local energy infrastructure is significant, and it is likely to be beyond the capacity of the public sector to deliver on its own. However, building on the previous point, local energy projects may not attract private investment without significant support. This points to the need for a hybrid model combining public and private-sector finance.

LMEX's experience suggests that the most appropriate role for public investment is to de-risk projects through pre-investment due diligence and the development of projects into more standardised forms. Private investors can then bring the scale of investment needed to develop de-risked and standardised projects to operation.

There is a need for future projects to tackle each aspect of this challenge, identifying ways to de-risk and standardise projects and to look for more efficient ways to use limited public investment to draw in and maximise private funding.

> **"LMEX set out to prove the value of local trade of energy services to delivering net zero for the country as a whole. The technology is there and the investor interest is there. All we need is for electricity frameworks to catch up."**
>
> **Hugo Chandler, New Resource Partners**

How does this help solve whole system challenges?

Smart	The development of the smart network controller and its integration with a fully designed, wider local energy market architecture represents a significant part of the technology model needed for a smart city-wide local energy market in Liverpool.
Local	The model will facilitate local resources to meet local demand and flexibly requirements. In addition to reducing bills, it will ensure that more money spent on energy in Liverpool is kept in the local economy.
Whole energy system	Whilst focused on markets for electrical energy and flexibility, the project links to mobility and heat demands and has the potential to expand to cover other energy vectors in the future. The development of investment support tools focus on identifying investment opportunities across all vectors of the energy system.

More information:

- Liverpool Energy Xchange
- Email: Hugo Chandler, hugo@newresourcepartners.com

Who is prospering?

✓ **Small scale generators:** Including owners of behind the meter generation who will be able to trade their surplus output locally across the LMEX.

✓ **The DNO and their customers:** Who will be able to purchase flexibility based on location in a competitive local energy market.

✓ **Large scale building owners:** Looking to manage their portfolio's energy demand will be able to buy local energy to reduce their overall bills.

✓ **Future local energy projects:** Looking to identify the value of different investment propositions, who will benefit from the data mining activities of the exchange operator.

✓ **Commercial project partners:** Who will move the LMEX model into deployment in Liverpool and explore delivery in other cities.

✓ **City councils**: For whom local energy exchanges can provide a stimulus towards achievement of their net zero carbon objectives.

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Detailed design project

Milford Haven: Energy Kingdom (MH:EK)

The MH:EK detailed design project is about exploring the role of hydrogen in a whole energy system approach to the development of smart local energy.

Project summary

The MH:EK detailed design project is about exploring a whole energy system approach and the potential for hydrogen alongside renewable electricity in supporting the decarbonisation of transport, heat, and electricity demand. It has developed a series of SLES propositions suitable for early investment aimed at boosting local decarbonisation across the energy system, and a long-term route map for the decarbonisation of Pembrokeshire. In doing so, it has explored the synergies between regional SLES opportunities and decarbonisation of the large-scale national energy infrastructure, including the UK's largest energy port and opportunities for offshore wind in the Celtic Sea. The project has also carried out technology demonstrations for the use of hydrogen in mobility and heat.

Project objectives	1. To establish seed markets for the use of hydrogen around the Milford Haven Waterway by integrating a wide range of major energy facilities, renewable energy generators and energy consumers in the community. 2. Use a systems architecture that can be implemented with commercially ready solutions and which focuses on underlying fundamentals and is robust in the face of regulatory change.

Key project elements

- **Whole energy system approach:** Interconnectivity of transport, heat, gas and electricity using hydrogen from renewable energy sources.
- **System architecture and trading platform:** Design of an energy and flexibility trading platform across electricity and hydrogen vectors along with an underlying system architecture, integrating both national and local infrastructure, including a detailed gas network model.
- **Decarbonised smart local energy system concepts:** Development of a conceptual proposal for a 2050 decarbonised Milford Haven energy system and investable short-term proposition to kick-start the decarbonisation journey, including a study of notable international investments impacting the medium-long term vision for Milford Haven.
- **Hydrogen infrastructure trials:** Demonstration of two hydrogen vehicles and a refueller station, which creates hydrogen from electrolysis, and the design and demonstration of the world's first smart hybrid heating system (air source heat pump and a hydrogen boiler) retrofitted in a commercial setting.
- **Data ecosystem:** Explore the establishment of a robust data ecosystem for MH:EK which integrates beyond the local boundary and supports the delivery of wider initiatives to modernise and digitalised energy system data.
- **Consumer Insights:** Co-designing a switch to hydrogen with customers in a scenario of a repurposed gas grid to supply hydrogen instead of natural gas to perhaps solve the toughest Net Zero challenge: decarbonising domestic heating.
- **Community/STEM Education work:** Development of freely available Key Stage 2/3 education resources, visits to schools/colleges, community events and integration with initiatives for future skills and training needs.

What have been the successes? What has been delivered?

1. Three propositions for short and medium term SLES developments of which two have been identified as immediately investable.

These cover a proposal to decarbonise the existing Milford Haven marina, an integrated SLES within the new-build development of Pembrokeshire Food Park, and a proposal to decarbonise schools, a leisure centre and docks in and around Pembroke itself. The project has been able to recommend pursuing the first two proposals immediately.

2. Development of an MH:EK long term pathways focused on decarbonising Pembrokeshire's energy system by 2050.

These start by implementing propositions one and two and then building a coordinated whole energy system to deliver net zero in 2050. Key elements include: integrating hydrogen into the development of offshore wind in the Celtic Sea; the repurposing of Milford Haven port away from oil and gas to enable hydrogen import and export; support for both blue and green hydrogen production; the development of a Pembrokeshire-wide SLES during the 2040s; the creation of a dedicated hydrogen pipeline to connect into a UK hydrogen gas backbone; and the formation of a hydrogen town concept around the Milford Haven Waterway.

3. The refueller station developed as part of the hydrogen vehicle trials has stimulated council and community interest in hydrogen mobility.

Discussions are under way to explore a number of opportunities for hydrogen production and refuelling for Pembrokeshire County Council's fleet vehicles, the potential for hydrogen buses, port vehicles and marine vessels and possibilities around publicly available hydrogen refuellers.

4. Expansion of the use of the hybrid air source heat pump and hydrogen ready boiler heating system.

The MH:EK hybrid heating system is continuing in operation and providing ongoing operational learnings. The MH:EK trial has stimulated new project collaborations including the Welsh Government funded HyMaker Heat scheme to retrofit a smart hydrogen hybrid into a multiple occupancy building, and HyProspect which builds on the MH:EK hybrid demonstrator project to design and develop the tools needed for a new micro-grid service operator (MSO) functionality. Hybrids offer a potential solution to decarbonise heat in hard-to-treat buildings across the county, for example, port buildings and schools, creating anchor demand for hydrogen in and around project boundaries.

5. Development of a template process for building the systems architectures for future SLES.

MH:EK is one of the most detailed explorations of systems architecture options for SLES to date and one of the only ones to focus on hydrogen in the local energy system. It has added to evidence showing the importance of whole system and the value of a systematic, well-defined process capturing local opportunities and challenges alongside technical knowledge and the more general interdependencies between different parts of the system. The approach represents a repeatable methodology useable by future SLES projects capable of capturing the depth, breadth and interplay between the elements within an integrated energy system.

6. STEM education for future generations and integration with future skills and training needs.

Development of the education resources, visits to schools and colleges, community events creating informed citizens and energy consumers in the community, and integration with initiatives for future skills and training needs, such as the new Destination Renewables course at Pembrokeshire College preparing students for the renewables jobs market.

What have been the barriers? What impacts have they had?

1. Local hydrogen use in the three SLES propositions is limited by economic and physical considerations related to the interaction between electricity and hydrogen vectors.

These considerations include the opportunity cost to local renewable generators of diverting grid export of electricity to hydrogen production, and the intermittent availability of excess renewable generation meaning that behind-the-meter electrolysis at solar and wind farms could operate at low load factors.

Outcome: Techno-economic modelling identifies that a significant fraction of transport energy demand could be met by hydrogen across the three propositions. However, it is likely that much of this will come from imported rather than locally produced hydrogen for the reasons mentioned above. The modelling suggests hydrogen is unlikely to be suitable for the majority of heat in the SLES propositions explored.

2. The third SLES proposition, based around Pembroke Town, is not sufficiently strong to take forward in the near term.

This is driven by the lack of district-level integration between the buildings' heating systems and very limited interaction between energy vectors. Delivering the proposition would rely heavily on existing solar PV that currently exports its generation to the national grid for income.

Outcome: Although not recommended for investment, the proposal demonstrates the opportunity to increase local renewables if wider constraints can be overcome. It also promotes the potential to integrate existing hydrocarbon-based industries into a wider SLES in the longer term.

3. Although MH:EK aimed to follow emerging best practice for data management, the ability to maximise this was limited by existing data management practices beyond the control of the project.

This included the quality, formatting, accuracy and availability of suitable data. The project identified solving data challenges as critical for the wider development of SLES and other aspects of energy decarbonisation.

Outcome: The project undertook a review of data challenges as a case study against recent Energy Data Taskforce recommendations. This review proposed establishing a robust data ecosystem at local level and put plans in place to prepare for initiatives such as open data and data standards.

> "RWE has a hydrogen business and we are looking to deliver 2GW of hydrogen projects by 2030, including a green hydrogen project in Pembrokeshire. Key to this is the economic viability of projects producing hydrogen for use across sectors such as transport, power and industry. RWE welcomes the work of MH:EK in helping to make the storage, use and distribution of hydrogen cost-effective".
>
> **Jeremy Smith, RWE**

What are the key lessons learned?

Technical

Decarbonised smart local energy system concepts

- **Hydrogen is a critical part of any future energy system and has the potential to play an important role in any whole-system SLES project.**

MH:EK is the only hydrogen-focused detailed design project funded through PfER and has explored how best to integrate hydrogen into the energy system. The project has identified the importance of hydrogen as an alternative vector where electricity networks are constrained. In some cases, without a flexible, storable, zero-carbon energy vector such as hydrogen, there is a risk that an integrated approach to decarbonisation proves impossible.

Pembrokeshire is particularly well suited for demonstrating hydrogen. It lies at the overlap of several national energy infrastructures: Milford Haven, the UK's largest energy port, Pembroke power station, the nationwide electricity and gas transmission systems, a centre of the developing offshore wind interest in the Celtic Sea, and the landing point of the Greenlink electricity interconnector between the UK and Ireland. Together, these provide a unique national opportunity for the development of a hydrogen economy which can be supported through a smart, local approach.

Hydrogen infrastructure trials

- **Hydrogen demand for transport could potentially rise to nearly 2000 kg/day by 2050 in Pembrokeshire if hydrogen was fully exploited in the vehicle segments that are challenging for Battery Electric Vehicles (BEV).**

A detailed review of the business case for a publicly accessible hydrogen station identified a potential role for hydrogen across the vehicle fleet. This includes around 18% of the private car fleet where it is assumed that hydrogen is preferred because home charging is not possible. It also includes a significant fraction of light commercial vehicles, buses and heavy duty trucks as well as a small market for emergency service vehicles.

The review identifies that using hydrogen fuel cell electric vehicles (FCEVs) currently on the market would require the cost of green hydrogen to fall to between £2.09/kg and £5.26/kg to be competitive on running costs with BEVs and assuming 2021 prices. Using more efficient vehicles, such as the Riversimple RASA demonstrated in the MH:EK project, would mean that prices of between £5.48/kg and £13.76/kg could be competitive.

This level of hydrogen use would require between 75 and 112 MWh of electricity per day to produce depending on the efficiency of the electrolyser, equivalent to the average daily output of 7 to 10 MW of wind capacity or 30 to 47 MW of solar.

A key area explored by the project is how a local hydrogen transport economy should be developed. Public access to a hydrogen refueller is deemed critical as no one mode of transport or vehicle fleet is likely to provide sufficient demand in the initial stages to justify private investment. It also identifies that green hydrogen projects already in development are expected to produce hydrogen at close to the tipping point identified above.

Hydrogen infrastructure trials

- **Hydrogen for heat remains financially challenging. Techno-economic modelling of the SLES opportunities only saw around 10% of heat demand met from hydrogen highlighting its relatively low position in the hierarchy of energy supply and demand for hydrogen.**

The use of hydrogen to meet heating demand is low down the energy hierarchy identified by MH:EK and is unlikely to be economic against alternatives in many situations. The project explored a wide range of sensitivities around assumptions for heat provision and hydrogen prices. In most cases, hydrogen was limited to meeting less than 10% of heat demand due to the relatively low efficiency multiplier of moving energy from electricity generation to heat: electricity to hydrogen via electrolysis delivers 84% of the original electrical energy to the end user as heat compared with 221% for heat pumps where the additional energy is drawn from the local environment.

These efficiency differences are already well understood, but the MH:EK modelling reinforces the limitation and the need to focus future SLES projects on alternative uses for hydrogen, particularly transport and industry.

System architecture and trading platform

- **Significant consideration needs to be given to the transition between different phases of a local and a national hydrogen system.**

Unlike the electricity system, the UK's hydrogen system is at an early stage of development, and a key part of the challenge will be the coordination of its development at both a local and national level. MH:EK identified seven Potential System Arrangements (PSAs) representing sets of physical, organisational and market architectures which define the hydrogen system. PSAs range from a simple self-consumption model where hydrogen production and use occurs on the same site and under the same ownership, through to a fully developed national or regional dedicated hydrogen system complete with hydrogen networks and markets. Intermediate PSAs include bilateral trading, local and regional blending of hydrogen into gas networks and local dedicated hydrogen systems.

What are the key lessons learned?

Technical

In addition to considering what is necessary for a fully functional system, the project also considered the transition between PSAs and the challenges that market participants as well as local and national regulators and policy makers will face in managing those transitions. For example, the analysis shows the complexity of moving from a local blended hydrogen system with a single producer blending their output into the local gas network, to a multi-producer blended system where there is a need for potentially complex arrangements to ensure that the blend level remains within predefined limits.

As market participants are likely to be investing in infrastructure with design lives and payback-periods that could be measured in decades, elements of these transitions will need to be considered during initial design. For example, investors in hydrogen production capacity may want to consider the value of designing in the controllability that might be required to respond to balancing blend requirements.

System architecture and trading platform

- **Standards, standardisation and interoperability are critical for hydrogen and MH:EK. Future SLES projects have the potential to act as a convener, champion and demonstration site**

  Standardisation is expected to be crucial to the efficient development of a hydrogen economy. A hydrogen system like an electrical one, will have many parts which need to work together to ensure secure and efficient operation. In addition, future hydrogen projects must integrate seamlessly with electricity, for example through electrolysis, with natural gas, for example through reformation processes, and with carbon capture and storage.

  MH:EK has identified the importance of standards on a national and international basis and has the potential to support the process. For example, MH:EK can support the development of cross-vector coordination for markets and future trading platforms and convene electricity and gas network companies to discuss interoperability challenges and solutions. As possibly one of the first SLES to directly integrate hydrogen, MH:EK has the potential to act as a trial site, demonstrating and verifying the value of emerging standards.

Business model and business practices

Decarbonised smart local energy system concepts

- **The techno-economic modelling identified important limiting factors for the use of locally electrolysed hydrogen with the SLES propositions modelled.**

  Hydrogen use was largely limited to meeting transport demand, whilst the balance between locally produced green hydrogen and hydrogen imported from outside of the SLES was dependent on two important factors: the balance in value for a renewable generator between selling electricity or selling hydrogen and the profile of the excess renewable generation.

  For example, in proposition one, the Milford Haven Marina SLES, the highly favourable electricity export price of £0.10/kWh for the existing solar farm made it difficult to justify diverting electricity export to hydrogen production. In propositions two and three, the Pembrokeshire food park SLES and the Pembroke schools, leisure centre and dock SLES, around 30% and 50% of the SLES's hydrogen transport demand was met by local hydrogen production respectively. In these cases, delivering greater local hydrogen would have required large electrolysers which would then have been had low utilisation factors, particularly during winter.

System architecture and trading platform

- **A trading platform integrating hydrogen can create additional value compared with platforms designs purely for electricity trading.**

  Although several PfER projects are either designing or demonstrating local energy trading platforms the majority of these and other innovation projects focus on trading electricity and electrical flexibility. MH:EK is the only project to specifically consider the potential to integrate hydrogen trading with electricity and identifies a number of important hydrogen-based products and services. These include local trading of the hydrogen itself, procuring hydrogen reserves and system services, trading transportation services for hydrogen (both network and non-network options), and the development of guarantees of origin (GOO) products which would verify the carbon intensity of the hydrogen brought and sold. Ultimately, there will be clear value in the trading of hydrogen products and services being integrated with their equivalents on the electricity system.

  Of those identified, the trading of hydrogen GOOs was the only one with clear benefit within the next 5 years whilst the others are more likely to deliver value in the medium to long term. The project's conclusion is that developing a hydrogen trading platform is unlikely to be the right option to take forward now due to the relative immaturity of the market.

What are the key lessons learned?

Data

Data ecosystem

- **Data management is a major challenge to good quality energy system modelling. It is important that SLES projects aim to follow emerging best practice and develop an ecosystem to ensure the existence of data lasts beyond the initial funding period.**

The need to improve the way that data is used and managed in energy projects was identified by the Energy Data Taskforce in 2019 which highlighted many of the challenges faced by the energy sector.

MH:EK has faced a number of data related barriers whilst undertaking detailed energy system modelling aimed at identifying optimal pathways to decarbonising Pembrokeshire's energy systems. As an example, many datasets received from external providers required manipulation in order to convert them to appropriate formats, consistent with other data within the ecosystem. Determining and communicating the accuracy and reliability of datasets where assumptions and aggregation was required proved particularly challenging.

The conclusions highlight the importance for all SLES projects of aligning to the recommendations made in the energy data taskforce report and the importance of focusing on best practice across the full life cycle of both the data and the infrastructure.

Carbon

Decarbonised smart local energy system concepts

- **MH:EK has identified opportunities to decarbonise a wide range of local carbon emission sources as well as support decarbonisation of locally located national fossil fuel infrastructure.**

These opportunities include two major Liquified Natural Gas (LNG) terminals, a 2.2 gigawatt (GW) gas-fired power station and a major oil terminal with a throughput of 270,000 barrels a day, which together account for around 680 TWh of fossil-fuel based energy. In the transition, these assets will need to have clear plans to manage their exposure to risk and capitalise on clean growth opportunities. Hydrogen opportunities for these sites include the conversion of LNG infrastructure to import or export of hydrogen or linkage to the reformation of natural gas combined with CCS. There is the potential to repurpose the power station to use pure or blended hydrogen, and the opportunity to decarbonise the oil terminal's existing use of hydrogen. Hydrogen is also an important feedstock for various processes, including in the agricultural sector where it is used to produce ammonia for fertilizer.

MH:EK also identified that the region is particularly well placed for the decarbonisation of marine applications including local ferries and tugboats, and in the longer term, the potential to scale up to play a role in decarbonising national and international marine transportation.

Focusing on decarbonising existing use of hydrogen could support the development of low carbon hydrogen production without the uncertainty associated with the development of new demand. Today, the UK produces 27 TWh of hydrogen, 96% of which is from unabated fossil-fuel processes. An early action recommended for MH:EK is to carry out an assessment of current hydrogen use across project partners and others such as the South Wales industrial cluster and the agricultural sector.

Finance and investment

Decarbonised smart local energy system concepts/system architecture and trading platform

- **SLES projects involving hydrogen infrastructure need to pay particular attention to risk exposure due to uncertainty around the scale and pace of hydrogen development and the form of future legislative, policy, and regulatory frameworks.**

Investment in low-carbon hydrogen infrastructure is particularly risky given the immaturity of the hydrogen market. Factors affecting the level of risk an investment faces include national carbon policy and support mechanisms for hydrogen production, the requirements of end-users and the strengths of demand as well as regulatory barriers and other developments across the energy system.

The project identifies a number of ongoing roles for MH:EK in supporting partners to manage risk. This includes carrying out detailed risk assessments for hydrogen-based technologies in the Milford Haven area and, for example, identifying ways in which local authorities could help mitigate risk in order to attract new investment. As an expert group, MH:EK should also aim to lead debate on how policy, markets and regulation should evolve at a local, devolved and national level.

The project identified two elements of a hydrogen system in Pembrokeshire which may be investable and where risks faced by investors may be manageable over the coming five years: electrolysis, which takes advantage of existing and planned renewable electricity generation; and shipping, which aligns with the UK Government's Clean Maritime Plan and commitment to a £20 million investment in demonstration projects.

How does this help solve whole system challenges?

Smart	MH:EK explores the role of hydrogen in a smart energy system and lays out a pathway to co-develop low-carbon energy and energy services across hydrogen and electricity.
Local	By developing investable proposition for local schemes which integrate hydrogen with electricity across a range of local demands, MH:EK has the potential to kick-start a locally led energy transition in South West Wales.
Whole energy system	Hydrogen is expected to be a crucial component of any energy system, complementing electricity and heat networks by providing a storable and transportable energy vector. MH:EK helps understand where it is valuable, where it might not be, both at a local level within SLES projects, and as part of a UK-wide transition to net zero.

Who is prospering?

- ✓ **Local businesses:** Such as those planning to locate within one of the investable SLES designs.
- ✓ **Local renewable generators:** Through the development of opportunities to increase the value of their output as part of SLES projects.
- ✓ **Milford Haven's national energy assets:** Through greater understanding of potential decarbonisation pathways which can allow them to support a net zero local and national energy system.
- ✓ **Future hydrogen innovators:** Through access to significant learning from the MH:EK project.
- ✓ **MH:EK commercial partners:** Riversimple are building on their experience of hydrogen fuel cell vehicle deployment, delivery, and operation of the public refuelling station. Milford Haven Port Authority through its plans to pursue the development of its site at Liddeston Ridge as one of the recommended investable propositions. Pembrokeshire County Council are looking to hydrogen mobility as an answer to the introduction of ultra-low emission vehicles, including lorries, buses, plant and cars, to take advantage of the rapidity of refuelling, the long range and ability to contend with hilly topography offered by hydrogen fuel cell vehicles.

More information:

- Milford Haven Energy Kingdom Virtual Room
- Pembrokeshire county Council MH:EK homepage
- Data Ecosystem report
- MH:EK strategic outline case for a smart local energy system
- Milford Haven: Energy Kingdom - System Architecture Report
- Key stage 2/3 education resources
- Bookcase of additional detailed reports

- Email: Steve Keating, Steve.Keating@pembrokeshire.gov.uk

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Detailed design project

Peterborough Integrated Renewables Infrastructure (PIRI)

The PIRI concept includes using Peterborough's energy recovery facility to supply a next-generation local heat network.

Project summary

PIRI aims to deliver an integrated smart local heat and electricity network in Peterborough which contributes to net zero carbon and reduces energy bills. The design brings together energy generation assets along with demand and storage. Initially using output from an energy-from-waste plant, the scheme is designed to be capable of taking energy input from a range of technologies to support future growth. PIRI has explored delivery models bringing together both public and private finance and ensuring the scheme enables investment as well as meeting the needs of local energy users.

Original objectives	1. To understand the commercial advantages and viability of developing a place-based, integrated, multi-vector approach to energy provision and create flexible, enabling infrastructure for renewable sources. 2. Establish low-carbon and renewable energy networks and systems across the city, considering building heating, electricity and cooling demands, electric vehicle charging and an array of green energy sources.

Key project elements

- **Technical economic and detailed project development study:** Which proposes a two phase development for Peterborough to meet heat and electricity demand. The design focused on delivering enabling infrastructure and initially connecting the energy-from-waste plant and water-source heat pumps using the River Nene. Over time, the design is sufficiently flexible to migrate to alternative energy sources.

- **Distributed Energy Resource Management (DERMS) specification:** Defining the smart grid monitoring, decision making and control architecture of the electricity elements of the PIRI scheme.

- **An outline business case for investment:** Which needs to be commercially viable, deliver real-world returns and be capable of attracting investment to finance delivery of the technical design for Peterborough.

- **Learning review:** Capturing and presenting key outcomes from the PIRI project team and covering a range of domains in order to make findings available to future integrated energy projects.

What have been the successes? What has been delivered?

1. The technical design can deliver nearly 120 GWh of energy each year.

This includes 24 GWh of heat and 96 GWh of electricity. The vast majority of heat, 95%, would be from zero-carbon sources and the private wire would allow the connection of 7.5 MW of solar PV electricity generation.

2. When combined into a single investment opportunity the combined heat and electricity system modelling suggests that it can deliver an 8.75% internal rate of return on investment over 40 years.

It used a realistic counterfactual which compared the investment against a shift from gas to alternative low-carbon heating sources in the medium to long term.

3. Identification of carbon savings in excess of 4.7 k Tonnes CO_2 per year over 40 years compared with natural gas heating systems.

Carbon savings were significantly less against the more realistic counterfactual of a future where the alternative, post 2030, is likely to be heat pumps. However, this highlights the importance of choosing appropriate counterfactuals and thinking carefully about how investment in low-carbon generation should be justified.

4. PIRI is delivering a central part of Peterborough's Local Area Energy Plan (LAEP) adopted in December 2022.

The advantages of schemes such as PIRI were recognised in the LAEP for Peterborough which highlighted that district heating serving public, commercial and private buildings in core city centre locations is a low-regrets intervention. Since the formal closure of the project, Peterborough City Council (PCC) has been working with BEIS and its consultants as part of the heat network zoning pilot, which is identifying other potential locations where the PIRI network could be expanded.

What have been the barriers? What impacts have they had?

1. Electricity licence exemptions rules.

The licence exemption frameworks for electricity supply and electricity distribution place significant constraints on the ownership options of the electricity private wire and who can act as electricity supplier.

Outcome: This has limited the delivery options for the overall project because it requires that the supplier of electricity under PIRI is also the owner of the generation. As the existing owner of the energy-from-waste plant, Peterborough City Council (PCC) is likely to be obliged to act as the electricity supplier and owner of the private wire network. Alternative delivery models, such as ones in which commercial providers deliver the PIRI system on a concessionary basis, are not currently feasible. However, the project continues to explore alternative options which would allow a private-sector organisation to own and operate the scheme.

2. Commercial viability.

The heat network as a standalone project was only marginally commercially viable pre-optimisation. However, the combined PIRI scheme across electricity and heat has significantly improved prospects.

Outcome: The proposal has explored ways in which the heat and electricity vectors are combined in a single multi-vector SLES investment opportunity with a potential internal rate of return in excess of 8%. This benefits from higher returns associated with the electricity component and a sharing of costs between the electricity and heat infrastructure.

What are the key lessons learned?

Technical

DERMS specification

- **The DERMS specification highlights the key technical smart requirements for a private wire electricity system aiming to minimise electricity bills whilst maximising the use of renewable and low-carbon electricity.**

The control solution identifies seven operational principles and reflects that all electricity generation connected to the private wire system will be low carbon. Principles include minimising operating costs, reducing imports of electricity from outside the private wire network, maintaining technical and contractual limits, and forecasting future system conditions, including the external grid's generation, demand, and carbon intensity.

The scheme is similar to existing smart grid control algorithms. However, novel elements were added to forecast future carbon intensity and to support optimising the system to minimise the carbon intensity of electricity supplied when electricity imports from the wider network were needed. The technical design also evolved to consider optimisation across the electricity and heat vectors.

Regulatory and policy

Technical economic and detailed project development study

- **Development of a financially viable private wire electricity network requires exemptions from supply and distribution licences which leads to complex constraints on ownership and delivery options.**

Obtaining a supply licence is a significant undertaking beyond the scope of a SLES project. Licence exemptions are possible where electricity is generated and supplied across a private network, however, this is only allowed under specific circumstances. The most relevant for PIRI is where the organisation that generates the electricity is the same organisation that sells (supplies) it to the end user.

Restrictions also exist on the private wire network which must be owned either by the generator, the customer, or the owners or tenants of the property where the electricity is generated or consumed.

In this case PCC, as owner of the energy-from-waste plant, is the obvious organisation to act as both the electricity supplier and owner of the private wire network. However, this limits the delivery options and means that alternative options such as a private-sector concession model or a joint venture involving a special purpose vehicle as the delivery organisation are not feasible.

Business model and business practices

An outline business case for investment

- **The project explored the potential of a range of business delivery options including private and public ownership. However, due to regulatory constraints the model most likely to be deliverable involved full ownership by PCC.**

The options considered in detail include a concession model with a private-sector partner delivering the whole project to the PCC's specification, a joint venture model with both the local authority and private-sector partner investing in the project potentially through a special purpose vehicle, and a public-sector council delivery model.

In choosing which model to take forward, the project had to consider a wide range of constraints. These included the threshold of return on investment above which PCC was willing to support, the need to install private wire cabling and heat network piping together in order to realise capital savings through shared trenching, and the need to integrate electricity and heat sale to ensure a project that is, overall, financially viable.

These constraints combined with the licence exemption issues discussed above led to the project recommending a council delivery model for PIRI. Whilst this has significant benefits and opportunities for the council, it will be challenging where local authority budgets are constrained. It also involves the council taking ultimate responsibility for the project including delivery risk for the construction phase and demand risk in operation phase. As a council owned and operated model is not PCC's preferred option, further work is exploring how the project could be structured to allow a private-sector, concession based model to be used.

An important point for future projects to note is the complexity of constraints and tensions from a wide range of sources which impact on the choice of business delivery model. As the PIRI project shows, ownership arrangements for existing infrastructure, the overall purpose of the project, likely customer base, and practicalities of construction are all examples of the type of consideration which can influence the most appropriate model to use.

What are the key lessons learned?

Social and community

Learnings review

- **The project carried out a review of recent literature around local energy demonstrators which showed there is an absence of structured learning, that the majority of learning has been technically focused, and there has been less focus on engaging stakeholders and consumers.**

PIRI aimed to overcome some of these gaps by conducting semi-structured interviews with senior members of the PIRI project team, with a focus on capturing the knowledge developed across different domains including stakeholder engagement, communication, and information management. This highlighted the growing awareness of the importance of ensuring that options for energy system change are developed with local people and communities rather than imposed on them.

The review also highlights the risk that future projects duplicate the less desirable features of current work if learning is not captured and effectively communicated to future innovators. Critically, it will be important that appropriate knowledge transfer roles and responsibilities are defined both for existing and future innovation projects to ensure that the next generation of projects builds on existing learning rather repeats it.

Carbon

Technical economic and detailed project development study

- **District heating using energy from waste produces strongly positive emissions savings against a gas counterfactual, but against a low-carbon electricity counterfactual with high efficiency heat pumps, energy from waste may lead to higher overall emissions.**

The project defined three different counterfactuals for both carbon and techno-economic analysis. These consisted of:

- Gas-heating counterfactual: the current status quo of heat demand being met from natural gas is maintained across the lifetime of the PIRI project.
- Low-carbon counterfactual: heat demand met from air source heat pumps.
- Combined counterfactual: where natural gas continues to be used throughout the 2020s before a switch to air sources heat pumps in the 2030s.

Against the natural gas counterfactual, the PIRI scheme is estimated to save 188 kTonnes CO_2 over 40 years, whilst against the low-carbon counterfactual PIRI leads to an increase of emissions of around 1kTonne CO_2 over the same period. Whilst PIRI is largely low-carbon, there are residual emissions from small quantities of gas used to meet peak demand and the parasitic load of the energy centre and plant room. By contrast, emissions associated with air source heat pumps start at more than 1.5 kTonnes CO_2 per year but quickly fall to zero as the electricity used to supply them is fully decarbonised.

This highlights both the importance of the choice of counterfactual, and the potential limitation of justifying future SLES projects on carbon savings. As the broader energy system decarbonises over time, individual projects will contribute to that shared low-carbon system rather than displacing significant emissions elsewhere. It is likely that new metrics will be needed to show how proposals support an overall low carbon system.

For PIRI, the combined option represents a realistic counterfactual which mirrors the expected trend of heat provision over the coming decades and therefore is more likely to represent what would happen in the absence of the project. The result is an estimated 8.8 kTonnes CO_2 delivered over 40 years.

Finance and investment

Technical economic and detailed project development study

- **As a standalone scheme, the district heating element of PIRI does not meet PCC's minimum hurdle rate of 5% and the sale of heat does not recover the initial capital outlay in anything but the very long term.**

The financial viability of PIRI is calculated in comparison with the same three counterfactuals used for estimating carbon impacts. Natural gas remains significantly cheaper than any low-carbon heat options. However, the district heating project does give a positive but low internal rate of return against both the alternative low-carbon heat and the combined counterfactuals with payback on investment coming between the 30th and 33rd year of operation.

The outcomes of the techno-economic analysis highlight the importance of combining the heat and electricity vectors together as a single business case. Once the two vectors are combined, the internal rate of return is attractive against all three counterfactuals. Against the alternative low-carbon heat counterfactual the IRR for PIRI is over 9%. Using the more realistic combined counterfactual gives an IRR of 8.72%.

What are the key lessons learned?

Finance and investment

This highlights one of the important challenges of delivering fully integrated SLES projects, namely that some elements may be commercially untenable on their own and need to be packaged with elements that will deliver higher returns. Whilst there are likely to be synergistic benefits from co-developing different SLES elements (for example, PIRI identifies shared installation of electricity cables and district heat pipeline), under traditional approaches to delivering energy infrastructure there is a real risk that elements that are financially marginal are left out whilst developers cherry pick more lucrative investment opportunities.

PIRI's place-based approach and the coordinating role taken by Peterborough City Council were central to identifying the integrated route forward and the opportunity to pair together elements in a way that delivered overall best value. This approach should be built on for future projects.

Learnings review

- **The structure and conditions on grant funding can place constraints on the ability of projects to innovate. It is important that funding models match the agile approach that innovation projects need to take, allowing flexibility to respond to challenges and take advantage of newly identified opportunities throughout the project lifecycle.**

PIRI experienced delays and restrictions on the ability to change scope due to the design of match funding models used by PfER. This required that any change to the project budget needed to be matched by adjustments to the level of contribution from project partners, leading to delays as approval was sought across multiple organisations. The learning report highlights this as particularly important for integrated infrastructure projects where opportunities can arise that need a small amount of budget increase to enable delivery of a much bigger gain.

> **“This is an innovative project which could deliver huge carbon savings, helping Peterborough to become a carbon-zero city.**
>
> **“There's still a long way to go until its completion, but the concept has been proven … it takes only a little imagination to see that in the future it could be scaled up to provide heat to many more businesses, public buildings and homes across the entire city.”**
>
> **Elliot Smith, commercial manager at Peterborough City Council**

How does this help solve whole system challenges?

Smart	PIRI will help optimise the smart use of energy from waste across multiple energy vectors and end uses.
Local	The project is grounded in the specific opportunities and challenges of Peterborough and shows how good ideas can be turned into real-world, commercial viable projects that support placemaking.
Whole energy system	PIRI delivers decarbonisation across heat demand and the use of electricity, including for mobility. In doing so, it highlights the importance of combining vectors to ensure that the overall package is commercially viable and investment can maximise the decarbonisation potential of SLES.

Who is prospering?

✓ **Peterborough City Council and its rate payers:** Who will benefit from maximising the financial and carbon abatement value of the energy from waste plant and investment in the delivery of PIRI.

✓ **Local commercial, industrial and public-sector energy consumers:** Who wil have access to low-carbon heat and electricity of local origin at lower cost than alternative decarbonisation options.

✓ **Project commercial partners:** Including Seco through demonstration of its 'sustainability sun' data-driven visualisation and analysis of organisation sustainability successes.

More information:

- PIRI homepage
- Project overview slides
- Learning Summary
- District heating detailed project development stage techno-economic feasibility analysis review
- DERMS Design Specification
- Article on PIRI aimed at helping young adults understand the pathways to net zero
- New Civil Engineer' article on PIRI

- Email: https://pirienergy.co.uk/contact/

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Detailed design project

REWIRE NW

REWIRE NW takes a revolutionary mission-oriented approach to the smart local energy system proposition. The project included creating a digital twin of Warrington's energy system.

Project summary

REWIRE NW takes a revolutionary mission-oriented approach to the smart local energy system proposition through its combination of the SLES framework and its focus on community and local benefit and value retention across the borough of Warrington. Its core objective is the creation of an energy system that is not only optimised and balanced at the local level in energy terms, but also in terms of welfare of, and benefit to, all its stakeholders. The project focuses on scoping out the business models, institutions, and frameworks needed to deliver SLES.

Original objectives	1. To support Warrington in meeting its climate objectives through a resilient energy transition. 2. Give the council the tools and capacity to undertake this challenge. 3. Derive learnings for replication to similar localities in the UK.

Key project elements

- **Innovative SLES framework and a system outline:** Consisting of an intelligent local energy architect tool, a mission-oriented energy market and a smart local energy company. The proposed SLES includes heat networks, local energy centre, solar farms, rooftop PV, battery storage and heat pumps in homes.

- **Digital twin:** Of Warrington's energy system covering 50,000 properties with data from Warrington Borough Council, EPC databases, and the Distribution Network Operator.

- **Business models:** Eight investable SLES business models ready for future deployment in Warrington.

- **Understanding SLES enablers:** Exploring APIs, open standards for SLES data, 5G communication infrastructure and regulatory reform.

What have been the successes? What has been delivered?

1. A range of regulatory compliant SLES business models with attractive rates of return for investors.

These include the set-up of a smart power pool for local electricity trading, a retrofit market-place, a novel community biomass with carbon capture and storage proposal, opportunities to support SEM decarbonisation, and EV business models, including a community collaboration.

2. Use of the digital twin to simulate potential borough-wide retrofit strategies.

Three strategies were modelled involving increasingly costly interventions and included cavity wall insulation, solid wall insulation and full-building retrofits.

3. Development of the SLES company concept reflecting regulatory barriers and potential future operating models.

This responds to the current regulatory and policy landscape and proposes several operating models and development pathways, including key regulatory changes needed to ensure delivery.

> "Working with Warrington Borough Council on the REWIRE North West project has shown how we can quantify energy-saving measures and support local councils in seeking to secure investment in decarbonisation initiatives. These models are easily replicable to any UK city and hold a huge amount of potential ... so we really hope to see more councils implementing this kind of technology."
>
> **Fergus Ross, ICL project manager at IES**

What have been the barriers? What impacts have they had?

1. The existing regulatory framework and future uncertainty around regulatory change limited the ability to deliver each element of the original vision.

This included limits on the ability to trade electricity locally without an electricity supply licence and uncertainty around future regulatory and legislative requirements or limitations on the role of local authorities in delivering SLES.

Outcome: The focus of the project moved away from a fully integrated SLES capable of being delivered largely within the existing regulatory framework to one which focused on developing specific business cases and identifying key areas of regulatory reform.

2. Energy market volatility and the challenging environment for supply companies led to the collapse of Together Energy in early 2022 and similar, innovative, supply companies.

Together Energy was a small-scale, socially minded supply company 50% owned by Warrington Borough Council. Its role in REWIRE NW involved linking energy demand and retrofit into a business model capable of supporting the upgrade of energy efficiency in buildings across Warrington.

Outcome: Together Energy's collapse came too late in the project to easily find a replacement. However, the model under development could be delivered through other companies in future.

3. A lack of open standards for communication protocols and data definitions.

This hampers the interoperability of integrated energy systems like those being developed in REWIRE NW.

Outcome: The project has highlighted the challenges of operating with existing proprietary standards and has actively worked to promote a move to open standards.

What are the key lessons learned?

Technical

Understanding SLES enablers

- **Well designed communication systems will be central to delivering SLES and these must be specified to reflect the characteristics of the energy assets, their location at the grid edge, and the types of services a SLES aims to deliver.**

A SLES involves distributed energy assets communicating with each other and with market platforms or other central controllers operating across a local area. Many of the energy assets will be small-scale and located at the grid edge, and some maybe in areas poorly served with existing public communication networks.

Designing a distributed energy system capable of operating as a SLES means having robust hardware capable of physically delivering communications to and from the grid edge. In some cases, existing public networks may be suitable, but installing new hardware will be necessary for others. In all cases, energy assets must be fitted with communication and control equipment linked to the communications network.

The specification of communications equipment needs to be developed alongside the broader design of the SLES. For example, the types of flexibility services that must be provided will determine the latency, speed and security of communications required. A DNO flexibility service might require a response within one second following a fault. Delivering such a service would place more stringent requirements on communications than a service requiring a response within minutes or hours.

REWIRE NW has explored the potential value of private 5G networks in maximising the benefit of SLES, particularly where public networks have limited coverage. As with the energy network itself, there is the potential for digital networks to be delivered through new models such as community ownership, and for private networks to deliver a range of communications services to residents and businesses beyond the operation of the SLES.

There is also a feedback loop with the wider design of the SLES, including control systems and the traded products; these elements need to be designed to reflect the capabilities and limitations of the communications system. For example, issues with poor communication network reliability can be mitigated by ensuring that operational data is logged locally and transmitted immediately. This means data from periods where communications drop out can be filled in later.

A second example is the development of a precise specification for how grid edge energy assets should respond to a loss of communications, for example should a distributed generator continue to generate or stop generating and disconnect from the electricity network. This decision is likely to depend on the range of services that it is providing at the time.

Designing suitable communications models is a critical component of any smart energy system and an important avenue for future innovation projects to explore.

Regulatory and policy

Business models

- **There is a need to balance blue-sky thinking with deliverability within existing regulatory environments.**

Across the project REWIRE NW's regulatory focus moved from one of designing a fully functional SLES within existing regulatory arrangements to one of identifying requirements for regulatory change.

There is substantial value in future projects allocating resources early in their project for detailed engagement with previous SLES schemes. This could include directly funding organisations involved in previous projects to allow them to provide support and to ensure that the lessons already learned are embedded in new projects. Such an approach could be particularly valuable in understanding regulatory and policy barriers and opportunities as, across REWIRE NW and the wider PfER portfolio, there is now a cohort of organisations with detailed understanding of which business models are possible in today's regulatory environment, and which are not.

A suitable approach could be to encourage projects to develop a regulatory strategy. This could identify elements of the project as either inside or outside of the existing regulatory framework. For those outside, a high-level approach to delivering that element should be developed, for example, identifying suitable derogations from regulatory rules and pathways to gaining those derogations.

What are the key lessons learned?

Business model and business practices

Innovative SLES Framework and a system outline

- **Local authorities have multiple roles to play within a SLES.**

REWIRE NW reviewed the range of roles that WBC could play in a future SLES for the town. These fell into five broad categories:

- Owner and operator of the SLES itself.
- Owner of distributed energy assets connected to the SLES.
- Consumer of energy, customer of the SLES and potential flexibility provider.
- Developer and financier of projects that will connect to the SLES.
- Local planning including local area energy plans, wider aspects of local planning, and the setting of planning policy.

In addition to these specific roles, WBC has indicated a desire to undertake a role of ecosystem facilitator that will guide the development of all necessary parts of a future SLES. WBC is well placed to do this due to its significant existing expertise: it owns two solar farms with a combined capacity of 70 MW and has experience of the retail electricity market through part ownership of Together Energy, an energy supply company that entered administration in February 2022.

REWIRE NW identified two important aspects of a local authority approach to participation in a SLES project. Firstly, it identified the importance of senior buy-in within the local authority, ideally with sponsorship at chief officer level. The cross-cutting nature of SLES and the multiple roles for the local authority mean that someone able to take a strategic view across all the local authority's activities and who has significant decision making power is critical. In the case of WBC, the head of corporate finance also has responsibility for overseeing planning and delivery of net zero within the borough.

The project also identified the value of local authorities having a clear long-term strategy. SLES projects are, by their nature, complex arrangements that can take significant time to develop. Early enthusiasm needs to be matched by commitment on costs and resources over several years of development and potentially decades of operation. Conversely, a risk-averse approach early in the project could mean losing opportunities such as ownership of key assets.

Future SLES project need to ensure a strong an early focus is place on long term strategic plans from local authorities along with senior sponsorship and buy-in for both the concept and ambition.

Digital twin / business models

- **A borough-wide digital twin provides the opportunity to support a retrofit marketplace which can help individual building owners to align with a borough-wide building decarbonisation and energy efficiency strategy.**

REWIRE NW successfully developed a digital twin of the Warrington energy system complete with building level detail for energy use. This provides an important tool to the REWIRE NW project and to WBC for the development of a strategy for decarbonising buildings across the borough. Whist WBC and other project partners can take this strategy forward in regards to its own buildings, investment in existing privately owned buildings will be largely down to their owners.

REWIRE NW developed a business model which would provide individual building owners access to their own buildings with the digital twin which would highlight interventions that align with the wider strategy, provide indications of investment costs and energy savings, and link building owners to energy efficiency installers.

The project has identified the potential to set up a platform to facilitate a retrofit market-place with minimal upfront investment required and a return on investment within two to three years. Project partner IES is currently developing the retrofit marketplace concept with a view to delivery in the near future.

What are the key lessons learned?

Business model and business practices

Business models

- **A local community supply model can be delivered through a third party intermediary (TPI) partnering with a licensed supply company.**

  Delivering local electricity supply is challenging within existing market arrangements. However, REWIRE NW has developed a viable business model that is being taken forward and involves the use of a TPI linked to a licensed supplier and aggregation of community-level generation.

  TPIs act as energy brokers and work with non-domestic consumers to develop bespoke and potentially smart tariffs delivered through partner supply companies. These tariffs can include headline rates and rebates, which can be related to savings associated from effective aggregation, forecasting and scheduling of multiple assets.

  REWIRE NW's local supply model involves linking community generation to demand through a TPI partner licensed supplier. Multiple local generators are then combined with the non-domestic consumer demand with each consumer being offered a unique smart tariff reflecting its ability to support a balanced local portfolio.

  REWIRE NW estimates that the model has the potential to reduce non domestic customer bills by up to 25% whilst increasing revenue to community energy groups by 30%. The additional revenue to community groups reflects the fact that for community groups that have installed generation since the end of the Feed-In Tariffs scheme, value is often based around behind-the-meter use with little revenue available for energy exported to the grid.

Data

Understanding SLES enablers

- **Proprietary data standards can represent a significant and costly barrier to the development of new entrants to the energy marketplace.**

  Open and transparent access to data is an important enabler for innovation within the energy system. The development of SLES approaches depend on finding new ways to use data: analysing it in original ways and combining datasets from different fields, such as demographic and energy data. This is likely to involve combining data from different applications and across different providers. The value of data can only be realised if the way it is formatted and communicated is open and standardised.

  Metering and billing data provides an example of the barriers that proprietary data standards can create. There are several providers on the market with their own property data standards which are inoperable with each other. Energy supply companies wishing to change from one supplier to another, for example, as the size or focus of their business makes their existing provider less suitable, can face significant financial, resource and time costs associated with making the transition. This has acted as a barrier to the growth of some new entrants to the energy supply market during the 2010s and could be an even larger barrier for SLES projects where the way data will be used remains unknown.

  Since REWIRE NW was commissioned, there have been a number of developments in energy data. The Energy Data Taskforce has produced a set of recommendations and a vision for future energy data and a significant modernising energy data access work stream was set up by Innovate UK. The importance of data should continue to form a focus for future SLES projects and where opportunities arise, these projects should adopt emerging standards.

How does this help solve whole system challenges?

Smart	REWIRE NW defines the institutional framework needed to deliver SLES together with an exploration of key smart enablers including communication infrastructure and open data standards.
Local	The project supports the development and delivery of Warrington Borough Council's energy strategy and decarbonisation ambitions and the proposed SLES would increase the local supply of energy demand and the use of flexibility.
Whole energy system	REWIRE NW brings together elements from across the energy system and takes a wider social perspective on energy challenges through its mission-orientated energy market.

More information:

- Warrington REWIRE NW
- Email: Paul Gilligan, paul.gilligan@pureleapfrog.org

Who is prospering?

✓ **Warrington Borough Council:** Through greater understanding of the local energy system, access to the borough-wide digital twin and new tools to support decarbonisation.

✓ **Warrington residents:** Through better access to scenario data on retrofit opportunities through analysis conducted via the digital twin.

✓ **Project commercial partners:** Including EIS developing improved understanding of the role of digital twin models in SLES projects.

✓ **Community energy sector:** Through the potential for increased revenue streams for grid-exported electricity under the community supply business model.

✓ **Local businesses:** Through access to their building's data on the digital twin, potential access to cheaper, local community-generated electricity in future and the opportunity to work with Rewire NW partners to deliver the business models developed.

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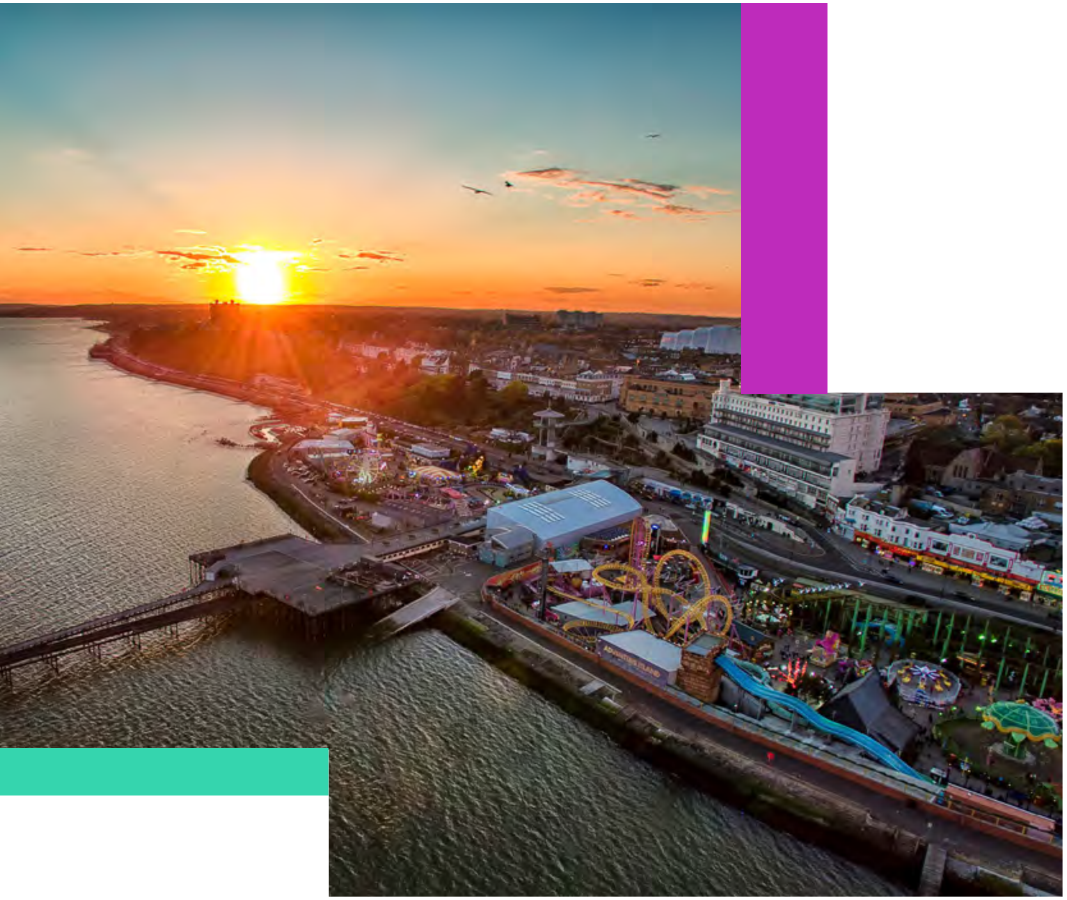
Detailed design project

Project REMeDY

Focusing on Southend-on-Sea, REMeDY has developed an innovative smart local energy system model for decarbonising energy use across heat, transport and electricity based around a smart heat network.



Project summary

REMeDY has developed an innovative SLES model for decarbonising energy use across heat, transport and electricity. The model is based around a smart heat network combined with a private wire electricity network linking renewables generation and battery storage. The REMeDY model optimises energy production, storage and use and has been shown to be a viable low-carbon energy solution for new domestic and commercial developments. The model has been developed in response to the needs of stakeholders across a building's lifecycle, including developers, social housing providers, owners and tenants. The model is informed by a detailed review of the energy needs and opportunities in and around Southend-on-Sea. REMeDY has also created a project pipeline, exploring the potential to deploy the model in new build and retrofit real-world developments.

Original objectives

1. Designs produced for £75 million+ of proven commercially viable energy infrastructure projects, to be developed immediately at end of project.
2. Demonstrate that customer energy bill reductions of 10% are deliverable while achieving an attractive rate-of-return on infrastructure capital costs and reducing overall CO_2 per household per year.
3. To design a commercially viable turnkey energy solution that is compliant with legislation and regulation and delivers overall system costs savings along with benefits to key facilitating organisations.

Key project elements

- **Heat-centred SLES model for building developments:** The REMeDY model delivers low-carbon heat and electrical energy and encompasses heat networks, heat pumps, electrical battery, EV charging and local renewable generation. The model fits within today's regulatory structures and can be financially viable in real-world development.

- **Smart energy potential for Southend-on-Sea:** A detailed energy audit for the city of Southend-on-Sea including reviews of demand, building stock efficiency, energy supply infrastructure and carbon footprints.

- **People-centred approach to the energy transition:** Which has developed innovative routes to engagement with local citizens and community groups including embedding the energy transition within wider social and environmental engagements activities, such as a series of ECO days and a Net Zero Superheroes engagement programme, run over 10 weeks.

- **SLES business case analysis:** The project explored the cost and benefits for each stakeholder involved in a building's life cycle including developers, owners and tenants This ensured that the model can be embedded within typical development frameworks such as those involving commercial developments (domestic, non-domestic and mixed) and social housing developments.

- **Project pipeline:** The development of 8 real-world proposals for new and retrofit building developments across domestic and commercial use cases, resulting in number of viable proposals being taken forward with building developers.

What have been the successes? What has been delivered?

1. A viable SLES model built around a smart heat network.

The REMeDY model has been proven commercially viable and is within the bounds of existing energy system regulation. Its focus on smart heat networks places the biggest aspect of the net zero challenge, decarbonising heat, at the centre of the project.

2. One of the detailed REMeDY designs for a new build project is being taken forward with commercial developers.

The design is for a mixed commercial and residential development with 1,400 dwellings in Eggborough, Yorkshire. The REMeDY proposal performs well against alternative low-carbon heating solutions.

3. Improved understanding of the Southend-on-Sea energy system and options for building decarbonisation.

A detailed review of energy use and carbon emissions across the city identified that 38% of carbon emissions come from domestic heat and the introduction of smart networks, such as those proposed in REMeDY, could lead to savings of about £15 million in avoided local distribution network costs by 2035.

> "We are pleased to be blazing the trail for one of the UK's flagship strategic projects on local energy systems. The project supports our goal of reaching net zero carbon emissions by 2030 and enables us to share learnings with other authorities across the country, meaning we are making a huge difference nationally in the fight against global warming."
>
> **Cllr Carole Mulroney**
> **Deputy Leader & Cabinet Member for Environment, Culture and Tourism, Southend-on-Sea City Council**

What have been the barriers? What impacts have they had?

1. Licensing requirements for electricity network operation and supply.

Licence exemptions for electricity supply and distribution are not applicable to the REMeDY model where this includes supplying domestic customers.

Outcome: Domestic supply of electricity had to be de-scoped from the solution leading to a loss of some value and a smaller scope over which to optimise the remaining energy supply and demand. However, the adjusted model remains capable of serving domestic and commercial heat demand, and potentially commercial electricity demand, and integrating renewable generation, battery storage and EV charging on an electrical private wire.

2. Significant practical and contractual constraints to deploying REMeDY in retrofit projects.

Including space limitations and the impact of legacy energy supply contracts across individual tenants of a building or development.

Outcome: Although REMeDY explored a number of domestic and commercial retrofit projects, these were not taken forward for commercial consideration. The deployment focus of the REMeDY model has moved to new build developments where the infrastructure and commercial agreements can be built in from the start.

3. The costs and benefits of a REMeDY solution for developers, landlords, tenants and owners do not align.

For example, commercial developers may look for solutions with low upfront costs which still meet regulatory and client requirements and may not be incentivised to fully consider ongoing running costs or the system that could deliver best value across its life-time.

Outcome: REMeDY placed significant focus on understanding and mapping out the costs and benefits to each stakeholder involved in the lifecycle of a building, with the final model designed to meet needs throughout the chain.

What are the key lessons learned?

Regulatory and policy

Heat centred SLES model for building developments

- **Without a licence, it is not possible to include domestic customers' electricity supplies and their behind-the-meter PV generation and battery storage within the overarching SLES.**

  This is due to regulations designed to give customers choice over their electricity and gas supplier and maximise competition. To act as a supplier would require either an electricity supply licence, which is a major undertaking beyond the financial and technical capability of a REMeDY-scale project, or a licence exemption. Licence exemptions are limited to small scale projects with a specific limitation of less than 1 MW peak demand for domestic customers and eligibility includes a number of criteria around the arrangement of domestic and non-domestic customers. The result of these criteria is that it was not feasible for REMeDY to include domestic customer electricity supplies within its model.

  However, the project was still able to integrate electricity generation and electrical storage into the REMeDY concept where that generation and storage connects to a private-wire electricity network and is used to run the heat network heat pumps. It is also possible to supply commercial customers' electricity and integrate any behind-the-meter generation and storage associated with those commercial customers.

  The complexity of electricity licence exemptions means it is critical that projects fully understand the multiple classes of licence exemption available and consider the implications and potential limitations this may place on future SLES designs.

Business model and business practices

Heat-centred SLES model for building developments

- **Local authorities have multiple roles to play in supporting the development of SLES including through setting planning policy, supporting demonstration projects and as a potential investor in, and customer of, REMeDY style solutions.**

  The project identifies the importance of local area energy planning to support evidence-based energy policy. It suggests that this could be integrated with the existing spatial planning role that local authorities deliver including in its capacity as the local planning authority (LPA) under which it sets evidence-based planning policies effecting low carbon development.

  There is also an important convening role for the local authority. This could include bringing together businesses, property developers, and energy developers in and around development areas to understand the wider opportunities and benefits before making their own decisions. This role could extend to the wider community with the local authority supporting or leading the process of educating citizens, developing local dialogue and facilitating community wide decision making.

  A local authority can also lead by example, investing in low-carbon solutions for buildings that it owns and investing in REMeDY models where it takes part ownership or sets the parameters for a development, of which it will eventually become a leaseholder.

SLES business case analysis

- **It is important to consider the costs and benefits to stakeholders throughout the lifecycle of domestic and commercial building development and ensure the needs of developers, owners and occupants, including tenants, are catered for.**

  The overall societal objective of low-carbon heat with low lifetime costs maps onto different sets of costs and benefits at each stage of the building lifecycle. For example:
  - Commercial developers are driven by financial impacts within the constraints of planning, building standards and client requirements. Reduction in upfront investment is a key consideration and developers do not face the ongoing operation and maintenance cost themselves.
  - Private landlords require a return-on-investment for properties and would assess the attractiveness of any REMeDY style solution based on the costs to their own operation as well as to tenants.

What are the key lessons learned?

Business model and business practices

- Social housing landlords have a primary responsibility to deliver affordable homes for those in most need, and address the current shortage in affordable housing. They do have an interest in ensuring tenants can acquire affordable energy and need to meet the Standard. However, funding for energy and refurbishment is often limited and where available are often allocated competitively meaning that some social housing providers will lose out.

Owner-developers will focus more on lifetime ownership costs including both operational and maintenance. However, where owner-developers intend to rent their properties, landlord resale regulations mean only the costs of energy can be recovered in resale costs, making capital investment challenging for renewals and upgrades.

Ensuring that SLES projects can be delivered in practice means ensuring that each of these stages is considered. For example, it may not be appropriate to ask a commercial developer to make the decision on whether to invest in a REMeDY solution which will likely involve higher upfront capital costs in return for reduced operating costs and greater reliability. Rather, the interests of future owners or tenants needs to be represented. For fully commercial developments, this may best be done through updated planning regulations which encourage or require integrated low carbon solutions, or where initial investors are also likely to be either owners or long-term leaseholders of the development, through clear specification at design stage.

Social and community

People-centred approach to the energy transition

- **A successful people-based approach to the energy transition requires an innovative engagement approach and allowed the project to better understand both consumer attitudes to energy products and citizens' relationships to net zero.**

The approach used by the project included ECO days in which project partners were able to undertake detailed discussions on energy system change with residents, alongside wider environmental themes ranging from food to fashion. Net Zero Superheroes involved 30 residents spending some time each week for 10 weeks to take action on net zero. Participants were linked via a WhatsApp group and website and the processes encouraged them to take on mini-missions which support net zero within their own lives and that of the local community.

Key outcomes from the people-based approach included identification of local residents' strong support for improving energy efficiency in homes across Southend-on-Sea, and their views on potential development of the energy system. For example, engagement showed people remain unconvinced that a monopoly energy supplier would act in their best interests and there were significant concerns over how consumers would be protected in a REMeDY energy system, particularly given the fact that this is a relatively new model.

This is important understanding for all SLES projects, as the delivery of more efficient and effective models of local energy has the potential to limit consumer choice over the type of heating and the supplier of energy. Even where these models have demonstrably lower costs to consumers, issues of choice and protection, whether real or perceived, have the potential to act as a barrier to delivery.

Carbon

Smart energy potential for Southend-on-Sea

- **Around 80% of Southend-on-Sea's carbon emissions are related to residential and non-domestic energy demand, with nearly half of this coming from the private housing sector.**

Detailed analysis of Southend-on-Sea's housing stock shows more than 173,000 domestic properties have an EPC rating of D or lower (90% of the total) and that around 50,000 of these do not have the potential of reaching EPC rating C or better. This reflects the age distribution of housing in Southend-on-Sea with only 10% of all houses built after 1980 and around 70% built pre 1960. This creates a significant barrier to the uptake of individual house-level heat pumps, as buildings need to be energy-efficient for these systems to be effective.

The conclusion of this work suggests that high-temperature heat network solutions such as those proposed by REMeDY are likely to be needed to cost-effectively decarbonise a significant fraction of existing, inefficient housing stock. In doing so, the heat networks can deliver energy system flexibility through thermal storage connected to the heat network, providing an alternative to attempting to integrate more energy storage in individual buildings that are often not suitable.

What are the key lessons learned?

Carbon

An estimate made by Imperial College London suggests that if REMeDY style solutions were used to meet 20% of national heat demand they could save up to £1 billion per year annually compared with other forms of heat decarbonisation.

This analysis highlights the scale of the retrofit problem and the need for future projects to tackle difficult to decarbonise housing sectors as well as insulated modern buildings. Smart heat networks provide a potentially important tool, but there is a need for further exploration of both the potential and the limitations of this approach.

Finance and investment

Project pipeline

- **REMeDY solutions can be financially viable for new, high density, new-build developments when compared against other low-carbon heating solutions. However, appropriate decisions need to be made early to ensure that lower cost, simpler, less smart solutions are not chosen by the developer without consideration of overall life-time costs.**

Viable proposals for REMeDY solutions were initially developed for two new-build domestic developments, one in Southend-on-Sea (Fossett's Farm) and the other at Eggborough, Yorkshire.

The REMeDY design for the Eggborough development was proposed early when the masterplan and initial energy strategy had been developed. This allowed alternative designs, counterfactuals and infrastructure arrangements in a way that was suitable for comparison against a heat-network-based design. At this early stage, no formalised development design had taken place and it was possible to ensure the space needs for the heat network and energy centre were built in from the start.

By contrast, engagement with the Fossett's Farm development started later in the process. Procurement for the development was already underway with many parameters already defined. This meant that although Southend-on Sea City Council is both an investor and final leaseholders in the development, it no longer had the flexibility to stipulate future requirements such as the choice of energy system or the importance of including an integrated SLES within the development. By this stage, the choice of final heating technology was at the discretion of the commercial developer who will be incentivised by minimising capital costs.

The REMeDY team continue to engage with the developer to communicate the advantages of a REMeDY solution. The project has several phases and there is the potential that REMeDY will be considered in a later phase.

Project Pipeline

- **Refurbishment projects, whether commercial or domestic, are likely to involve significant complications due to existing commercial relationships, supply agreements and the practicalities of delivering a heat network solution.**

REMeDY has explored proposals for a number of commercial and domestic retrofit projects but has been unable to find a financially viable project. For example, a project to retrofit Victoria Shopping Centre in Southend-on-Sea, a commercial development owned by Southend-on-Sea City Council, did not have sufficient energy demand density to make the proposal economic and would have faced significant contractual challenges, as each of the 76 retail units had its own energy supply contract in place. For the domestic and mixed-use retrofits explored, practicalities such as limited space for the required centralised plant and the complex arrangements the projects could have faced for retrofitting communal heating loops would have increased costs.

Future projects need to be aware of the significant challenges facing decarbonisation of heat in retrofits despite often high levels of inefficiency and the theoretical potential for large savings in running costs. This is a major societal, as well as project challenge.

How does this help solve whole system challenges?

Smart

REMeDY brings 'smart' to the design of communal and district heating networks integrating PV and battery storage on an electricity network with high-efficiency heat pumps, thermal storage and heat distribution. The system allows optimisation across electricity and heat vectors.

Local

The solution focuses on decarbonisation of heat, a challenge which is inherently local, and REMeDY delivers a solution that can be fully integrated into developments, neighbourhoods and localities.

Whole energy system

In addition to the integration of energy vectors, REMeDY directly considers the lifecycle of building developments and aims to meet the needs of all stakeholders from commercial developers through to tenants and owner-occupiers and the concept looks at the societal challenge of decarbonising heat in existing, poorly insulated buildings.

More information:

- Project REMeDY homepage
- Green Love Southend – Citizen engagement website
- Southend Climate Action Projects Page
- SMS REMeDY project page

- Email: Geeta Gaundar, GeetaGaundar@southend.gov.uk

Who is prospering?

✓ **Domestic and commercial leaseholders, property owners and tenants:** Through affordable low-carbon heat provided in an efficient and non-intrusive communal heating network.

✓ **Social housing providers and their tenants:** Through access to a more efficient integrated low-carbon heating system for new build social housing development.

✓ **Southend-on-Sea citizens and energy consumers:** Through increased levels of engagement and involvement in the local debate on energy transition.

✓ **Southend-on-Sea City Council:** Through improved understanding of carbon emissions, building stock characteristics and emissions reduction options for the city. Also in its triple role as local planning body, potential investor in and customer of low-carbon heat decarbonisation options.

✓ **Commercial building developers:** Through access to well defined and costed integrated energy solutions with the potential for cost-reductions as the model develops. REMeDY provides commercial developers with an offering which can meet the growing demand for future zero carbon developments.

✓ **DNOs and future DSOs:** Through reduced grid constraints, the managing of large numbers of electrical connections, and the availability of aggregated sources of flexibility.

✓ **Commercial project partners:** SMS and VITAL Energi are pursuing opportunities to deliver the REMeDY model in developments across the UK and People for Places is exploring the application of the model in its existing portfolio.

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Detailed design project

West Midlands Regional Energy system Operator (RESO)

The RESO project has explored giving cities and localities a stronger role within the UK's established model of energy market regulation.

Project summary

The RESO project has developed and explored the hypothesis that giving cities and localities a stronger role within the UK's established model of energy market regulation offers significant potential for releasing additional value, particularly given the need to transition the UK economy to net zero. In doing so, it has developed an innovative system operator framework which brings planning and development of the energy system in a locality together with the wider local planning and the service-delivery roles of local authorities. The RESO model provides an opportunity to deliver meaningful, coordinated and efficient local energy systems integrated into the wider social and economic activity of a region. The project illustrates this through scenarios for the development of Coventry's energy system as it supports the wider ambition of delivering a carbon neutral West-Midlands by 2041.

Original objectives	1. Develop a range of smart technology pathways and scenarios for decarbonising Coventry. 2. Develop a preliminary organisational and governance model for a local energy system management structure, a RESO. 3. Work towards developing commercial funding models for smart local energy systems with a view to these being applicable nationally. 4. Engage with stakeholders across the city, identifying local ambitions, opportunities and data gaps.

Key project elements

- **RESO implementation pathway:** A progressive least-regrets delivery pathway starting with development of a local data governance capability and whole systems planning and delivery role, evolving to include consumer and vulnerable citizen protection functionality and support for security of energy supply.

- **Cost benefit and value pool analysis:** Covering reduced energy system costs and broader social, environmental, and economic value.

- **Coventry Future Energy Scenarios (CFES):** This starts from Western Power's (the local DNO) Distribution Future Energy Scenarios (DFES) based on the national Future Energy Scenarios produced by National Grid ESO. The CFES expands on traditional energy system planning by considering other infrastructure elements and linking directly to wider local authority plans, such as plans for public-sector buildings across the city looking at trajectories up until 2032.

- **RESO market design:** Identifies 9 emerging local market types as relevant for Coventry with 3 explored in more detail including a market for avoiding electricity network reinforcement costs, a market for trading electricity connection rights, and an overview of a local hydrogen procurement market.

What have been the successes? What has been delivered?

1. A clear, deliverable, and well-articulated framework for developing the RESO concept.

RESO will be responsible to the national system operator for efficient energy market operation in Coventry, for ensuring Coventry stays within agreed parameters to support local and national security of supply, for protecting vulnerable customers in Coventry, and for ensuring the city reaches net zero carbon emissions at the lowest cost to Coventry and UK citizens.

2. A cost benefit analysis for a RESO in Coventry which estimates its present value at £721m over the next 30 years.

This represents a benefit-cost ratio of 2.37 and shows that customer bill reductions of up to 35% are deliverable under the right national and local scenarios.

3. Clear articulation of sources of local value created by RESO.

These highlight the city as the appropriate level for identification and solution of many local energy challenges. This is based on the ability of city-level institutions to effectively engage local citizens and to understand the similarities and differences between the local area and the national picture, whilst at the same time retaining sufficient scale to deliver an integrated city-wide solution across multiple sectors

4. A springboard for a full-scale pilot of the RESO model.

Including evidence that this should be carried out in parallel with the development of the Future System Operator at a national level.

What have been the barriers? What impacts have they had?

1. Local authorities are historically under-resourced and are not immediately credible homes for the kind of specialist functionalities required by a RESO.

Delivering the complexity associated with local energy system change will be difficult for local authorities that lack expertise in the energy system. Without careful and competent management of the linkages between energy, detailed local planning decision making and local democratic accountability, there is a risk that attempts to implement a RESO will be ineffective.

Outcome: This is a compelling argument to deliver a pilot RESO properly, in full, and with the right resourcing and skillsets.

2. Today's public and private-sector investment models are unlikely to deliver the smart local energy systems model.

The net present value of the RESO technical design is heavily negative with current levels of grant funding. Project financing models tend to focus on cherry picking individual high-return projects rather than supporting the synergies that come from developing the whole of a SLES portfolio.

Output: Through financial modelling RESO has provided greater levels of clarity around the net present value of a SLES and the components of it and has developed a proposed financing framework that should form the focus of future projects.

3. Market design and modelling revealed data gaps, regulatory barriers and structural misalignments that limit the efficient operation of local energy markets.

Many of these issues are a consequence of the existing energy system structures, where gas and electricity are managed separately and local authority input into energy infrastructure planning is ad hoc.

Outcome: The proposed RESO model shows how the value of a whole system perspective, close knowledge of local energy infrastructure and accountability to local citizens can improve outcomes through local energy markets.

What are the key lessons learned?

Technical

RESO market design

- **There is value in considering targeted use of hydrogen, particularly for high-temperature industrial processes and some hydrogen-for-heat in the commercial sector.**

  Modelling suggested that replacing 8% to 22% of high temperature processes (depending on the scenario) in the industrial sector with hydrogen boilers and integrating hydrogen heating for 3% of commercial consumers, helped to save an average of 20% of flexibility market running costs. That is equivalent to £1.7 million to £3 million in savings for Coventry annually up to 2032.

  This consideration of cross-vector technologies is important in identifying the most effective way to develop any one sector and deliver a solution close to optimal overall.

Articulation of local value

- **Detailed analysis is critical to identifying the right solution and accurately predicting impacts but is only likely to be feasible if responsibility is devolved to the appropriate local level.**

  For example, detailed work undertaken around domestic building thermal losses showed that savings from domestic building retrofit calculated with more detailed input data could be significantly higher per year than when using more generic, less detailed values. Modelling housing stock at this level of detail is unlikely to be feasible at the national level but delegating some aspects of responsibility to city or region level would allow the use of more granular modelling, suitable for context, which would allow such benefits to be identified and realised.

  As SLES models such as RESO become more prevalent, it will be important to identify the most appropriate geographical level at which modelling should be carried out and who should hold responsibility for action based on that modelling. Future projects should aim to further explore and define the value in cascading decision-making down to the most suitable level.

Regulatory and policy

Cost benefit and value pool analysis

- **A defined role for cities and localities in the UK energy system will support faster, more cost-effective national pathways to net zero.**

  The greatest value from a RESO comes from whole system planning and delivery across energy, housing, transport, waste and economic systems. Key datasets and competencies covering these areas are held at city and local authority area level. Empowering the city or local authority to lead energy system planning and delivery and ensuring that they have the expertise and support needed to integrate this with their wider roles, underpins much of the value identified through the project.

RESO implementation pathway

- **A progressive, least-regrets pathway to RESO implementation is possible starting with data governance and whole system planning functions and supported by rapid implementation of neighbourhood-level citizen engagement and consumer protection.**

  None of these require wholesale energy market reform, although statutory powers may be needed to ensure data is released to local data authorities. However, there is value in securing regulatory change to enable an institutionalised funding model for RESO structures.

  This might be achieved as part of the transition of the current electricity system operator (ESO) to the proposed Future System Operator (FSO), which is expected to deliver a whole-energy-system view at the national level. Estimates from RESO suggest that replicating the model nationally could cost between £400m and £700m, a level that is commensurate with the existing £2.1 billion cost of the ESO. There is the potential to relate funding to RESOs where there is evidence that specific outcomes are better delivered at a local rather than national level.

  There is an opportunity for future projects to continue developing the RESO model in parallel, and ideally partnership, with national reforms to the ESO.

What are the key lessons learned?

Business model and business practices

RESO implementation pathway

- **Delivering the calculated £721 million benefit would likely require about 35 specialist staff and an annual revenue budget of around £4.4 million and will work best with an associated annual capital budget of around £31 million.**

  This represents a significant allocation of funding; however, resources and expertise could be shared with neighbouring cities and local authorities, particularly for the more skilled technical and commercial functions. There are likely to be opportunities for economies of scale and scope, for example in terms of holding local network operators to account. As the RESO model is expanded to neighbouring areas, it will be sensible to explore regional or sub-regional shared service functions.

RESO implementation pathway

- **A review of international examples of municipal energy government suggests that an adaptation of the New York public benefit corporation model could be suitable for a RESO. This has been used to estimate initial functional resource levels and costs for Coventry.**

  Public benefit corporations in New York are formed for the purpose of creating a general public benefit which is deemed to have a materially positive impact on society and the environment. The New York Power Authority, the largest state-owned utility in the US, is one of the most well-known examples. It owns 16 power stations (mainly hydropower) and 1,400 miles of transition lines as well as supplying electricity to customers in New York State.

  An advantage of public benefit corporations is that they can issue their own debt, allowing them to make commercial investments and take on and manage the associated risk. This allows public authorities to make potentially risky capital and infrastructure investments without directly putting the credit of New York State or its municipalities on the line. As a result, public authorities have become widely used for financing public works, and they are now responsible for more than 90% of the state's debt.

  The public benefit corporation is just one of the many energy governance models used internationally. Exploring these global examples can provide new ideas for organising and financing UK energy projects, particularly where public and private finance need to be combined.

Cost benefit and value pool analysis

- **The project has identified 9 value pools at city level which offer value under supportive institutional structures.**

  Value pools directly related to energy costs cover the ability of the RESO to support reduction in the unit cost of energy, energy consumption, and fuel costs in the transport sector. Broader value areas covered include reduced NHS and social service costs, positive impacts on the local economy and environmental benefits, including those associated with carbon emissions and waste disposal.

  The largest benefits lie in:

  - Accelerating reductions in the cost of transport fuels, estimated to have a value over 10 years of over £113 million.
  - Release of local economic benefits at over £114 million with the potential to create more than 4,000 jobs; and
  - Reduction in energy bills through lower prices and consumption, estimated at £86 million over 10 years.

  The analysis highlights the importance of looking beyond the energy system for a truly whole system value chain. It reflects the fact that the role of the energy system is not only about delivering energy but about the broader social and economic value that energy enables.

Data

RESO implementation pathway

- **Alignment between administrative and physical boundaries of infrastructure networks, local authorities and RESOs would be helpful to reduce data and engagement costs but will rarely occur without major restructuring.**

  In particular, the area served by each primary substation on the electricity distribution network provides a useful geographical unit. At the start of the project, RESO defined the boundary of the area of study to include 201 local super output areas (LSOAs), a geographical unit used for reporting small area statistics.

  However, as the project evolved it became apparent that areas served by primary substations were a more relevant geographic unit, as it is the topology of the network infrastructure which directly affects electricity flows, the ability to connect generation and demand, and the value of flexibility.

What are the key lessons learned?

Data

It is unlikely that, outside of DNOs, many datasets will be aggregated across geographical units based on electrical network infrastructure. However, it is worth future projects considering the most appropriate and practical geographical units to use, and the challenges that will come where datasets are aggregated on different and often overlapping units.

Coventry future energy scenarios

- **Detailed data requires a trusted independent organisation to be able to coordinate, collect and analyse at a detailed raw data level.**

The RESO project has benefitted from having project partners that were prepared to share detailed data that is not publicly available. Western Power Distribution (electricity networks), Cadent (gas), Engie (heat network), the Local Authority (Coventry City Council), and West Midlands Combined Authority all provided data to the RESO project under data sharing agreements. This has provided a glimpse into what is possible and produced a greater understanding of the type of data that is valuable, the challenges of interoperability between different data providers, and the richness of insights which can be delivered when different data are combined.

Future projects need to be aware that this is not the normal situation today and achieving the level of data sharing in RESO required significant resources and goodwill from an engaged and supportive group of organisations.

The project concluded that it should be a fundamental role of any future RESO to create a local data lab and become a trusted source of local energy data between different stakeholder groups.

RESO market modelling

- **A major challenge was the absence of data on forecast network reinforcement costs for Coventry's distribution network to 2032.**

This limited the project's ability to confidently model the value of flexibility and demand reduction in terms of reduction or deferral of distribution network investment. Analysis therefore focused on modelling the local DNO as a price taker in the flexibility market. This points to a significant gap in the data needed to estimate the impact of SLES systems on a major source of local value.

In line with learning from across the PfER portfolio, this highlights both the importance of network companies improving the data they collect and of sharing that data publicly. In the near future, until DNOs can improve data visibility, projects need to remain aware of this significant limitation.

Carbon

Coventry future energy scenarios

- **Implementation of the ambitious RESO technical design for the 'leading the way' scenario in the CFES could achieve emissions reductions of over 80% versus 2018 figures, and over 72% versus the steady progression counterfactual, by 2032.**

This includes a reduction in total energy consumption of 30% compared with 2018, with substantial reductions in gas and liquid fuel consumption, the addition of a small amount of hydrogen (attributed to decarbonisation of specific road transport) and an increase in electricity consumption. Additional electricity consumption is a result of the electrification of processes such as road transport (57%) and domestic heating (45%) Heating is also supported by the rollout of district heating.

Achieving these results would require a radically different approach to domestic energy efficiency as over 67% of existing homes would require improvement to some element of the building fabric.

What are the key lessons learned?

Finance and investment

Cost benefit and value pool analysis

- **Overall, the RESO technical design is not an attractive investment due to the heavily negative net present value (NPV) of domestic retrofit.**

The objective of the RESO technical design, used in the financial modelling, includes getting all properties in Coventry to EPC level C by 2032. This requires investment of approximately £3.8 billion. At present grant funding levels, the SLES has a heavily negative NPV of £2.4 billion. Modelling indicates that grant funding would need to rise to 79% of capex to lift equity internal-rate-of-return to 10% over 25 years.

There are elements of the SLES technical design which do produce an attractive investment case. However, part of the value of RESO is in bringing projects together to act as a synergistic, self-optimising local energy system of scale in which investors, developers and innovators do not cherry pick the easy projects whilst leaving the harder ones to others. It is therefore important to highlight the more general point that not every project that saves carbon or increases energy performance also makes a return on investment within the modelled term (15 years to 40 years.).

The project concludes that whilst the technical design would deliver customer savings it does not repay the investment. Projects, particularly those focusing on heat decarbonisation across a relatively poor efficiency housing stock, should have this at the forefront of their financial planning and consider the role of public grant funding and commercial and private investment.

RESO implementation pathway

- **Delivering SLES requires new forms of financing frameworks which separate out investment roles and provide a structure which can support investment from a wide range of sources.**

Today's project financing models are a barrier to investment in integrated, synergistic, SLESs. They tend to focus on individual projects and aim to identify those with the highest potential returns whilst ignoring others. RESO has developed a financing framework to overcome these issues.

The framework is split into two parts. The first is based on a master developer role which works projects up into investable propositions, carrying out early stage due-diligence, and marketing them to investors. The master developer will also aim to maintain commercial synergies between different projects. The second part is a suitable framework to support the design, build, own, operate, maintain and refinancing phases of a project (the DBOOMR framework).

RESO highlights this area as one where there is a need for significant learning and proposed two approaches to developing SLES financing: a specific innovation focus on how to develop SLES projects to investment-ready stage and the use of grant funding to manage the risk associated with early pioneers of innovative approaches to financing.

> "The Regional Energy Systems Operator project clearly demonstrated the importance of a place-based approach to enhancing the energy system and the criticality of accurate and accessible data to inform that. RESO enabled us to bring together disparate data sets … and horizon-scan wider availability and data gaps. Building off that work, we're currently working to better define electrical substation service areas … to address a key data gap in local energy system planning."
>
> **Dr Grant Wilson, University of Birmingham**

How does this help solve whole system challenges?

Smart

The RESO design has the potential to better integrate energy infrastructure with housing, transport, waste management and other services across a future smart city. A smart energy system will benefit both from the data curation and sharing and its physical and digital integration with activities delivering public good across the region.

Local

RESO shows the value of giving responsibility and authority for significant elements of energy system planning and delivery to city-level institutions. It will be an enabler for greater democratisation of energy and the ability to flexibly apply national principles to specific local context. By empowering the city, it will release value and opportunity that is only visible to those operating at a local level.

Whole energy system

RESO's whole system ambitions go beyond energy to encompass broader social, environmental, and economic opportunities and outcomes. Through its analysis of total energy use in Coventry across electricity, heat and transport, it gives insight into how infrastructure for electricity, gas, hydrogen, and petroleum should evolve. And it provides a pathway to support the delivery of West Midlands', 2041 carbon neutral target.

More information:

- RESO home page
- RESO Data Catalogue
- Energy system Catapult Report – The RESO effect: a smarter fairer energy future

- Email: Cheryl Hiles, Cheryl.Hiles@wmca.org.uk

Who is prospering?

✓ **Coventry City Council and West Midlands Combined Authority:** Through a detailed understanding of energy system decarbonisation delivered through the CFES and as the foundation of asks of central government for Devolution Deal funding.

✓ **Ofgem, NGESO and UK Government:** Through the delivery of a detailed, comprehensive, and high-quality model for the development of local energy systems and as an important evidence base feeding into the development of the FSO, a process that RESO is applying for funding to support.

✓ **Electricity and gas network companies and their customers:** Through more detailed understanding of the likely development of the energy system in Coventry and the ability to explore new models of local engagement to inform their business planning processes.

✓ **Local citizens:** Through the potential for a better, more accountable, locally focused energy system planning process and, through the proposed financing framework, the opportunity to draw in public and private investment to deliver energy projects of significant local value.

✓ **RESO commercial partners:** Enzen developed detailed multi-vector modelling capability which can be applied to many applications and sectors. Electron has gained experience and refined its approach to designing and modelling local flexibility markets and stakeholder engagement.

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Detailed design project

Zero Carbon Rugeley (ZCR)

Zero Carbon Rugeley has delivered a detailed energy system design for the Rugeley area which is sustainable and low-carbon and responds to the town's rich energy heritage.

Project summary

Zero Carbon Rugeley has delivered a detailed energy system design for the Rugeley area which is sustainable, low-carbon, and helps to drive the regeneration of the town and local energy infrastructure while offering additional services and value to residents and business. The project has put the involvement of the local community at its heart, working actively and creatively with local groups and residents to identify what those living and working in Rugeley want from a future energy system, and it responds to the town's rich energy and industrial heritage stretching back centuries. ZCR complements other PfER projects by exploring the challenges and opportunities for SLES in a market town environment.

Key project elements

- **User-centric design and community engagement:** The ZCR model was designed in conjunction with the local community and is centred on users of the system. It involves a creative community animation approach to engagement which helps break down existing power structures and ensures every voice is heard.
- **Technology building-blocks:** Including the development of energy efficiency retrofit pathways, mobility as a service, automated vehicle, and energy system management and optimisation including in-home control and SLES-wide optimisation.
- **Business models:** Developed adaptive, investable business model for delivery of the technology building blocks.
- **Finance and investment framework:** Exploration of opportunities for effective investment of public and private finance in SLES infrastructure and businesses.
- **Policy and regulation review:** Assessment of the national and local policy landscape including opportunities and barriers to realising integrated SLES offerings.

What have been the successes? What has been delivered?

1. Overarching SLES ready development framework for the Rugeley area.

Based on interventions planned across electricity, heat and mobility in the existing community and with opportunities to incorporate new developments in the area.

2. Community engagement through the user-centric design process.

Engagement with local residents, businesses, and stakeholders was a critical part of the project from the start and significantly shaped the final ZCR model. The approach was creative and helped develop a narrative for the project, embedding it within Rugeley reflecting the local community's historic contributions to energy through the coal industry and industrial revolution.

3. Use of data to develop deliverable town-wide retrofit pathways.

The project has pioneered a data-driven approach to developing retrofit programmes for thousands of properties, using household analytics supported by in-person surveys for a sample of the buildings, to calibrate the emerging pathway and ensure accuracy. The approach has been refined throughout the ZCR programme and has already been deployed on other projects.

4. Inspired local authorities to develop and adopt local area energy plans (LAEPs).

Cannock and Lichfield and Stafford Borough local authorities have both been inspired to develop LAEPs in response to ZCR. This is a result of deep engagement between the project and local authorities, which saw their appreciation of the challenges of decarbonisation grow along with their understanding of the value of taking an integrated whole system approach to designing the solutions.

> "Zero Carbon Rugeley has made us realise that there are others that care about the climate and want to see change. It has encouraged us to join up and try and take this movement forward."

What have been the barriers? What impacts have they had?

1. Significant challenges accessing data on Rugeley's energy system across energy networks, production and use.

ZCR dedicated significant time and resource early in the project to identifying and accessing data sets from the wider energy sector. However, few organisations had a culture of open access to their data and the project initially found it challenging even to understand what data existed. Where data sets were identified, there was a lack of standardisation and good quality data management, which created further barriers to its use.

Outcome: The past few years has seen a growing awareness of the importance of data for net zero and pressure from across the sector, to which ZCR has contributed, has started to drive significant change. This has led to a realisation across the sector of the need to standardise and share data and has seen significant growth in data sharing portals and the availability of data sets.

2. The current policy landscape fails to support SLES.

The policy environment at both a national and local level has yet to respond to the need for a joined up whole system approach. Each part of the energy sector is currently treated independently both from other parts and from wider policy ambitions. For example, at local level, there is a need to better link wider spatial planning initiatives. At a national level there is a need to ensure that regulatory frameworks enable best value to be achieved across vectors.

Outcomes: The lack of an appropriate national framework has led to ZCR needing to adjust its ambition away from designing a fully functional SLES that is ready for deployment, towards ensuring that Rugeley is SLES ready. At a local scale, the project has identified missed opportunities, such as the potential for ZCR to support development of local plans in the area.

3. Local Authority capacity.

Local authorities hold many of the important levers for energy-system change, but do not have in-depth understanding, resources, experience, and relevant skills related to the energy system. This can create the conditions for poorly informed decisions, delays, and a reticence to engage openly.

Outcomes: Several local authorities in the area declared climate emergencies in 2019 alongside ambitious targets to decarbonise. Since then, the scale of intervention and cost required to deliver on these ambitions have become clear. During the project, ZCR has built a reputation for an in-depth understanding of the energy related challenges facing local authorities and potential solutions. In doing so, it has helped develop local authorities' understanding and begun supporting them to make well informed decisions.

4. Mismatch in understanding and expectation between private-sector investors and SLES designers.

There is a lack of willingness within the private-sector finance community to adapt their business models to suit the characteristics of SLES. This is combined with a lack of understanding around how to best use public-sector funding to prepare SLES for private investment.

Outcome: ZCR, in conjunction with the RESO project in Coventry, convened an investor panel to inform detailed discussion between public and private-sector investment communities. The result is improved understanding of risk and return on investment and the role of the public sector in setting policy that supports clear quantification and management of risk.

What are the key lessons learned?

Technical

Technology building blocks

- **There are tensions between the optimal solution at different levels and for different stakeholders within the SLES. ZCR developed an iterative approach to balancing these tensions as shown by the retrofit pathways.**

ZCR aims to optimise interventions across the energy system to deliver the best solution for Rugeley. However, what is optimal for the SLES as a whole may not be optimal for particular interventions.

An example of the challenge was seen in the development of retrofit pathways for the town. Developing these involved carrying out detailed analysis across the domestic building stock to optimise investment in a way that maximised the impact on overall energy efficiency across the town. However, the resultant energy demands were not necessarily optimal from the perspective of the electricity network.

The solution was to iterate between building stock and electricity network analysis until an appropriate balance of investment at both levels was identified. For example:

- Initial building stock analysis focused on achieving EPC level C whilst decarbonising heat demand across the town.
- The resulting energy demand was modelled in the whole-system PROSUMER model which includes electricity network constraints. This showed the EPC C retrofit pathway would require significant upgrade of around two-thirds of the 101 secondary substations.
- This identified the need to reduce the demand, particularly peak demand, associated with electrified heat. The project iterated back to building stock modelling, developing deep and deeper retrofit pathways, with the result fed back into the PROSUMER model.

The result was a more nuanced pathway where energy efficiency interventions beyond the original expectations of EPC C were used in some areas of the town in order to reduce pressure on the electricity network.

This iterative approach is likely to be a characteristic of any SLES project. Future SLES projects should consider where tensions could exist and how their process can resolve them.

Regulatory and policy

Policy and regulation review

- **Recent changes to the regulatory structure affecting how electricity is metered and supplied open up new possibilities for SLES.**

One change, known as P375, allows individual energy assets behind a customer's main electricity meter to be metered separately so it can provide flexibility services independently from other activity on the site. This could include electricity generation, energy storage and specific flexible demand assets. The change better enables a customer's flexibility to deliver value for the system and to be rewarded for it.

A second change, known as P379, allows a customer to use multiple suppliers for different elements of their electricity demand, flexibility and generation. For example, a customer could use one supplier with a fixed-rate tariff to meet its baseload electricity demand, whilst using a different supplier offering a bespoke time-of-use tariff for EV charging or heat pump operation. This can support SLES by allowing projects to develop local tariffs for specific elements of demand and use the tariff to reward customers for flexibility, which supports a more efficient operation of the local electricity system.

These changes have come during the delivery of the ZCR and, where possible within its timeline, the project has adapted to reflect them. Future projects should investigate the opportunities that these key changes create.

Policy and regulation review

- **The development of an integrated approach to energy is equally important at local government as at national government level.**

Much of the policy debate focuses on the need to make national UK policy more flexible and joined up in its approach to energy. The experience of ZCR supports this conclusion and highlights the importance of local government in taking a more holistic approach.

What are the key lessons learned?

Regulatory and policy

An example is the role of the local authority in developing local plans. These can directly inform the development of SLES, such as highlighting areas for new development, but should also be themselves informed by energy plans such as the LAEP and development of SLES in the local area. Local plans can also help identify where funding or mitigation is required to address the impact of new development upon energy systems from the perspective of carbon reduction and cost. Key energy-related inputs to wider local planning include the locational alignment of demand and supply, particularly important for heat where waste heat and heat network opportunities could play a significant role.

There is a risk that under-resourced local authorities do not identify and capitalise on the value of integrating these local policy functions. An important role of SLES projects today is to support that integration.

Business model and business practices

Technology building blocks

- **Domestic retrofit business models need to be adaptable to a full range of ownership and tenancy arrangements.**

The ZCR Retrofit pathway lays out an approach across the whole tow covering around 10,500 homes. These include a range of tenures including owned outright (34%), mortgaged (38%), private rented (13%) and socially rented (13%). Each of these groups has different characteristics and requires a different business model to enable retrofit.

For example, owner-occupied houses where the resident is able to pay could be supported through a low-interest loan potentially linked to a mortgage, whilst those less able to pay under any tenure might be better served by an energy service model where a monthly fee over several years finances a mix of retrofit and energy options to deliver a defined service level. Capital investment in buildings that are private or socially rented needs to respond to the obligations and requirements of landlords.

Business models / finance and Investment framework

- **Relying on large anchor loads from the commercial sector to underpin a SLES can be risky even where there is significant support within the anchor organisation.**

The initial approach taken by ZCR to non-domestic energy demand was to focus on the biggest users in the town based on the assumption that this could have the largest impact. For example, the project worked with several large energy users exploring the potential to integrate significant energy demand within the developing SLES model.

ZCR learnt that the internal decision making process in national and multinational business organisations can cause delays and uncertainty for the wider project. For example, local managers may be enthusiastic about an approach that can reduce their costs and support the local community. However, they are often constrained by company-wide policies, such as centrally implemented energy management policies or national energy supply contracts which limit the ability to engage with local SLES projects.

On reflection, ZCR has identified that aggregating small non-domestic customers may be a more appropriate approach. Although it removes the certainty that a committed anchor load can create and requires a wider engagement and learning exercise, it also removes the risk associated with that anchor customer pulling out. The cumulative energy and emissions associated with smaller non-domestic customers are sufficiently large to deliver similar benefits. Smaller organisations are also more likely to be embedded within the economy and community of the town and more likely to be willing to align their energy management with a SLES.

Technology building blocks

- **A mobility as a service (MaaS) business model is feasible but challenging and will face difficulties in integrating information from multiple travel providers, in particular real-time data.**

The project has explored a MaaS business model for Rugeley, which would allow customers to make a single journey booking for travel over multiple modes. The business model for a MaaS provider could include the charging of a small commission to travel providers, commission on sales made during the journey, advertising and in-app purchases.

However, there are significant challenges to overcome, notably related to the complexity of drawing together data and ticketing requirements across multiple travel providers. It is possible to overcome these issues in the right context. For example, MaaS offerings are appearing in London where aligning ticketing across transport modes is significantly easier due to the multi-modal reach of Transport for London and the volume of travellers.

What are the key lessons learned?

Social and community

User-centric design and community engagement

- **Adapting SLES approaches to the community, social, and historical context will be important in their success.**

  Rugeley has a significant energy heritage. It has played an important part in the development of the electricity system through the large coal power stations that operated next to the town from 1961 to 2016. The local area was an important coal mining region until the closure of the last local colliery at Littleton in 1993. Further back, Rugeley played a leading role in the industrial revolution with a significant number of mills using the River Trent for energy.

  The community is steeped in the town's heritage and is facing the challenge of reinventing itself and regenerating following closure of the power station and other industries. The project worked with community ambassadors who helped the ZCR team to understand Rugeley's relationship to energy. They supported the project in working with the local community, ensuring the language and approaches used were clear and appropriate.

  Through this ongoing process, the project developed a positive narrative centred around Rugeley's historic place at the cutting edge of energy innovation, from the vanguard of the industrial revolution through its contribution to the UK's energy security delivered through reliable electricity generation in the second half of the 20th century and the start of the 21st. This narrative helped navigate the tensions which could have emerged when discussing the need to move away from fossil fuel energy in a town with significant involvement in the coal industry.

  ZCR provides an example of the importance of place within the development of SLES. Each locality has its own heritage and context and SLES projects, wherever they develop, need to listen to communities in order to understand that context and respond to it.

User-centric design and community engagement

- **Engagement cannot be passive. Creative engagement and community animation are likely to elicit more useful inputs and help develop a more supportive community.**

  The methodology for engagement, user-centric design, has been developed between Keele University and the New Vic Theatre company. Described as community animation, it aims to break down existing power structures and support everyone in engaging and thinking about the energy system in new ways.

  One example was energy heritage walks. These participatory events used actors to bring heritage stories alive in-situ at sites across the town. The walks visited sites of old mills and finished at the old power station. They allowed informal discussion about how participants felt about their history, and the challenges associated with regeneration, and opportunities to reflect on the elements of Rugeley's history portrayed by the actors.

  A second community animation approach was to use storytelling as a way to describe SLES business models. This responded to the fact that many SLES models are complex and can be challenging to understand. Storytelling involved developing personas and knitting these together to show how different people could benefit from SLES or find the process challenging. Workshop participants were able to respond to the stories, identifying which characters they saw themselves reflected in, and the opportunities and worries that they saw in the stories for their own lives.

  ZCR Rugeley shows the value of creativity in the community engagement process. It resulted in nuanced feedback and an increased sense of ownership by the local community which means the outcome is strongly rooted in the town. Future projects should consider the approaches used and learn from the level of resource that ZCR has put into this aspect.

What are the key lessons learned?

Carbon

Business models

- **There is a gap in our understanding of the impact that embodied carbon can have on the optimal pathway for energy systems.**

  ZCR has aimed to develop a pathway that minimises costs along with operational carbon emissions. However, it is becoming increasingly clear that embodied carbon plays a significant role in the overall emission impact of a project. Embodied carbon was also a concern raised in community engagement. Without considering it there is a risk that SLES favours solutions with low operational emissions, but significant emissions associated with construction and the supply chain.

  Identifying the embodied-carbon impact of a project is challenging. Data is poor quality, and long international supply chains can make it very difficult to estimate embodied carbon. The ZCR team is keen that future projects consider the potential to analysis embodied carbon, adding it to the list of outcomes that might be included in optimisation modelling or iterative design. This is an open challenge, one that is important and is likely to require significant effort to solve.

Finance and investment

Finance and investment framework

- **The public sector role in supporting investment includes setting a less complex and more stable policy landscape as well as providing institutional support to help de-risk investment.**

  It is critical that SLES can attract private investment. This needs private-sector investors to adjust their business models to take account of the characteristics of SLES projects. The complexity, relatively long periods over which returns on investment will accrue, and the profile of risk all create uncertainty, which, at present, many in the private sector are uncomfortable taking on.

  A core role for the public sector is to help investors to develop their understanding of SLES and gain the confidence needed for investment. There is an important role for public funding such as supporting the early stage development and de-risking of projects.

  Fully addressing the complexity and risk concerns of investors will, however, require a wider response from the public sector. These concerns can be mitigated by the creation of a stable policy and regulatory landscape and a more standardised approach to SLES.

  An example of this approach can be seen in Homes England which supports the development of affordable housing across the country and works to draw in private-sector funding. Its 2018 corporate plan highlights its role in working with institutional investors. It offers to help open up creative options for long-term, low risk investment opportunities in return for investors becoming more active in addressing the housing crisis and leveraging their significant funds and expertise to deliver new high quality homes.

  At present there is little in the public institutional sphere that can play a similar role in the energy system. A key recommendation of ZCR's finance and investment work is that such an institution is needed to support investment in SLES infrastructure.

How does this help solve whole system challenges?

Smart

ZCR focuses on smartness both within the technical elements of the energy system and the need to design 'smart' to support the users and beneficiaries of SLES. Reflecting near the end of the project, partners identified that "SLES needs to be smart, but it's a different kind of smart than just technical." Non-technical issues such as supply chain, skills or resident engagement present significant barriers to implementing broad systems change without being fully understood.

Local

The project shows that a successful SLES is a community empowered to drive solutions to net zero supported by finance and regulation, rooted in a particular place and responding to the heritage and ambition of the local community.

Whole energy system

By exploring the services that energy provides across electricity, heat and mobility ZCR identifies the importance of taking an iterative approach to balancing the multiplicity of costs and benefits across stakeholders, constraints and opportunities.

More information:

- Equans project home page
- Rugeley Housing Stock analysis report
- ZCR community engagement strategy
- Evaluation of market structures report
- EngageZCR Facebook page

- Email: Louise Alter, louise.alter@equans.com

Who is prospering?

- ✓ **Local Authorities:** Including Cannock and Litchfield, through access to ZCR's in-depth knowledge of the local energy system and through contributions to local planning, including LAEPs.
- ✓ **Local residents and businesses:** Through clear building-by-building retrofit pathways and associated business models that can support householders and non-domestic tenants and building owners to decarbonise and save money.
- ✓ **Public transport users:** Through access to a trial mobility as a service app and ground-breaking automated vehicle trials.
- ✓ **DNO:** Through a SLES ready framework for Rugeley which can work with them to support efficient and flexibility use of the electricity network.
- ✓ **ZCR commercial partners:** Including Equans through development of the PROSUMER model and methodologies for large scale retrofit pathway developments, and Conigital through the development of a smart mobility as a service app.
- ✓ **ZCR community, social and academic partners:** Including SHAP housing partnership through significant enhancement of their understanding of how to develop an energy efficiency strategy for social housing groups, and Keele University through development and validation of their user-centric design process.

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Prospering from the Energy Revolution

This report was complied by Simon Gill of The Energy Landscape for Innovate UK.

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