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# Bills and carbon impact of Smart Local Energy Systems

## Portfolio report on smart local energy systems funded by the Prospering from the Energy Revolution programme

February 2023

# Contents

# Executive summary

**This report sets out the findings of Energy Systems Catapult's (ESC) assessment of quantitative greenhouse gas and cost savings to participants across the portfolio of Prospering from the Energy Revolution (PfER) projects.**

This is one of three reports by ESC evaluating 10 detailed designs and three demonstrator smart local energy system (SLES) projects funded by Innovate UK's PfER challenge.[1] The 13 projects evaluated are a subset of the full PfER portfolio.[2] This report describes the quantitative evaluation of each project's potential impact on greenhouse gas (GHG) emissions and participant bills in 2032, while the other reports evaluate:

- Public awareness and appeal of SLES[3]
- Why SLES?[4]

The evaluations gave insight to features across the PfER programme. Results should not be viewed as 'scoring' each project's implementation and success, but rather as an indication of future performance of different SLES. Key findings from analysis of outcomes across the programme provide insight into the challenges and opportunities faced when designing and implementing a SLES. Overall, the evaluation provided ranges of **greenhouse gas savings from 2% to 108%** (with the greater than 100% saving representing net export of zero carbon energy), with **user bill savings ranging from 0% to 57%.**

Evaluating projects in a time of great volatility in energy markets is challenging. In order to be fair to projects, projections and assumptions were held constant throughout the evaluation period. These were based on 2020/21 data;[5] however, bill impacts in particular would be affected by the volatility and sharp rises in wholesale energy costs observed in 2022, potentially making the SLES propositions more attractive.

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[1] ESC, 'Prospering from the Energy Revolution Can Be Greater than the Sum of Its Parts', Energy Systems Catapult, 2020 <https://es.catapult.org.uk/insight/prospering-from-the-energy-revolution/> [accessed 4 January 2023].

[2] UKRI, Smart Local Energy Systems: The Energy Revolution Takes Shape (UKRI, January 2022), p. 32 <https://www.ukri.org/wp-content/uploads/2022/01/UKRI-250122-SmartLocalEnergySystemsEnergyRevolutionTakesShape.pdf>.

[3] https://es.catapult.org.uk/report/public-awareness-and-appeal-of-smart-local-energy-systems

[4] https://es.catapult.org.uk/report/why-smart-local-energy-systems

[5] Price projections were from a wholesale market model of 2032, in turn based on National Grid Future Energy Scenario (FES) and SONI TES 2020; see Appendix 8.2 for more detail and the ESC data repository for published common forecasts. (https://usmart.io/org/esc/discovery?tags=Eris)

## Key findings

**Savings on both GHG emissions and consumer bills are feasible in a SLES,** with evaluation data not showing evidence of a GHG vs participant cost-saving trade-off. The evaluation criteria focused explicitly on participants' bills in a modelled future year and results show that concurrent savings in GHG and bill savings are possible, both for detailed design and demonstrator projects.

**Implementing full ambition of smart operation remains challenging** in the current environment. Demonstrator projects showed good percentage savings, but in all cases those projects were forced to reduce scope during the project.

The reduction in scope involved reduction in ambition for smart operation of assets. Some of this was undoubtedly due to the impact of Covid-19; however, difficulties in implementation and working with multiple partners to coordinate asset installation, API development and commercial agreements to enable smart operation were also key.

In one case, smart operation of heat pumps was limited to a much-reduced trial as such operation became financially non-viable for participants in 2021. This is a key insight: many detailed designs describe smart operation as part of their solution but insight from demonstrator projects indicated that realisation of this is difficult. Therefore, the progression from detailed design project to demonstration is recommended to facilitate development of solutions to overcome challenges revealed in implementation.

**SLES facilitation of low carbon technology substitution** is a key benefit with greenhouse gas (GHG) and energy usage savings typically attributable to technology substitution. Network savings generally reflect both overall reductions in energy used and extra savings provided by smart operation offering flexibility to the grid. Across the portfolio, benefits accruing to consumers facilitated by accelerated technology substitution due to smart design of systems were several times greater than those observed from simply utilising smart operation. However, it is important to consider that smart operation can be a key enabler to allow networks to accommodate more connection of low carbon assets.

## Further findings

**Defining counterfactual scenarios and cost assumptions is crucial** in evaluating future benefits under uncertainty. Within the scope of this evaluation, annual savings for the year 2032, usage and network costs are only those seen by participants. Capital costs for installation of local low carbon assets (e.g. rooftop PV or EV) are not reflected in costs to users. This caveat means that energy usage savings do not account for amortised asset costs. However, it is considered likely that capital costs of installation would be defrayed prior to 2032.

**Embedding data requirements and timings in funding agreements with project consortia** would greatly aid the process of evaluation, particularly quantitative assessments of future programmes. In addition to the key findings, several insights to aid embedding evaluation from the inception of future innovation challenges are drawn out in section 6.

# Introduction

**This report sets out the findings of Energy Systems Catapult's (ESC) assessment of quantitative greenhouse gas and bill savings to participants across the portfolio of PfER projects.**

## What defines a SLES?

A SLES describes an innovative way of delivering energy to system participants in a particular geographical area. They can be **smart by design**, using data to inform locally beneficial configurations of assets and networks to accelerate the Net Zero transition, or **smart by operation**, using automated asset operation and potentially automated trading of energy. SLES are local, defined by a geographical boundary, potentially a local authority or even smaller area.

This can provide better outcomes for the community in that area and can provide constructive alignment with local Net Zero plans, i.e. local area energy plans (LAEPs). SLES operate as a **system** – by operating local assets as a system with a more granular approach, there is potential for a more efficient energy system. SLES can take a **multi-vector**[6] **approach**, optimising the whole system locally. **Local users** form a crucial part of considering the system as a whole and can be better integrated at design stage using a SLES approach in contrast to national approaches.

**What is ERIS Energy Outcomes Evaluation?**
The Prospering from the Energy Revolution (PfER) Programme is supporting the development of SLES projects with the ESC's Energy Revolution Integration Service (ERIS), bringing learnings from across the programme together to provide recommendations for what is needed to accelerate the development of more local energy systems. ERIS has evaluated the energy outcomes of each project across the PfER programme.

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[6] Multi-vector here means different carriers of energy to consumers (for example electricity from the grid, gas, hydrogen, heat network, electricity from private wire). A particular use (for example heating) might be supplied by any of these, singly or in combination.

## PFER projects and evaluation criteria

Energy outcomes evaluation was conducted for 10 detailed design and three demonstrator projects funded by PfER challenge fund (Table 1).[7]

**Table 1** PfER project list

| Project type | Project name (acronym) |
|---|---|
| Detailed Design | • Girona **(Girona)**<br>• Greater Manchester Local Energy Market **(GMLEM)**<br>• Green Smart Community Integrated Energy Systems **(GreenSCIES)**<br>• Liverpool Multi-vector Energy Exchange **(LEX)**<br>• Milford Haven: Energy Kingdom **(MHEK)**<br>• Peterborough Integrated Renewables Infrastructure **(PIRI)**<br>• Rewire North West **(Rewire)**<br>• Spearheading a Revolution in Energy Market Design **(REMeDY)**<br>• West Midlands Regional Energy System Operator **(RESO)**<br>• Zero Carbon Rugeley **(ZCR)** |
| Demonstrator | • Energy Superhub Oxford **(ESO)**<br>• Local Energy Oxfordshire **(LEO)**<br>• Responsive Flexibility Orkney **(ReFLEX)** |

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[7] UKRI, Smart Local Energy Systems: The Energy Revolution Takes Shape (UKRI, January 2022), p. 32 <https://www.ukri.org/wp-content/uploads/2022/01/UKRI-250122-SmartLocalEnergySystemsEnergyRevolutionTakesShape.pdf>

Each of the projects was assessed across a common set of evaluation criteria, agreed with UKRI (Table 2). This report focuses on findings from the quantitative criteria highlighted.

The scope of the detailed design projects was to produce a design with evidence to show that it could deliver the PfER objectives, whereas the demonstrator projects' scope was to realise a SLES. Despite these scope differences, energy outcomes were evaluated using a common method (see section 3) for all projects.

**Table 2** Evaluation criteria

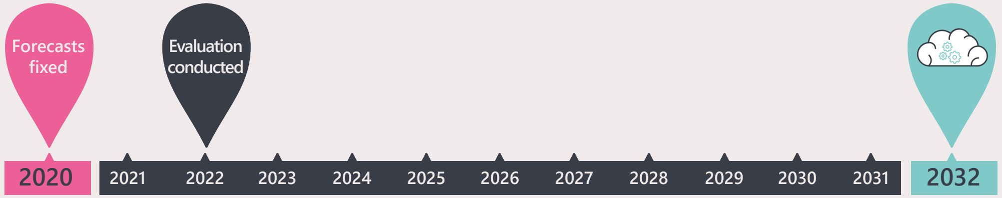
| # | Evaluation Criteria |
|---|---|
| 1 | The impact of SLES designs on participants' bills due to number of units purchased or the cost per unit of energy |
| 2 | The impact of SLES designs on participants' bills as a result of network usage costs on a bill (forward and recovery) |
| 3 | The impact of SLES designs on greenhouse gas emissions |
| 4 | The participant acceptance of the SLES designs |
| 5 | The investability of the SLES designs |
| 6 | The scalability of the SLES designs |
| 7 | The replicability of the SLES designs |

# Quantitative evaluation process

## Basis for evaluation

Projects were evaluated on the forecast difference in **annual** greenhouse gas (GHG) emissions and **annual** bill costs for the year 2032 for a **factual** scenario where the project exists in 2032 and a **counterfactual** scenario where it does not. This is illustrated in Figure 1. 2032 was chosen as the reference year to coincide with the end of the fifth carbon budget.

**Figure 1** Basis for evaluation of PfER projects



Annual bill costs are evaluated on the basis of direct effects on participants' bills. This excludes potential indirect costs or benefits to the system as a whole, for example avoided network investment due to smart operation of assets on a constrained section of the network. While this impact does not form part of the participant bill savings identified, it is considered in the evaluation of commercial investability of the projects.[8] The method does not take account of the cumulative savings between 2022 and 2032, which has the greatest effect on projects that accelerate decarbonisation. This is predicted to happen via a different path by 2032 in the counterfactual scenario.

## Criteria breakdown

**Bill impacts** are evaluated for two specific components of participants' bills in 2032: **energy (wholesale equivalent) cost** and **network cost**. Evaluation of **energy cost** saving uses projected wholesale and flexibility prices in 2032 combined with data from the project on participant consumption patterns and wholesale equivalent cost of any newly introduced energy vectors (e.g. locally generated heat) to evaluate the bill impact of changes in number of energy units used by a participant or changes in price per unit of energy.

Evaluation of **network cost** again combines projected costs of using the electricity and gas grids with project data on the changes to the use of those grids (e.g. by switching from grid electricity to private wire or reducing overall network use). This allows calculation of the bill impact of changed network usage. The bill impacts are calculated in pounds sterling (GBP)[9] and presented as both absolute and percentage savings.

The proportion of a typical participant's bill attributable to these energy and network costs are illustrated in Figure 2 and Figure 3 for electricity and gas respectively, based on the most recently available Ofgem data. In 2022, these proportions are particularly volatile, with energy costs rapidly increasing and therefore contributing a larger proportion of bills. The figures also illustrate those components of a typical domestic bill which are

[8] https://es.catapult.org.uk/report/why-smart-local-energy-systems

[9] All values were calculated and presented in 2021 £. Where necessary underlying data for forecasts were inflation adjusted.

excluded from the evaluation, including those due to use of the balancing system (BSuoS), policy and metering; these costs are assumed to be the same in both factual and counterfactual 2032 scenarios, in effect unchanged by the projects.

The scope also gives rise to a second exclusion from the overall impact on consumer finances: the capital costs of installation of local low carbon assets (i.e. the cost of installing rooftop PV or an EV participating in a project) are **not** reflected in costs to users, although they are considered in commercial evaluation of the project as a whole. This caveat on the savings evaluated means that evaluation of energy usage cost (wholesale equivalent) is based on marginal cost for a unit of energy, in contrast to levelised cost of electricity, for example.

**GHG emissions** are evaluated across the project as a whole, as well as being apportioned to the appropriate consumer or consumer segment where possible (see Appendix 8.2 for further detail). The emissions are calculated as tonnes of $CO_2$ equivalent ($tCO_2e$) and presented as both absolute and percentage savings.

Each of these criteria was evaluated as an overall figure for the project, as well as breaking the impact down into per-participant impacts and impacts on heat, mobility and power individually, to allow evaluation of the impact of the project on particular segments of energy usage.

**Figure 2** Breakdown of domestic electricity bill highlighting the evaluated components. Patterned segments are wholesale and network costs, evaluated by ERIS EOE. Source Ofgem data portal[10], data correct at August 2021.

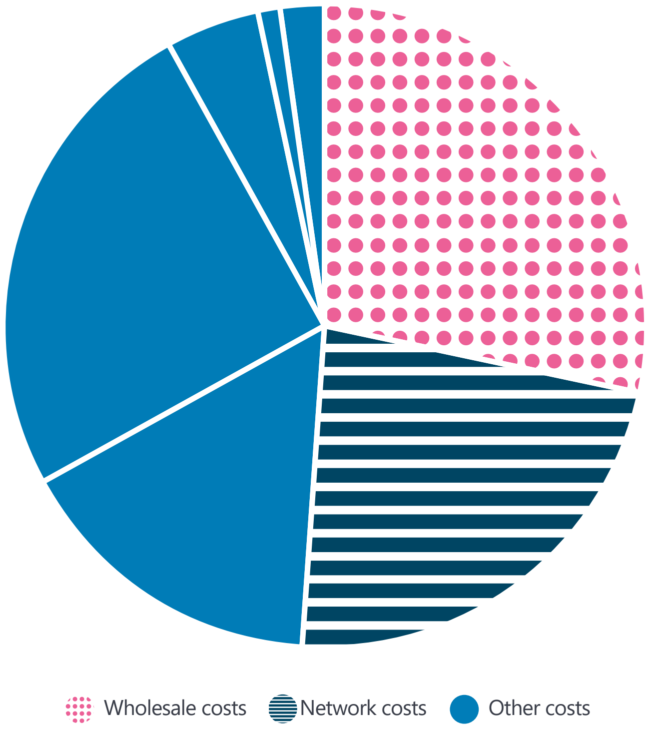
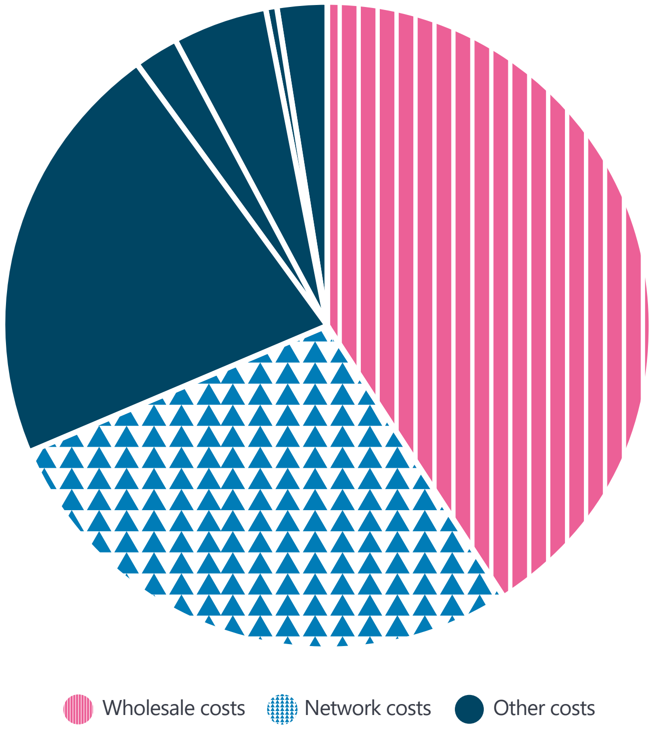


**Figure 3** Breakdown of domestic gas bill highlighting the evaluated components. Patterned segments are wholesale and network costs, evaluated by ERIS EOE. Source Ofgem data portal[11], data correct at August 2021.



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[10] Ofgem, 'Ofgem Data Portal' (Ofgem, 2021) <https://www.ofgem.gov.uk/energy-data-and-research/data-portal/all-available-charts?keyword=bill&sort=relevance>.

[11] Ofgem, 'Ofgem Data Portal' (Ofgem, 2021) <https://www.ofgem.gov.uk/energy-data-and-research/data-portal/all-available-charts?keyword=bill&sort=relevance>.

## Defining the counterfactual and factual scenarios

A key element of defining the counterfactual scenario was determining the technology mix in 2032 in each locality without the project.

In the first instance, projects were invited to suggest realistic counterfactuals with ESC sense-checking these and making suggestions for changes where counterfactuals appeared unrealistic.

Projects were also invited to supply usage data for each energy vector in 2032, for both counterfactual and factual scenarios. Ideally these would be in the form of half-hourly consumption profiles for each participant or participant segment within the project, in both counterfactual and factual scenarios. Where this granularity of data was not available, aggregated data was post-processed by ESC using project-specific documented assumptions to derive half-hourly usage profiles for the year.

In addition, for the factual 2032 scenario, projects were invited to supply data for GHG intensities, energy costs and network costs for any project-specific energy vectors. These may include, for example, the energy cost of locally generated electricity, cost of hydrogen and cost of heating/cooling on a heat network.

Many projects contained multiple propositions within the overall SLES design. For a number of projects, meaningful data was only available for a subset of the propositions. In these cases, the subset was evaluated, with the number of participants projected to 2032.

## Evaluation tool and outputs

An evaluation tool was developed which took common forecast data (see Appendix 8.2.1) combined with project inputs (section 3.3) and calculated yearly GHG and bill impacts. The tool performed a Monte Carlo analysis over every combination of potential forecast scenarios, outputting an average and range for each of the three evaluation criteria.

The output from the tool comprises a detailed breakdown of savings against each of the three criteria. This information was presented in the form of **dashboards for each project**, accompanied by a description of the underlying **assumptions** involved in each evaluation, details of counterfactual and factual scenario, and a summary of the notable features and underlying reasons for the savings presented. The draft dashboards for each

### Counterfactual heat in 2032?

**Project design:** move participants onto a heat network supplied with low carbon heat.

**Counterfactual conundrum:** would those participants use gas heating in 2032 as they do today, or would it be realistic that without the project they would be using heat pump heating?

The answer is **project specific**, depending on whether the project is for new build or applying to existing buildings, locality-specific constraints and demographic features. As this was a crucial part of the evaluation, this process was conducted with the involvement of both ESC and project experts.

# Cross-portfolio findings

## Common features

Across the portfolio, major savings in GHG emissions are achieved where projects facilitate or accelerate transition to electric vehicles and heat sources. The smart operation of these assets has a much smaller direct effect on GHG emissions reductions. However, when considering the cross-portfolio results, the enabling effect of smart operation should not be neglected. Projects that focus on flexibility and smart operation, while not showing high direct savings, create the potential for greater future technology transfer that will enable increased GHG and bill impacts.

There is wide variation in the effects of the projects on participants' bills. Again, where large energy cost savings are predicted, this is largely due to the switch away from fossil fuels to electricity. While this effect is less pronounced for bills than GHG emissions, the projected price of petrol, diesel and gas in 2032 as compared to electricity across all potential scenarios means that the technology switch will yield bill savings on wholesale energy cost.

## GHG vs cost trade-off

There is no evidence from this evaluation that there is a trade-off to be made between bill savings for participants and GHG emissions reduction (see Figure 4); the evaluation instead suggests that projects can achieve savings in GHG emissions and deliver bill savings to participants concurrently. SLES can provide large GHG savings, with either low or high energy cost savings. The trend from this sample of 13 projects shows that cost savings on a percentage basis are comparatively difficult to achieve compared to GHG savings. However, only **LEO** potentially saves large percentages on cost without modest or high GHG savings. This is due to the focus of that project – see section 5.2.1 for more detail.

Projects that deliver bill impacts larger than 20% and GHG savings above 60% involve large changes of fuel for mobility or heating between counterfactual and factual scenarios. Examples of this included the move from petrol- or diesel-fuelled vehicles to hydrogen in Milford Haven (**MH:EK**) or electric vehicles in Oxford (**ESO**) and Orkney (**Reflex**). Moving from gas to electrically powered heating was projected to deliver big impacts in Rugeley (**ZCR**).

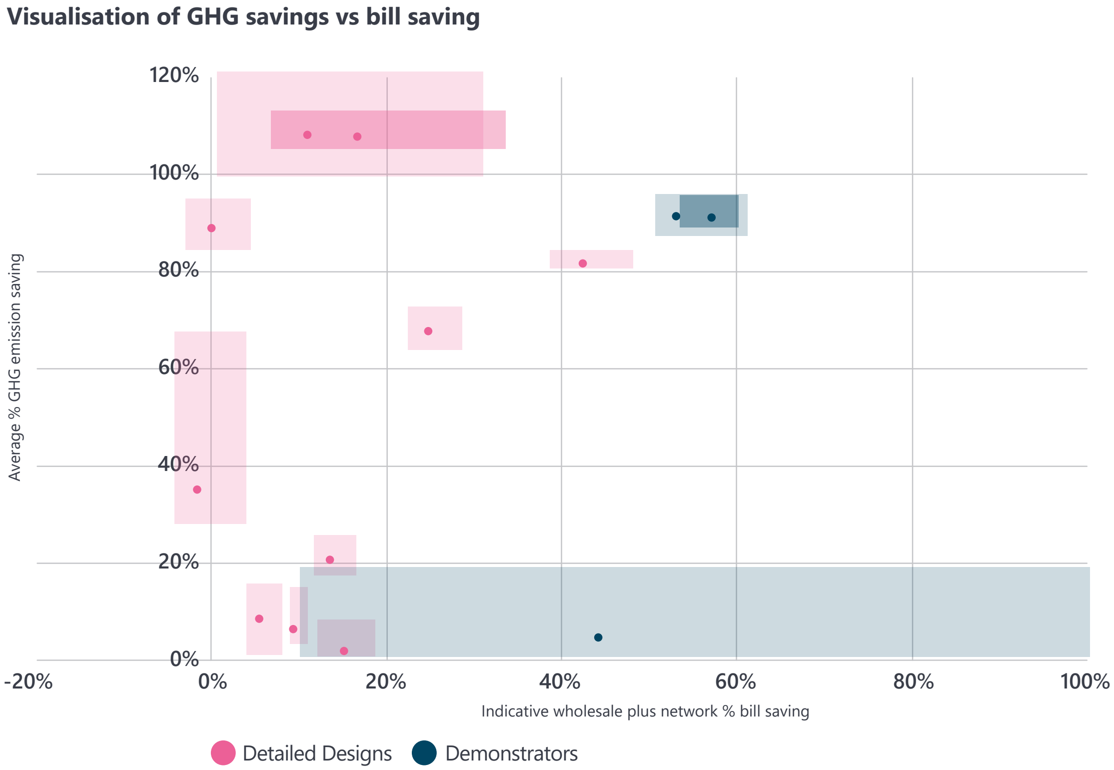

**Figure 4** Visualisation of average GHG % reduction vs average bill reduction (energy + network). Each point is a project; shaded rectangles represent ranges of outcomes resulting from Monte Carlo analysis

## Theory into practice: Detailed designs vs demonstrators

Both detailed design projects and demonstrator projects show large variation between projects on savings achieved. Large percentage savings are recorded against demonstrators that have large capital spend on asset replacement. The evaluation of these projects forecast the project impact of the demonstrators on the amount of technology substitution that occurs as a result of the project **in addition to** the technology substitution that would occur without the project (in the counterfactual).

Due to the bill impact methodology, the large capital outlay on assets does not reduce the bill impact as these are based only on the marginal costs of purchasing a unit of energy in the year 2032.

Two factors in particular affected the demonstrator projects:

### Smart implementation

**Reflex** was forced to descope some smart operation due to a combination of Covid delays and technical difficulties. However, the smart design elements meant they were still able to install technology and accelerate electric vehicle usage, on the basis of which evaluation resulted in GHG savings averaged across scenarios of 91% and combined bill impact averaging 57% reduction for mobility costs to participants.

## Evolving scope

The demonstration projects have been required to engage with the inevitable issues that occur during implementation, meaning that their scopes have evolved over the course of the project. In general, smart operation of assets has proven difficult to demonstrate, with both **Reflex** and **ESO** descoping or radically reducing their ambition for smart operation of assets during the projects.

For this reason, the evaluation of those projects has been largely an evaluation of the impact on technology substitution rather than the benefit of smart operation or provision of flexibility. In contrast, while **LEO** did install a number of assets, the project indicated that they preferred to be evaluated on the flexibility market provision that was implemented and trialled in two phases.

As such, the **LEO** GHG savings appear to be smaller than the other demonstrators. However, this difference in evaluation means that the **LEO** savings effectively demonstrate the value of the smart operation of assets within a SLES, and not the local substitution of technology.

Detailed design projects had less evolution of scope during the project because the scope could be maintained in the absence of operational challenges during implementation.

## Difficulties in demonstrating smart operation in the current regulatory and economic climate

A specific challenge encountered by the demonstration projects was implementing schemes in the current regulatory and policy climate. This in turn impacted the ability of projects to collect data for evaluation. The impact of the policy and regulation environment on the PfER programme is explored in more detail in the Innovate UK insight brief 'Smart Local Energy Systems: Policy and Regulation'[12] and in the report 'Enabling Decentralised Energy Innovation'.[13]

Decentralised energy (DE) is energy based at or near the energy user, which is a facet of many of the PfER projects. The report reviews the barriers and potential solutions that will enable DE to play a full role in decarbonisation, innovation and delivering positive outcomes for citizens and communities.

Evaluation of the demonstrator projects was inhibited by the fact that smart control of heat pumps and, to a lesser degree, EVs proved not to be financially viable for the consumer in the current (2022) energy price environment, leading to a lack of data available to evaluate impact in the 2032 scenarios. Rather than impacting the savings evaluated directly, this resulted in elements being descoped as described above, but it is important to recognise the difficulties that were encountered in realising smart operation. This element of projects is, of course, innovative, and challenges are to be expected.

## Risks/benefits of long-term contracts

Some of the projects that were evaluated utilised long-term contracts, such as power purchased agreements (PPAs). These projects included local zero carbon energy generation and therefore generally scored very well in terms of GHG savings, as power used by participants could be zero carbon for a large proportion of the time, with one project even showing net export of zero carbon electricity, hence negative carbon emissions.

Such long-term agreements do carry financial risk, however, which is explored in more detail in the 'Why SLES?' report that accompanies this report. Locking in to a specific price over the long term can reduce the potential for the SLES to react to shorter-term movements in the price of energy. This can be a benefit in terms of reducing instability in business models and projected cost savings but may also result in schemes locking into higher prices while national prices fall, putting evaluated cost savings at risk.

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[12] Regen, 'Smart Local Energy Systems: Policy and Regulation', 2022 <https://www.ukri.org/publications/smart-local-energy-systems-policy-and-regulations/> [accessed 4 January 2023].

[13] https://www.ukri.org/publications/enabling-decentralised-energy-innovation/

# Project findings

## Revisiting the dashboards

Across all dashboards, the sizeable GHG reductions found are usually due to technological substitution between factual and counterfactual scenarios (i.e. a switch from petrol or diesel cars to electric vehicles or from gas heating to a heat pump). The project-specific determination of the counterfactual technology mix has a significant impact on GHG savings.

**Girona** shows a very high reduction in emissions (average 108%), both per user and on a project total basis. The greater than 100% reduction is due to all energy vectors used in the factual case having zero greenhouse gas intensity (the Girona Solar PV and battery system and the wind Power Purchase Agreement PPA). The total factual emissions are in fact negative, due to on-site PV generation at times being exported to the grid, which offsets greenhouse gases associated with grid electricity. Note also that this saving applies to power usage only; heating and mobility were not addressed by the project.

The community-owned BECCS case study provided by **Rewire** also had a greater than 100% GHG saving (average 108%), in this case due to the exported power from the biochar plant displacing more emissions than the participants created in the counterfactual scenario. **Rewire** provided modest bill impacts, saving participants an average 16.7%, due to network usage benefits of exported power evaluated as benefiting consumers via the community ownership model.

## Project groupings

Although projects vary significantly in configuration, there are some broad groupings that can be considered together due to their similar characteristics.

## Market makers

Four of the projects focused on the creation of local markets, rather than specific technology installation and operation. Although a detailed design, **Girona** was able to benefit from a trial with a number of participants with rooftop solar to provide data on the potential for a smart local market platform to optimise the use of local zero carbon electricity to satisfy participants' demand.

## Decarbonising heat – the effect of counterfactual

Both **PIRI** and **GreenSCIES** include installation and smart control of a local heat network. The GHG impact between the projects comparatively seems quite different: PIRI shows an average 1.9% saving, with GreenSCIES showing 89% average. This difference is attributed to the differing counterfactual that was determined by the projects: PIRI determined that the counterfactual heating technology in 2032 will be air source heat pumps for their participants, whereas GreenSCIES determined it will still be gas boilers. The case where the SLES heat network replaces individual air source heat pumps understandably provides less GHG impact than where the network replaces gas boilers.

With the scale-up proposed in the detailed design and the assets included in the evaluation, the project has the potential to be a net exporter of zero carbon electricity. In the **LEO** demonstrator project, again the focus for the project was on creating local flexibility markets. While a number of asset installations and local sub-projects were undertaken, the evaluation data provided was only for the market platform.

Both **GMLEM** and **LEX** proposed ambitious market platforms enabling smarter operation of low carbon assets across areas of Greater Manchester and Liverpool respectively. Both of these projects provided data on exemplar participant groups, with **GMLEM** explicitly stating that they did not envisage the project directly changing the asset mix between factual and counterfactual scenarios but expected that products such as a green local tariff would be offered on their market that would enable both GHG and cost savings for local residents. This resulted in an 8.5% GHG saving and a mean bill impact of 5.5% saving for participants.

**LEX** provided data to support an initial 2032 scenario with several thousand participants and a range of low carbon assets. Due to limitations of available data from network providers, LEX does not have data on network costs. The scenario shows a mean GHG saving of 20.6% and a mean bill impact of 13.5% reduction. In practice, the type and locations of assets trading on the FLEX network may provide a reduction in network usage costs and increase in revenues from flex services for participants. However, data was not available to support quantitative evaluation of this. Alongside the direct participant impact evaluated, enabling effects of local flexibility could be significant, allowing local demand-and-supply balancing alongside low carbon technology installations while avoiding network reinforcement costs.

**LEO** provided evaluation data based on their demonstrated market platform for local flexibility, providing services to a future distribution system operator (DSO). This provided projected positive bill impacts to market participants, although the project focus was on smarter operation of distribution networks rather than direct bill or GHG savings. As with all projects, the impacts are based on a projection, not the outputs of the project in 2022.

GHG and bill impacts for market maker projects have two distinct components: the impacts of accelerated installation of low carbon technology and the impacts of smart operation of those assets to provide flexibility and make best use of local renewable generation.

**Impacts directly due to market operation in this group were more modest** than impacts due to significant technology substitution.

## Local flexibility

**LEO** demonstrated the potential of local flexibility markets, providing case study data for public buildings participating in demand side response (DSR), batteries and electric vehicles participating in a market to provide flexibility services. The direct impact on greenhouse gases was expectedly modest (saving an average 4.7%). Impacts on bills were calculated for participants in the trial flexibility market only, with payments to those participants for flexibility effectively offsetting network usage components of those participants' bills. Bearing this in mind, there was an overall average bill impact of 44% reduction on the evaluated components of participants' bills for those who participated in the LEO flexibility market, due to the payments made for flexibility services. These savings do not account for costs of participation in the flexibility market. Alongside the direct participant benefit through the network impacts, the enabling effects of local flexibility could be significant, potentially unlocking local demand and supply balancing and supporting low carbon technology installations while avoiding network reinforcement costs.

## Locality-specific systems

Some projects delivered solutions that were highly specific to their locality. **GreenSCIES** produced a detailed design for a heating and cooling solution making use of local geography to utilise an aquifer as a heat source and storage solution. The project had an explicit aim to provide heat to participants at the same cost as they are currently paying, while delivering significant GHG savings.

In Peterborough, the **PIRI** project utilised an existing power from waste plant, designing a heat network drawing waste heat from the plant, with top-up where required, to reduce overall GHG intensity with a particular focus on accelerating the transition to low carbon heat. Savings are modest in 2032; this is partially due to a counterfactual assumption that heating would be provided by heat pumps in the absence of the project and does not take account of the cumulative savings between 2022 and 2032, during which the heat network would bring forward the transition from gas-fuelled heating.

In **Milford Haven**, local propositions for a waterfront development and small industrial park, proposing significant use of hydrogen to substitute fossil-fuelled vehicles, were evaluated, delivering substantial GHG reductions (average 82%) and bill impacts (average 53% energy cost reduction with a 10% network cost increase resulting in an average net saving of 42%) for end users. It is important to note that these evaluated savings are based on a 2032 scenario where the hydrogen supply infrastructure has been constructed. The costs of developing the supply chain are not factored into the bill impact here and are discussed further in the commercial evaluation described in the accompanying report 'Why SLES?'.

The evaluated savings in this group differ widely, due partly to differing business models but also to the constraints of the existing infrastructure within the locality and the underlying scope and assumptions of the evaluation.

## Smart estate by design

**REMeDY** provided data for an integrated energy system on a new-build estate operated by an energy services company (ESCo). The integration of low carbon technologies with a novel supply market model resulted in average GHG savings of 6.4% and average bill reductions of 9%. It is likely that network savings may be even greater as the design is scaled up. GHG emissions are modest as the counterfactual assumption is for heat supplied by air source heat pumps on an individual household basis, which are already low carbon (see section 6.1.1)

## Local area plans

Some projects considered a portfolio of actions to enable local area plans, with schemes at a large scale. For example, **Zero Carbon Rugeley** proposed a scheme that would apply to the whole of Rugeley, while the West Midlands **Regional Energy System Operator (RESO)** would apply to all residents of Coventry, a medium-sized city; **ESO** covered the whole city of Oxford.

Those schemes all involved multiple propositions under the umbrella of a single project and proved challenging to quantitatively evaluate as a whole. For these projects, a subset of propositions for which the projects had detailed data were evaluated. Whole area plans showed substantial GHG impacts, with average savings between 35% and 81%, reflecting the significant substitution of existing assets with low carbon technology across the portfolio of local area projects.

Bill impacts were more varied for these schemes, ranging from a small net increase in energy cost (mean 1.6%) for RESO to 53% savings for ESO, where the project accelerated transition from petrol/diesel vehicles to electric vehicles. The evaluations indicate that a coordinated portfolio of smaller projects contributing to a SLES for a local area can yield substantial benefits for participants.

## Whole area SLES design

**RESO** was unique in providing a suite of inputs to the evaluation to match different projected national conditions based on National Grid Future Energy Scenarios. This resulted in a wide range of potential impacts in 2032, with the project providing between 11% and 66% GHG reductions (35% average) and bill impacts ranging from a 4% saving to 6% increase to participants depending on the combination of inputs. It was not possible to evaluate network impacts of the project due to the aggregated nature of RESO data, meaning that there could be further impacts from that component of bills.

# Challenges and opportunities

## Evaluating under future uncertainty

Quantitative assessment of project benefits in a forecast future year presents a number of challenges.

### Defining the counterfactual

The quantitative evaluation of GHG and bill impacts is highly sensitive to the counterfactual scenario. This is particularly true of technology mixes and participant combination in each project location without the project.

While out of scope for this evaluation, a benchmark counterfactual for each project built on common assumptions on uptake rates for low carbon technologies (particularly EVs, heat pumps and batteries) would have been useful and is recommended for future evaluations of this type.

The approach taken in this evaluation for developing national assumptions for the electricity market from National Grid Future Energy Scenarios (FES)scenarios has proven to be a useful approach. Extending that approach to develop agreed counterfactuals for each local area could start from Distribution Future Energy Scenarios (DFES) defined by the Distribution System Operator (DSO) but would need to be extended to a further level of granularity to develop benchmark counterfactuals for a specific SLES area.

Development of common, benchmark counterfactuals would be a substantial undertaking, but has the potential to remove some variability in outcomes that is difficult to explain other than by reference to the project provided assumptions on counterfactual scenarios.

### Sensitivity to unforeseen changes

Evaluating projects in a time of great volatility in energy markets is challenging. In order for an evaluation to be fair to all projects, it is necessary to have a cut-off date when all common data, such as price forecasts, is set. For this evaluation, that date was winter 2020. However, as the projects progressed during 2021, the electricity and gas markets went through a period of unprecedented volatility.

On the one hand, the use of forecasts taken prior to such volatility provided a known benchmark against which projects could be judged. On the other hand, the projects themselves developed in a context where these changes affected business models significantly and this could lead to the evaluation benchmark appearing remote from the reality experienced by the project. For some projects, certain aspects of the initial scope were not viable in the current economic climate, but it is difficult to reflect that in quantitative analysis.

## Timing of evaluation

The timing of the evaluation has proven challenging, especially for the demonstrator projects. Quantitative evaluation is highly dependent on project supplied data and all of the demonstrators were still awaiting substantial portions of their trial results at the time of evaluation. This meant that evaluation had to proceed with partial trial data, in many cases extrapolating from short time series or small numbers of assets to larger participant groups. For example, **Reflex** is still awaiting information from smart charging infrastructure at the time of evaluation, with trials planned for subsequent months.

There may be an opportunity for future evaluations to be undertaken over a period that overlaps the end of projects, with a specified delivery date for data from the projects, enabling data from the end of trials to be incorporated. Where this is possible without compromising project delivery timescales, it would be beneficial. In addition, early engagement with projects has proven helpful in many cases and is recommended for future evaluations.

## Data sharing

In addition to the timing of the evaluation, the provision of data to ESC from the projects presented some challenges. All projects were able to provide some data, despite the absence of a contractual obligation for them to provide data or the granularity of data that should be made available. Early engagement by the evaluation team with the projects built understanding of the evaluation's needs and helped ensure that evaluation could take place.

It is recommended that future projects of this scale that are evaluated by third parties include a data-sharing agreement in initial agreements with project consortium leaders, specifying the detailed nature of the data that is to be provided and the timings of the data sharing, and describing what the data will be used for. This data sharing could be part of a reciprocal arrangement with support and information provided by the programme lead, such as the counterfactual data referenced earlier. By aligning data-sharing expectations with the key performance indicators, efficient use of effort and information could be achieved.

# Conclusions

Across the PfER programme, quantitative analysis of bills and GHG emissions found that a wide variety of SLES configurations could present simultaneous reductions to both for project participants. Overall, **GHG emissions reductions ranged from 2% to 108%** (with the greater than 100% saving representing net export of zero carbon energy), with mean **user bill reductions ranging from 0% to 57%**. There is inevitable uncertainty in the benefits that could be predicted in 2032; however, a Monte Carlo approach to analysis allowed a mean and range of savings to be reported for each project.

Those projects where the fuel used to provide mobility or heat to consumers changed between counterfactual and factual 2032 scenarios delivered the most substantial reduction in both GHG and users' bills. Examples of this included the move from petrol- or diesel-fuelled vehicles to hydrogen or electric vehicles and moving from gas to electrically powered heating. This evidence shows that enabling, incentivising and accelerating switching to low carbon heating and mobility technology on the consumer side has a positive impact on GHG and consumers' bills and should remain a key focus of SLES design and implementation.

Where a SLES focused on enabling local markets and flexibility, the direct impacts on consumer bills and GHG savings were lower than for projects that focused on technology substitution, although these projects did deliver some direct savings. In addition, the indirect effects of these projects, enabling greater connection of low carbon technologies to the network and reducing reliance on GHG-intensive plant to meet peak demands, should not be overlooked. These impacts are evaluated in more detail in the commercial analysis of the 'Why SLES?' report that accompanies this report.

The counterfactual scenario for projects was of key importance, particularly when considering SLES designs which targeted heating. Where the counterfactual heating scenario was considered by projects to be fuelled by gas, GHG emissions and bill reductions were high. Where the counterfactual heating scenario was considered by projects to be heat pumps (unconnected to a SLES), reductions in both GHG emissions and bills were much more modest. A similar effect was evident for mobility: if a project focused on integrating EVs into the system, the largest gains were found where the counterfactual scenario included legacy petrol and diesel vehicles. Both these results suggest SLES can have larger quantitative benefits when targeting local areas where business-as-usual makes replacement of gas heating or ICE vehicles less likely. Where counterfactuals were individually installed heat pumps or EVs, smaller reductions in GHG and bills were found.

Evaluating projects in a time of great volatility in energy markets is challenging. In order to be fair to projects, projections and assumptions were held constant throughout the evaluation period, based on 2020/21 data.[14] Bill impacts in particular would be affected by the volatility and sharp rises in wholesale energy costs observed in 2022, potentially making the SLES propositions more attractive to consumers.

The evaluation identified some projects that delivered large GHG reductions alongside smaller bill reductions; however, there were no projects with large bill reductions alongside small GHG reductions. There were several projects that delivered large (>50%) reductions in both GHG emissions and bills.
Taken overall, there is no evidence of a direct trade-off between choosing whether to prioritise GHG reductions or bill reductions; they can both be delivered simultaneously.

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[14] Price projections were from a wholesale market model of 2032, in turn based on National Grid Future Energy Scenario (FES) and SONI TES 2020. See Appendix 8.2 for more detail and the ESC data repository (https://usmart.io/org/esc/discovery?tags=Eris) for published common forecasts.

# Appendix

## Data for section 1 graphs

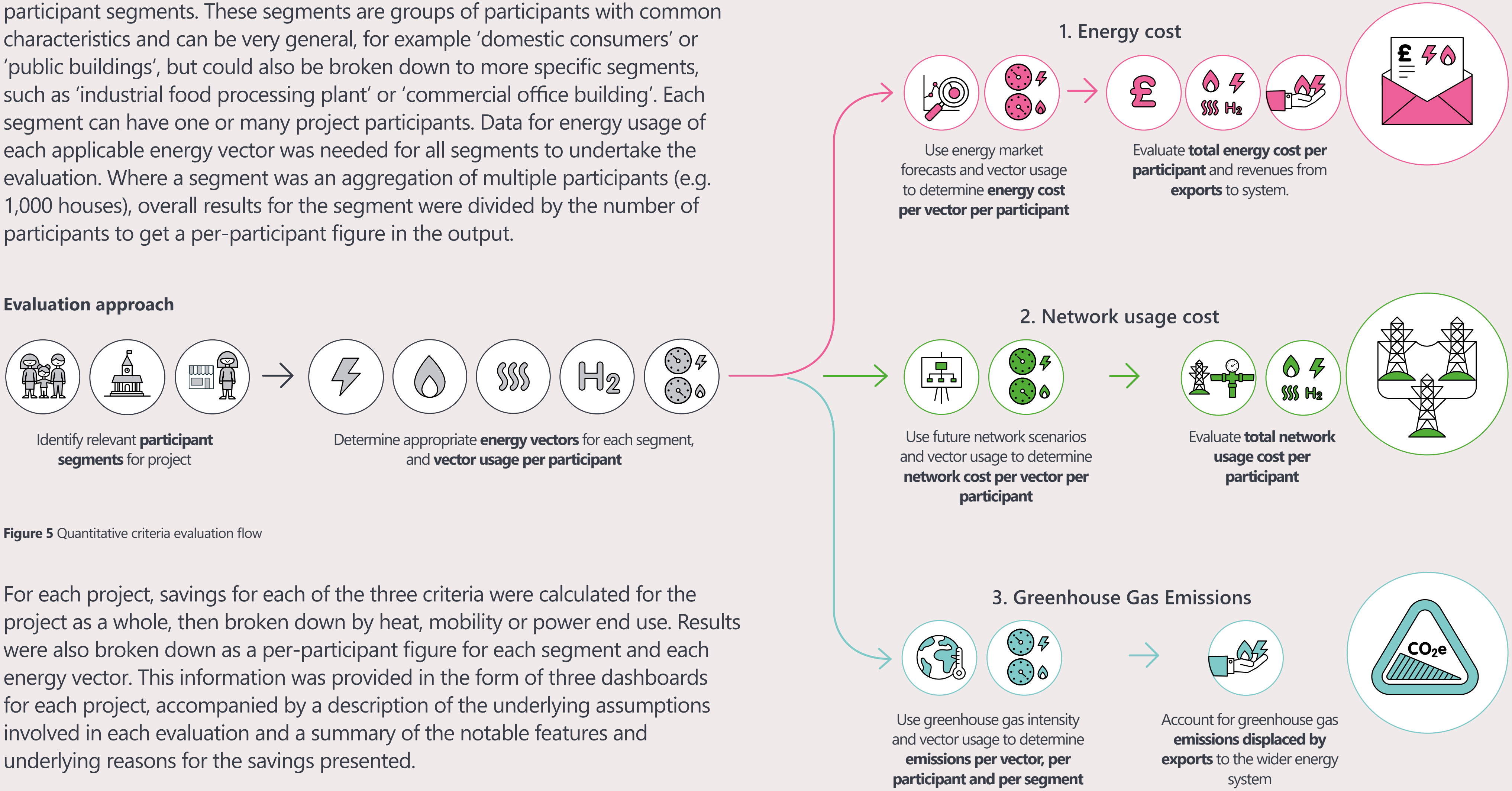
| Electricity consumer bill breakdown | |
|---|---|
| **Wholesale costs (EOE Criterion 1)** | **29.28%** |
| **Network costs (EOE Criterion 2)** | **23.37%** |
| Operating costs | 16.34% |
| Environmental and social obligation costs | 25.48% |
| VAT | 4.76% |
| Supplier pre-tax margin | -1.32% |
| Other direct costs | 2.09% |

| Gas consumer bill breakdown | |
|---|---|
| **Wholesale costs (EOE Criterion 1)** | **41.4%** |
| **Networks (EOE Criterion 2)** | **27.86%** |
| Operating costs | 21.54% |
| Environmental and social obligation costs | 2.46% |
| VAT | 4.76% |
| Supplier pre-tax margin | -0.44% |
| Other direct costs | 2.42% |

## Further detail on criteria breakdown and method

Many projects involve multiple participants and multiple energy vectors, which combine to give overall project benefits. The approach to reporting against each evaluation criterion is illustrated in Figure 5. The first step was to identify participant segments. These segments are groups of participants with common characteristics and can be very general, for example ‘domestic consumers’ or ‘public buildings’, but could also be broken down to more specific segments, such as ‘industrial food processing plant’ or ‘commercial office building’. Each segment can have one or many project participants. Data for energy usage of each applicable energy vector was needed for all segments to undertake the evaluation. Where a segment was an aggregation of multiple participants (e.g. 1,000 houses), overall results for the segment were divided by the number of participants to get a per-participant figure in the output.

**Evaluation approach**



Identify relevant **participant segments** for project

Determine appropriate **energy vectors** for each segment, and **vector usage per participant**

**1. Energy cost**

Use energy market forecasts and vector usage to determine **energy cost per vector per participant**

Evaluate **total energy cost per participant** and revenues from **exports** to system.

**2. Network usage cost**

Use future network scenarios and vector usage to determine **network cost per vector per participant**

Evaluate **total network usage cost per participant**

**3. Greenhouse Gas Emissions**

Use greenhouse gas intensity and vector usage to determine **emissions per vector, per participant and per segment**

Account for greenhouse gas **emissions displaced by exports** to the wider energy system

**Figure 5** Quantitative criteria evaluation flow

For each project, savings for each of the three criteria were calculated for the project as a whole, then broken down by heat, mobility or power end use. Results were also broken down as a per-participant figure for each segment and each energy vector. This information was provided in the form of three dashboards for each project, accompanied by a description of the underlying assumptions involved in each evaluation and a summary of the notable features and underlying reasons for the savings presented.

In focusing on the consumer perspective when considering cost impacts, decisions had to be made where projects installed or used assets owned and operated by third parties that were not participants with consumer bills. An example of such a case was the transmission connected battery installed by **ESO** but operated independently of the SLES end users. The battery is mainly used to provide frequency response services to National Grid (firm frequency response market and more recently dynamic containment). There is evidence from the project that this currently provides substantial GHG benefit, of order 25kt per annum, based on providing a service that would otherwise be provided by peaking combined-cycle gas turbine (CCGT) plants. It is likely that this installation will provide substantial savings as the electricity system transitions to Net Zero; however, there is too much uncertainty in the technology mix providing frequency response in 2032 to provide a meaningful evaluation of the carbon benefit in that year.

Where a storage asset was used in local flexibility or owned by project end users (for example batteries installed in a primary school for project LEO), the effect of operation was of course evaluated and attributed to the relevant SLES participant.

## Underlying forecasts and assumptions

To provide a common basis for evaluation, data for the GHG intensity, energy usage costs and network costs (transmission and distribution) for national-level energy sources were forecast for the year 2032. These variables were forecast for grid electricity, grid gas and other non-grid fuels. In addition, for grid electricity, a value for national and local flexibility services in 2032 was forecast. Where appropriate these were forecast as half-hourly time series for the entire year. Where quantities were not time varying (e.g. GHG intensity of grid gas) or high time resolution data was not available (e.g. wholesale petrol price in 2032), quantities were forecast as a single value for the year.

Where forecasts had fine-grained time resolution, but considerable uncertainty existed in the forecast (for example electricity wholesale price), several forecasts were produced combining sample weather years with projected generation mix in 2032. In GB, this resulted in 24 sample time series combining six sample weather years with generation mixes predicted for each of four National Grid FES scenarios. In NI, a similar process was conducted with three sample weather years and three generation mixes based on EireGrid/SONI TES, resulting in nine sample time series. The project was evaluated against each combination with results combined using a Monte Carlo approach (see section 3.3).

For network costs, DuOS tariffs and gas network usage tariffs, forecasts for 2023 have been produced, as well as forecast values of flexibility both on national (balancing) markets and on potential local flexibility markets, to allow evaluation of direct benefits from asset operation to provide flexibility services.

These forecasts have been published alongside a user guide with more detail on individual forecasts, available from the ESC data repository.[15]

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[15] ESC, '2032 United Kingdom Energy System Forecasts' (ESC, 2022) <https://usmart.io/org/esc/discovery?tags=Eris>.

## Basis table for graph

Table 3 summarises the quantitative evaluation outcomes for projects where permission has been obtained to publish raw data. This data formed the basis for Figure 4, which includes all 13 projects evaluated. The projects are grouped by category (detailed design or demonstrator) and then listed alphabetically. The outcomes for all three quantitative criteria are shown as a mean figure with a range from the Monte Carlo analysis in parentheses. All figures are for an annual saving in the year 2032, with positive numbers representing a saving due to the project and negative an additional cost. It should be noted that in some cases projects generate a saving in one cost area and an extra cost in the other. An indicative overall cost impact is provided, considering mean values only. Cross-project comparison should be undertaken with caution, bearing in mind

1. Project-specific predicted counterfactual technology mixes (see notes column) have a large effect on savings due to technology substitution

2. Some projects address all heat, power or mobility categories, where others address only one or two of these. Categories not addressed by the project are not included in the evaluation, which particularly affects interpretation of percentage savings as they are percentages of users' costs and GHG for the categories considered, not their entire energy bill.

**Table 3** Summary of all projects' quantitative evaluation outcomes

| | Project | Scale | Vectors calculated | | | Notes | Greenhouse gas emissions saving in 2032 | | Usage (wholesale) cost savings in 2032 | | Network cost savings in 2032 | | Indicative mean usage+network cost saving in 2032 (not from calculator) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Heat | Power | Mobility | | | | | | | | £m | % |
| Detailed design | **Girona** | Estimated uptake of Girona across all of Northern Ireland (~23,450 domestic dwellings, 400 farms +2 commercial/public – not scaled up). | | ■ | | Scaled from a trial of 62 homes using electricity (power) usage. GHG emission over 100% due to exports of zero GHG emission electricity. | 9.514kt (3.051kt to 16.81kt) | 108.1% (106.3% to 110.5%) | -£1.063m (-£1.339m to -£0.836m) | -23.6% (-31.2% to -17.5%) | £2.122m (£1.821m to £2.503m) | 41.7% (41.5% to 42.2%) | 1.06 | 11.0% |
| | **Greater Manchester Local Energy Market (GMLEM)** | 8,730 domestic dwellings and 2,721 commercial users on green & local tariff, 47,000 domestic users on heat pump pro tariff. All EV and HP domestic users in GM using flexibility (941,000). | ■ | ■ | ■ | Calculations are based on example tariffs only giving an indicative range of outcomes, as it would depend on exact tariff used and uptake. | 50.2kt (0.73kt to 115kt) | 8.5% (0.2% to 14.9%) | £4.57m (-£1.2m to £10.9m) | 1.5% (-0.3% to 3.8%) | £24.3m (£21.4m to £26.9m) | 12.9% (12.5% to 13.4%) | 28.87 | 5.5% |
| | **Green Smart Community Integrated Energy Systems (GreenSCIES)** | New River Scheme in Islington (~2,033 domestic dwelling and 6 commercial/public buildings including 1 data centre). | ■ | | | Counterfactual heat demand met by gas. Project business model was to match end users equivalent heating/cooling costs while achieving GHG emissions reductions. | 4.86kt (4.69kt to 4.95kt) | 88.9% (85.2% to 91.2%) | £0.00m (-£0.03m to £0.03m) | -0.1% (-3.9% to 3.8%) | £0.00m (-£0.03m to £0.03m) | -0.9% (-11.4% to 8.7%) | 0.00 | 0.0% |
| | **Milford Haven: Energy Kingdom (MHEK)** | Milford Haven Marina and the Pembrokeshire Food Park (190 domestic, 61 commercial, 1 industrial and 1 public building. 199 light vehicles and 1,007 heavy vehicles). | ■ | ■ | ■ | Project modelling had 2020 and 2050 counterfactuals only; 2032 counterfactual constructed from reasonable mix of these. | 8.49kt (8.18kt to 8.93kt) | 81.6% (80.4% to 82.6%) | £1.29m (£1.14m to £1.45m) | 52.9% (49.3% to 57.1%) | -£0.05m (-£0.06m to -£0.03m) | -9.9% (-13.8% to -6.9%) | 1.24 | 42.4% |
| | **Peterborough Integrated Renewables Infrastructure (PIRI)** | 21 public, commercial and industrial locations in Peterborough. | ■ | ■ | ■ | Counterfactual heat demand met by ASHP so GHG savings prior to 2032 (e.g. when transitioning from gas) are not shown. | 0.24kt (-0.00kt to 0.74kt) | 1.9% (-0.0% to 5.6%) | £0.19m (£0.16m to £0.22m) | 5.5% (5.5% to 5.5%) | £0.51m (£0.37m to £0.58m) | 44.0% (36.7% to 47.3%) | 0.70 | 15.2% |

| | **Project** | **Scale** | **Vectors calculated** | | | **Notes** | **Greenhouse gas emissions saving in 2032** | | **Usage (wholesale) cost savings in 2032** | | **Network cost savings in 2032** | | **Indicative mean usage+network cost saving in 2032** (not from calculator) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Heat** | **Power** | **Mobility** | | | | | | | | **£m** | **%** |
| **Detailed design** | **Rewire North West** | Based on example project: bioenergy, carbon capture and storage (BECCS) with 1 industrial and 1 public partner. | 🟩 | 🟩 | | Counterfactual heat demand met by gas boilers and electric chillers. Network costs are for power only (heat not included). | 1.28kt (1.2kt to 1.44kt) | 107.6% (99.2% to 122.0%) | -£0.03m (-£0.04m to -£0.02m) | -24.3% (-35.2% to -12.4%) | £0.05m (£0.04m to £0.06m) | N/A. as zero without project | 0.02 | 16.7% |
| | **Spearheading a Revolution in Energy Market Design (REMeDY)** | Fossets Farm new housing development (1,113 dwellings). | 🟩 | | | Counterfactual heat demand met by ASHP, hence lower GHG savings than if comparing to gas heating. | 0.008kt (-0.007kt to 0.026kt) | 6.4% (-8.0% to 15.9%) | £0.056m (£0.050m to £0.062m) | 7.1% (6.4% to 7.9%) | £0.024m (£0.021m to £0.026m) | 38.7% (35.2% to 42.5%) | 0.08 | 9.3% |
| | **Zero Carbon Rugeley (ZCR)** | Across Rugeley (~11,500 domestic dwellings, 370 small commercial & public, 26 large commercial, public & industrial). | 🟩 | 🟩 | 🟩 | Counterfactual heat demand met either by gas or legacy electricity (low efficiency) usage. | 50.7kt (49.6kt to 51.3kt) | 67.6% (65.0% to 69.0%) | £3.61m (£3.4m to £3.83m) | 27.0% (24.9% to 29.3%) | £0.47m (£0.19m to £0.74m) | 15.0% (6.6% to 22.3%) | 4.08 | 24.8% |
| **Demonstrator** | **Energy Superhub Oxford (ESO)** | Based on 198 domestic GSHP users and 250 commercial and public cars, vans, buses and sweepers in Oxford. | 🟩 | | 🟩 | Does not include GHG emission savings from batteries. Counterfactual heat demand met by gas or storage heaters. | 1.66kt (1.61kt to 1.7kt) | 91.3% (88.2% to 93.4%) | £0.27m (£0.25m to £0.28m) | 71.3% (66.4% to 76.2%) | -£0.01m (-£0.01m to -£0.01m) | -9.6% (-10.5% to -9.0%) | 0.28 | 53.1% |
| | **Responsive Flexibility Orkney (ReFLEX)** | Based on 435 domestic EV users. | | | 🟩 | Mobility only. Counterfactual an even mix of petrol and diesel cars. | 1.07kt (1.01kt to 1.1kt) | 91.1% (86.1% to 93.7%) | £0.19m (£0.18m to 0.20m) | 74.9% (71.0% to 78.3%) | -£0.03m (-£0.04m to -£0.03m) | -101.7% (-111.3% to -92.4%) | 0.22 | 57.1% |

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