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Industrial Strategy Challenge Fund: Prospering from the Energy Revolution

Interim Evaluation Report

Ipsos & Technopolis Group

Contents

Glossary

BAU	Business As Usual
BEIS	Business Energy and Industrial Strategy
CfD	Contract for Difference
CR&D	Collaborative Research and Development
DNO	Distribution Network Operator
DSO	Distribution System Operator
DSR	Demand Side Response
EDiT	Energy Digitalisation Taskforce
EDT	Energy Data Taskforce
ERIS	Energy Revolution Integration Service
ESC	Energy Systems Catapult
ESO	Electricity System Operator
EV	Electric Vehicles
FCA	Financial Conduct Authority
FCR	Field-Citation-Ratio
FiT	Feed-in-Tariff
IRR	Internal Rate of Return
ISCF	Industrial Strategy Challenge Fund
IUK	Innovate UK
MEDA	Modernising Energy Data Access
MEDApps	Modernising Energy Data Applications
Ofgem	Office of Gas and Electricity Markets
P2P	Peer to Peer Trading
PFER	Prospering from the Energy Revolution
R&D	Research and Development
SaaS	Software as a Service
SEG	Smart Export Guarantee
SLES	Smart Local Energy Systems
TCR	Targeted Charging Review
ULEV	Ultra-Low Emission Vehicles
V2G	Vehicle to Grid

Executive Summary

Ipsos, together with Technopolis, were commissioned in 2018 to undertake an impact evaluation of the Prospering from the Energy Revolution Industrial Strategy Challenge Fund (PFER). An evaluation baseline was established in Summer 2020 and early outcomes presented in September 2020. This report summarises findings from an interim evaluation of the PFER, undertaken throughout Summer 2021.

At the interim stage, it was found that PFER has progressed the funded demonstration activities towards commercial maturity and started to materialise some of the aspired system level value. It has also begun to shape system-level change through influencing discussions and policy decisions around broader design of the energy market and how it should be regulated to facilitate progress towards Net Zero. The remainder of this Executive Summary provides an overview of key findings and sets out recommendations emerging from these findings.

Programme overview

PFER was launched in 2018 with the aim of developing and proving new ways of combining distributed energy technologies with novel market arrangements that deliver consumer-centric business models that are cheaper, cleaner, scalable, investable, and resilient for the long-term. The programme committed £102.5m to demonstrate integrated intelligent local systems which can deliver power, heat and transport to customers in cost-effective, innovative ways. Its objectives are to:

- By 2023, prove[1] 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.
- Unlock 10x future-investment in local integrated energy systems versus business as usual in 2020s.
- Create real world proving grounds to accelerate new products and services to full commercialisation.
- To build UK leadership in integrated energy provision.

PFER addresses these objectives by bringing together:

- Real-world demonstration activities through large-scale Demonstrator projects
- Concept and Future Design and Detailed Design studies that develop novel business models for smart local energy systems (SLES)
- R&D funding competitions to address technology gaps (Innovation Accelerator)
- Funding to facilitate data sharing and access across the energy sector and to develop novel applications and products using this data (MEDA and MEDApps competitions)
- Coordination of national interdisciplinary research and innovation capability SLES and providing national leadership in taking a 'whole-system' approach (EnergyREV and ERIS)

[1] As per the PFER Business Case, 'proving' business models is defined as developing a business model which integrates local energy markets in way consumers find financially rewarding and easy to engage with, and the finance community wish to scale and replicate across the UK.

By 2023, prove investable, scalable local business models using integrated approaches to deliver cleaner, cheaper energy services in more prosperous and resilient communities

Substantial progress has been made towards proving the commercial viability of underlying technological assets and business models across the portfolio of Demonstrator and Detailed Design projects. Overall, two of the initial four Demonstrators are on track to deliver 12 months of 'live demonstration' of new business models and are progressing in line with expectations given the complex technical challenges.

User recruitment and demonstration activities have started on all three live Demonstrator projects, amidst several changes to project scope and ambition, indicating that projects have responded flexibly to continued challenges in implementation – it therefore remains unknown at this interim stage to what extent business models will be able to generate sufficient revenues and demonstrate a sufficiently attractive Internal Rate of Return (IRR) to be commercially viable beyond PFER funding.

Several Detailed Design projects have made substantial progress towards formulating market and customer needs, developing financial models to commercialise core project assets, and understanding potential revenue streams.

PFER has also actively addressed some barriers to progressing the commercial maturity of projects:

- PFER has continued engagement with regulators and policy makers to ensure that future market design and regulation facilitates the wider roll out of SLES business models, providing evidence into key policy initiatives at the Department for Business Energy and Industrial Strategy (BEIS) and the Office of Gas Electricity Markets (Ofgem).

- Results of the Icebreaker One project has led to the creation of an open energy data architecture and platform[2]. This has led to significant momentum across the energy sector and Government, with key players from across the energy supply chain having signed up to the initiative – this initiative will have substantial enabling effects on the development and testing of SLES business models.

Despite the efforts of PFER and its partners, the current national regulatory and market design landscape is limiting the commercial viability of SLES business models and the extent to which these business models attract investor interest.

Lessons can also be drawn from the Demonstrator project which Innovate UK (IUK) stopped funding towards the end of 2020. Issues with this project suggest that future programmes funded large-scale and complex technology demonstration should be staged into a scoping and implementation phase, to reduce some of the inherent risks of such projects.

Other residual risks to the demonstration of commercially mature business models remain which are outlined in this report (delays induced by COVID-19 are in most cases temporary risks to commercial viability of projects).

Unlock 10x future-investment in local integrated energy systems versus business as usual in 2020s

PFER-funded firms have been able to collectively raise £874.3m in funding from external investors since receiving PFER funding[3]. Hence, more than a third (40%) of the £2.2bn total equity investment in the UK

[2] https://openenergy.org.uk/
[3] Fundraising amounts are inclusive of those not directly attributable to the technology/service being funded by PFER.

between 2019-2021 was generated by firms funded by PFER, further highlighting the influence of the programme on UK investment competitiveness. There is also some emerging evidence that PFER has helped firms to leverage follow on investment:

- Firms involved in three out of the initial four Demonstrators have secured growth capital to scale-up their business model, raising private equity investments to the tune of £534m.
- Three technology developers participated in PFER Demonstrator projects have been acquired by energy suppliers and a major provider of smart meter installation services, suggesting that these firms offer mature technological assets in areas such as battery storage, energy system management and carbon capture.

A further 19 technology developers funded through a variety of PFER competitions have raised a total of £52m in venture capital funding to refine their technologies, scale-up business models and in some cases, access international markets. Several developers of digital platforms and energy storage systems underpinning the Demonstrator projects have received investment to fund scale-up and international growth.

Beyond the investments into firms supported by PFER, the work of the Investment and Finance Working Group has led to fruitful engagement with the novel National Infrastructure Bank, and conversations on how the Bank could support SLES initiatives in the future. A due diligence framework to aid local authorities in de-risking their project plans, developed by the Working Group, has fed into the Bank's work to develop eligibility and financing plans for energy projects and its local lending function.

Activities undertaken by the Energy Revolution Integration Service (ERIS) have also helped to build capability at the level of local authorities, helping them to plan and finance local solutions to reach Net Zero. ERIS has contributed to wider learning and knowledge sharing across PFER and beyond, raising awareness of system level approaches and solutions across the sector.

Create real world proving grounds to accelerate new products and services to full commercialisation

PFER has made substantial progress towards large-scale demonstration of flexibility and energy system integration products and services. The three live Demonstrator projects have made good progress in the technical development of their core technological assets, including: the successful development of a novel Optimisation and Trading Engine (OTE) to automate grid battery dispatch with a merchant energy trading model, and the connection of a 50MW lithium-ion battery energy storage system in Cowley, the first battery storage in the UK to directly connect and trade with the transmission system.

PFER has also supported technical innovation among projects funded through the Innovation Accelerator's Key Technology Components and Fast-Starts competitions. Several projects funded through the former have already reached high technology readiness levels and have commercialised their innovation such that they are now revenue-generating. While Fast-Starts projects experienced similar technology advancement rates to Key Technology Component projects, their starting position was at a lower technological maturity, meaning these projects have advanced less towards commercialising their PFER innovation.

A key step in fostering commercialisation of new products and services has also been taken through funding the Modernising Energy Data competition. This has led to the development of an open energy data architecture and platform which is intended to accelerate digitisation of the energy sector and foster the development of innovative SLES solutions and products.

PFER has also influenced the facilitation of proving grounds outside the activities funded, including:

- The £65m Flexibility Innovation Programme, set up to implement BEIS' novel Smart Systems and Flexibility Plan. Government stakeholders highlighted how influential work undertaken by PFER has been in drafting plan.
- A due diligence framework to aid local authorities in de-risking their project plans, developed by the PFER Investment and Finance Working Group has fed into the National Infrastructure Bank's (NIB) work to develop eligibility and financing plans for energy projects.

Build UK leadership in integrated energy provision

The PFER team has proven flexibility and agility in navigating change in the programme context and challenges to the implementation of funded activities, thus maximising the potential for PFER to materialise the expected outcomes. This included pivoting programme funding towards work on energy data access and sharing, as well as the development of tools and capabilities for the wider adoption of SLES business models (including a due diligence template for SLES finance). The stage gate process adopted by the PFER team helped identify critical issues early, mitigating some of the risks inherent in the ambitious and complex activities funded.

PFER is also expected to aid the UK in establishing a leading role in designing, financing and supply of local energy systems technology – generating UK business growth across the local energy systems supply chain. To this end, PFER funded a number of smart local energy technology development projects through the Innovation Accelerator and Modernising Energy Data Access Applications (MEDApps) competitions.

Some early commercial exploitation of project results from this portfolio of Collaborative Research and Development (CR&D) projects have been observed – with many projects still ongoing, three core assets have been commercialised, including a battery optimisation solution developed by Powervault, a wireless household metering solution by Hypervolt, and technology developed by EV Dot Energy to maximise grid services from electric vehicles. A full economic evaluation will be undertaken as part of the final evaluation planned for 2023.

Through EnergyREV, PFER has brought a more focused approach to integrated systems research. The programme has and will continue to produce a broad range of outputs across the six main themes/work packages that EnergyREV covers. Existing outputs provide evidence of PFER, opportunities, and successful models (or unsuccessful models) for scaling up SLES. A core strand of EnergyREV work and outputs has been dedicated to understanding what SLES are, what success in a SLES might look like, and how this can be measured. The consortium has also prioritised the development of knowledge management to link work packages to one another and ensure focus remains on activities and outputs focused on SLES.

Recommendations

Several recommendations have been developed based on the evidence emerging at the interim evaluation stage. Table 1.1 sets out the main recommendations emerging from this interim evaluation (see Recommendations).

Table 1.1: Recommendations

Evaluation finding	Recommended action	Responsible parties
Group A: Improvements to on-going programmes		
Despite the progress made since the launch of PFER, there is still uncertainty around the long-term energy market design model and policy framework and how this should evolve in order to achieve net-zero targets. This uncertainty is preventing commercially viable business models of SLES to be fully tested – holding back wider investment, scale-up and replication.	PFER should continue to engage with key policy makers and regulators to help shape a future market design conducive for the wider scale up of SLES business models – in particular: 1. Feeding into a consultation on Ofgem's strategic priorities, with regards to how Ofgem can support the Governments Net Zero and related innovation objectives. 2. Feeding into Ofgem's supply market review. 3. Invite Ofgem to finalise its work programme to implement the smart systems and flexibility plan. 4. Invite Ofgem to recognise the open energy standard for data sharing developed by Icebreaker One to further facilitate data sharing across the sector. 5. Invite BEIS to follow up on last year's call for evidence on the Licence Exemptions Regime. 6. Inviting Ofgem to draft proposals on more flexible licensing and use of derogations and exemptions in support of SLES. 7. Inviting Ofgem to provide certainty on costs and revenues from offering flexibility services. 8. Ensure results of PFER are fed through to other innovation programmes such as the RIIO-2 Strategic Innovation Fund and BEIS' Flexibility Innovation Programme.	PFER team, ERIS
Results of the MEDApps project portfolio are not yet available – but it is anticipated that these could help accelerate progression of business model development and local area planning activities funded through Demonstrator and Detailed Design projects.	UKRI should explore possible opportunities to link outputs from the MEDApps portfolio into programmes of Detailed Design and Demonstrator projects – potentially aiding the commercial viability of business models and local energy area planning through access to novel energy data.	IUK
Group B: Issues for future UKRI intervention		
The complexity and ambition of PFER Demonstrators imply the importance of scoping out in detail the technological, commercial, regulatory and financial aspects of their 'real-life' implementation.	Future Government programmes funding large-scale demonstration of energy system innovation should be phased into a scoping phase, with Government providing seed funding to detail out financing and partnership arrangements as well as regulatory requirements, and an implementation phase, focussing on the 'real-life' demonstration of technological and commercial viability. This would allow Government to maximise return on investment by selecting the most viable detailed plans from results of the scoping phase, instead of committing upfront so significant capital investments on potentially unviable demonstration activities.	IUK, BEIS
The PFER practice of stage-gating large projects with high levels of risk has clear advantages for project quality. Adoption of these practices	IUK may wish to consider the possible merits of diffusing these practices more widely. Stage-gating does, however, have implications for programme integration as changes in direction in individual projects may make it more challenging	IUK

Evaluation finding	Recommended action	Responsible parties
was not commonplace in historic CR&D competitions.	to plan cross-cutting programme activities to exploit project-specific results.	
The TCR minded-to decision to prefer 4-band options has provided some clarity for envisaged revenue streams, projects have also experienced regular changes to rules on cost allocation and charging – for instance, it is currently unclear how forward-looking network charges will be set.	Future Government programmes funding large-scale demonstration of energy system innovation should be undertaken in a regulatory sandbox environment by default, allowing projects to trial their commercial viability against agreed regulatory options without disruption.	IUK, BEIS, Ofgem
Some PFER projects have encountered issues in proving their commercial viability which could have been avoid by more extensive scoping of the requirements.	UKRI could consider adapting its assessment process for future competitions funding large scale demonstration activities to include a review of plans and arrangements for network access. The process should also be adapted to review evidence on local demand for the specific energy assets they plan to install and consider any requirements around FCA approval. This would help prevent some of the specific access issues that have held back part of the PFER demonstration activities funded.	IUK

1 Introduction

Ipsos, together with Technopolis, were commissioned in 2018 to undertake an impact evaluation of the Prospering from the Energy Revolution Industrial Strategy Challenge Fund (PFER). An evaluation baseline was established in Summer 2020 and early outcomes presented in September 2020.

1.1 Evaluation objectives

The overarching aims of this interim evaluation are to:

- Assess whether PFER is on course to meet its intended objectives as set out in its Business Case:
  - By 2023, prove[4] 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.
  - Unlock 10x future-investment in local integrated energy systems versus business as usual in 2020s.
  - Create real world proving grounds to accelerate new products and services to full commercialisation.
  - To build UK leadership in integrated energy provision.
- Explore changes in the context in which PFER is being implemented and identify any implications these may have for the achievement of these objectives.

1.2 Methodology

We adopted a mixed-method approach including:

- An analysis of IUK programme documentation, including project monitoring information, exploitation plans and stage gate documents to understand progress made by projects and issues faced.
- An update of secondary data using sources from the Office for National Statistics and Pitchbook, to update the evaluation baseline regarding investment trends and key contextual factors such as the UK's share of renewables.
- A set of 16 case studies updating case study work undertaken at the evaluation baseline stage, covering Demonstrator projects, Detailed Design projects, Innovation Accelerator projects as well as ERIS and EnergyREV. These case studies investigated progress made against the initial project objectives and realisation of the outcomes outlined in the Theory of Change (see Figure 2.1)
- Interviews with 12 wider stakeholders from Ofgem, BEIS, the Energy System Catapult and the EnergyREV consortium, as well as members of the PFER Investment and Finance Working Group. These interviews focussed on key developments in the wider context for PFER, including developments in the regulatory and policy environment.

[4] As per the PFER Business Case, 'proving' business models is defined as developing a business model which integrates local energy markets in way consumers find financially rewarding and easy to engage with, and the finance community wish to scale and replicate across the UK.

1.3 Limitations of this interim evaluation

For this stage of the evaluation, several specific limitations have resulted in a delay in some expected interim benefits of PFER being observable:

- **Timescales to impact** – Long-term impacts of PFER are not observable yet, thus the interim evaluation focussed on an assessment of progress towards such long-term results.
- **Impact of COVID-19** – The pandemic has introduced a number of delays to PFER, including a slow-down of planned energy asset installations. Whilst the PFER team has responded to this flexibly and all funded projects have been granted an extension, this has pushed back timings of some interim benefits that were expected to materialise in time for this interim evaluation.
- **Regulatory factors** – There is continued uncertainty regarding the future market design and regulation of the energy sector in the short-term. This has dampened investor interest and constrained commercial exploitation at this interim stage.

1.4 Structure of this report

The rest of this report is structured along the following sections:

- Section 2 gives an overview of how PFER has evolved from when it was first devised and discusses key developments in the wider context of PFER. It also provided an updated Theory of Change for PFER.
- Section 3 provides an interim update of key evaluation metrics.
- Section 4 discusses progress made by PFER towards commercialising SLES business models.
- Section 5 discusses the technological progress made by PFER funded firms and progress made in commercialising SLES technologies.
- Section 6 discusses the broader impacts of PFER generated through PFER's key knowledge enhancement groups.
- Section 7 provides our interim evaluation conclusions and recommendations.
- Section 8 summarises plans for the final stage of PFER evaluation.

2 Challenge Overview and Context

This section describes the changes in landscape for the development, demonstration and wider adoption of SLES since PFER was launched in 2018. The section draws on a review of the literature and public statistics available charting the recent evolution of the sector and technology area. This section also outlines recent developments of the programme.

2.1 Background

PFER was launched in 2018 with the aim of developing and proving new ways of combining distributed energy technologies with novel market arrangements that deliver consumer-centric business models that are cheaper, cleaner, scalable, investable, and resilient for the long-term. Smart local energy systems, if widely adopted, could result in system-level cost savings of around £1.2bn per year by enhancing the flexibility of electricity consumption through demand-side response (DSR) and facilitating the use of local energy storage and generation.[5]

The programme committed £102.5m to demonstrate integrated intelligent local systems which can deliver power, heat and transport to customers in cost-effective, innovative ways. Its objectives are to:

- By 2023, prove[6] 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.
- Unlock 10x future-investment in local integrated energy systems versus business as usual in 2020s.
- Create real world proving grounds to accelerate new products and services to full commercialisation.
- To build UK leadership in integrated energy provision.

PFER addresses these objectives by bringing together real-world demonstrations in three locations across the UK, supporting Concept and Future Design and Detailed Design studies, a programme of R&D to address technology gaps, coordination of national interdisciplinary research and innovation capability in smart local energy systems (SLES), whilst creating national leadership in taking a 'whole-system' approach. PFER also funds activities to facilitate data sharing and access across the energy sector and to develop novel applications and products using this data.

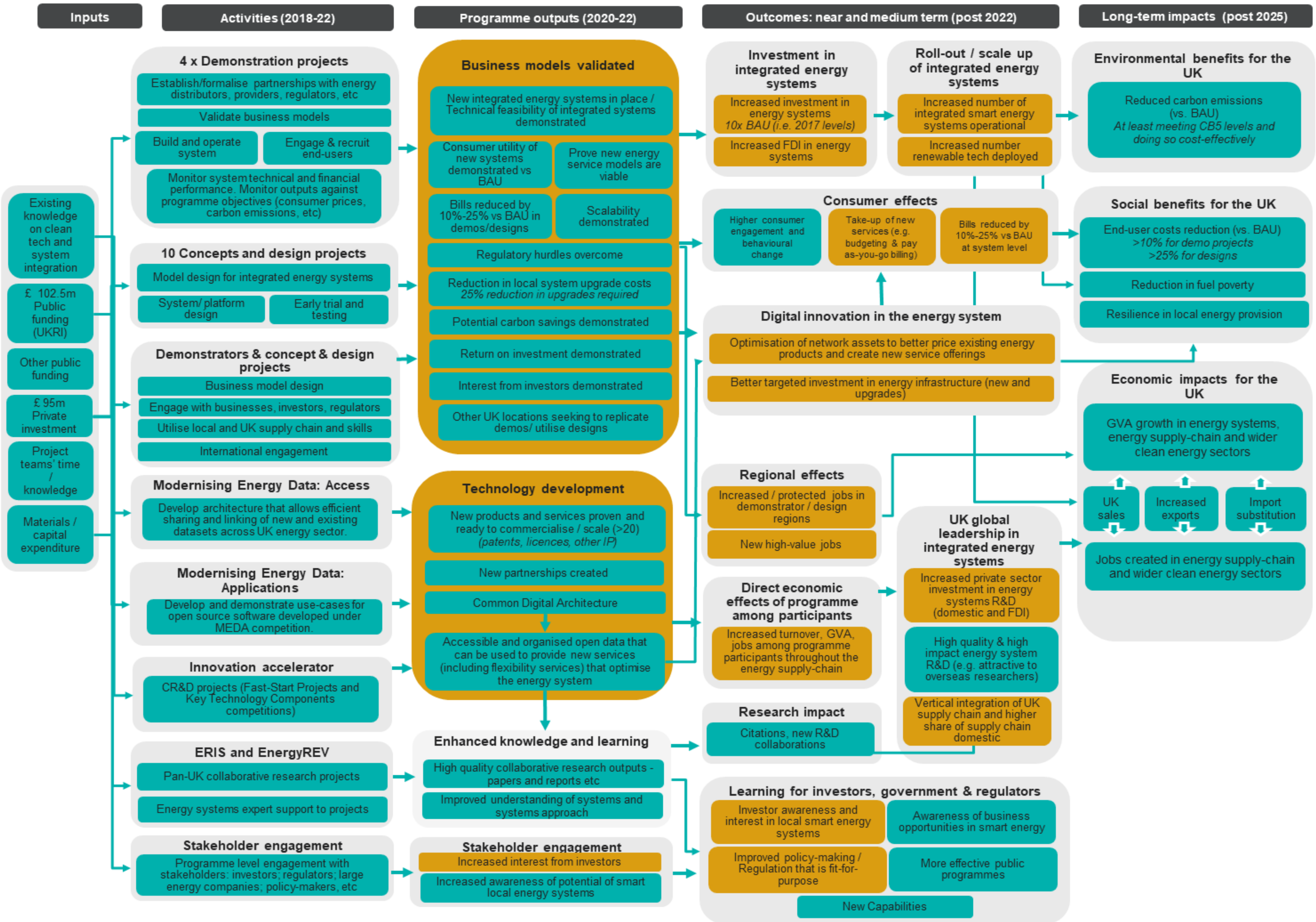
2.2 Theory of Change

A logic model is a visual representation of the outputs, outcomes and long-term impacts expected from the intervention. A logic model for the programme is presented below, including:

- The addition of the Modernising Energy Data Access (MEDA) and MEDApps strands. These strands were added in response to work undertaken by the Energy Data Taskforce (see section 2.4 below).
- Increased emphasis on knowledge sharing with investors, government, and regulators, highlighting the feedback loop established to influence regulation and new system level capabilities.

[5] M. Aunedi, T. Green (2020) Early Insights into System Impacts of Smart Local Energy Systems.
[6] As per the PFER Business Case, 'proving' business models is defined as developing a business model which integrates local energy markets in way consumers find financially rewarding and easy to engage with, and the finance community wish to scale and replicate across the UK.

Figure 2.1: PFER Theory of Change



2.3 Contextual developments

There have been a variety of developments in the wider context for the programme that have influenced the delivery of the programme and its results.

2.3.1 COVID-19 pandemic

The COVID-19 pandemic has slowed the rollout of distributed energy resources, having a direct impact on the viability and implementation of SLES business models that depend on the adoption of these assets. Consultations with PFER-funded firms indicated that social distancing restrictions have led to reduced asset rollout of distributed energy resources. For instance, access to domestic premises to install heat pumps has been restricted and the national rollout of smart meters has slowed.

The recent UK energy crisis has also highlighted the need for greater diversity of supply in the UK, which are potentially enabled by SLES models. Global reduction in demand for fossil fuels initially led to a sharp drop in prices, negatively impacting the economics of non-fossil-fuels that feature prominently in SLES. In late 2021, however, the UK faced a significant gas price increase due to the recovery of Asian demand and lower than normal gas stores as a result of a colder European winter. This has led to several energy suppliers going into administration as price caps prevented them from passing on a sufficient proportion of higher costs to consumers.

The Government has also provided a wider-ranging package of support for innovative businesses in response to the COVID-19 pandemic, including businesses funded through PFER. This could possibly amplify the effects of PFER funding or reduce risk exposure – for instance, Continuity Grants awarded by IUK may have enabled some firms to continue development of their projects in challenging and uncertain fundraising conditions.

2.3.2 Digitalisation of the energy sector

Future SLES will depend on the exchange of data between prosumers, the transmission system, DNOs, Electricity System Operator (ESO), aggregation and flexibility platforms, as well as different forms of retailers. At the start of PFER, there was limited visibility of data flows across the system and a lack of standards to establish data sharing and management. While data sharing and access remains a key barrier, several key developments have started to address these issues:

- The Energy Data Taskforce (EDT) was launched as a working group building on work undertaken by PFER's ERIS team. BEIS and Ofgem have committed to implementing the five recommendations made by the taskforce, including enhancing the visibility of energy system infrastructure and assets, and enhancing the visibility of data through formation of an energy system data catalogue[7]. BEIS also published the UK's first Energy Digitalisation Strategy[8] based on the work of the EDT in June 2021.

- Work of the new Energy Digitalisation Taskforce (EDiT)[9] aiming to:

[7] Energy Data Taskforce (2021), A Strategy for a Modern Digitalised Energy System. Available at: https://es.catapult.org.uk/reports/energy-data-taskforce-report/
[8] BEIS (2021), Digitalising our energy system for net zero: Strategy and Action Plan 2021. Available at: https://www.gov.uk/government/publications/digitalising-our-energy-system-for-net-zero-strategy-and-action-plan
[9] https://es.catapult.org.uk/news/energy-digitalisation-taskforce-launches/

- Refocus the energy sector on PFER and opportunities of digitalisation as a core component of transformation, not just an enabler.
- Accelerate digitalisation of the energy system to enable emerging Net Zero compatible business models, markets, and industry structures.
- Develop a digital architecture and a roadmap that draws on experience from other sectors and provide the energy sector with a focal point to ensure digitalisation efforts are coordinated and effective.
- Identify digitalisation gaps that require innovation support.
- Identify the governance risks that digitalisation raises and present frameworks to mitigate issues.

Other key highlights include DNOs initiating data sharing and digitalisation practices, introduction of Ofgem's data-related licences and BEIS' development of a data catalogue.

2.3.3 Market design and policy framework

Despite the progress made since the launch of PFER, there is still uncertainty around the long term energy market design model and policy framework and how this should evolve in order to achieve net-zero targets. This uncertainty presents a significant barrier to the testing of SLES business models.

Wider government policy has continued to focus on the energy sector's contribution to progressing towards Net Zero. The recent Net Zero strategy[10] sets out detailed plans to achieve this and explicitly highlights the opportunity that SLES have in delivering net-zero energy while delivering against local priorities across different sectors of the economy. There has also been increased recognition of systems approaches in work by BEIS[11] and the Energy Networks Association[12]. The Energy White Paper[13], published at the end of 2020, set out an initial conversation on wider reforms to the electricity market and provided some initial ideas on future market design. Place-based energy planning was also recognised in Ofgem's revamped price control framework[14] and could support uptake of PFER results.

However, most pressing is the need for decisions on the Targeted Charging Review (TCR) and Access and Forward Charging Reform, and how these will be implemented. Both review the way in which the costs of maintaining the electricity grid are passed down to domestic and non-domestic customers, and the extent to which these costs can be priced flexibly. Further regulatory change is expected for the heat and transport sectors that are comparatively further behind the electricity sector, including creating new consumer offers that are desirable and accelerate the net-zero pathway.

Policymakers and regulators will need to ensure consumers are protected and avoid the creation of digital monopolies following rapid digitalisation of the energy system. The Energy Systems Catapult (ESC) has recommended a number of ways in which the current architecture of the energy system could be

[10] BEIS (2021), Net Zero Strategy: Build Back Greener. https://www.gov.uk/government/publications/net-zero-strategy
[11] BEIS (2021), Smart Systems and Flexibility Plan 2021. https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021
[12] https://www.energynetworks.org/creating-tomorrows-networks/open-networks/whole-energy-systems
[13] BEIS (2020), Energy White Paper. https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future
[14] Ofgem (2019) RIIO-2 Business Plan Guidance: https://www.ofgem.gov.uk/sites/default/files/docs/2019/10/riio-2_business_plans_guidance_october_2019.pdf

redesigned to achieve Net Zero – with implications for the commercial viability and design requirements of SLES:

- **Changes to the charging regime**: ESC research suggests consumers were being under-charged for the fixed costs of making energy supply available; over-charged for the units of energy they consume; and those with generation on their own premises avoided costs that were still recovered through the bills of other consumers. To rectify this and recover fixed costs more efficiently, it is necessary to rebalance fixed and volumetric charges into standing and unit prices. This will potentially help in enabling cost-reflective pricing that could support the adoption of low carbon technologies used in SLES. Further changes are needed to the charging regime to accurately reflect the value that avoiding peak demand creates for networks, allowing suppliers to generate revenue from time of use tarrifs.

- **Aligning carbon incentives by replacing existing Contracts for Differences (CfD)[15] with obligations in line with carbon budgets:** The CfD and Capacity Market schemes are thought to reduce incentives for investing in renewables and introducing flexibility into the electricity market. This has stifled the potential of demand-side measures which are a significant component of SLES business models. For the system to be more efficient, it was recommended the reforms ensure firms face the costs they impose on the system and are rewarded for the system benefits they create. Earlier this year, the government identified several CfD scheme reform options to manage this[16].

- **Code reform** is seen as a key enabler in unlocking new technologies and business models. The energy market today is categorised by multiple industry codes which outline compliance procedures for businesses licensed to operate within the UK energy market. These codes are extensive and arduous to scour, making entry for new businesses and innovators challenging. The Energy White Paper has announced a consultation on this towards the end of 2021.

There is also an ongoing debate around the roles and responsibilities in energy sector governance, and what changes in sector governance are necessary to progress towards Net Zero and provide a market and regulatory environment conducive to SLES business models. Ofgem currently has no clear mandate on decarbonisation, and a consultation is planned in 2021 on revised strategic priorities. There has also been discussion around the introduction of a carbon regulator that would oversee monitoring, reporting and verification of greenhouse gas emissions reduction and removal across the economy.

2.3.4 Progress on SLES-enabling infrastructure and technologies

The viability of the business models for SLES is largely dependent on take-up of technologies and infrastructure that enable them. Key developments since the start of PFER include:

- **Smart Meters**: As of Q1 2021, the number of operational smart meters in domestic and non-domestic settings increased by 43% since the start of PFER to 19.8m across GB[17]. Despite this progress, 64% of all domestic and non-domestic meters across GB properties are without this core SLES technology. Smart meter rollout is an important aspect in optimising flexibility business models,

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[15] CfD is an arrangement which enables the energy generator to stabilise its revenues at a pre-agreed level (the Strike Price) for the duration of the contract.

[16] Department for BEIS (2021), Enabling a High Renewable, Net-Zero Electricity System: Call for Evidence. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/956815/high-renewable-net-zero-electricity-system-cfe.pdf

[17] https://www.gov.uk/government/statistics/smart-meters-in-great-britain-quarterly-update-march-2021

such as DSR or peer-to-peer trading networks, and the speed of roll-out experienced some slow-down during the pandemic (as highlighted above).

- **Household-scale generation**: Growth in Feed-in-Tariff (FiT) scale installations since the start of PFER has slowed due to closure of the FiT support scheme in April 2019, which was replaced by the Smart Export Guarantee (SEG) scheme in January 2020. The switch to SEG is expected to encourage energy suppliers to develop tariffs that provide more innovative solutions, such as tariffs that works for users with EVs or battery storage, as is the case under several of the PFER funded Key Technology Component projects. The SEG scheme is only possible if the generator has a smart meter installed, requiring continued rollout of the smart meter programme if more prosumers are to be seen across the GB energy system.

- **Electric vehicles**: Prior to the start of PFER there were more than 155,000 Ultra Low Emission Vehicles (ULEVs)[18] licensed across the UK. There has been a marked increase in the number of ULEVs since then, reaching 432,000 by September 2021.[19]

- **Distributed energy generation**: Renewables' share of electricity generation rose from 29% when the programme was launched to 42% in Q1 2021[20]. SLES such as those demonstrated through PFER offer solutions that provide the flexibility needed to manage distribution networks as distributed energy resources increase, especially in the wake of Net-Zero targets.

- **Electrification of heat**: UK Government remains committed to decarbonising heat exemplified through the launch of the Government's Heat and Buildings strategy[21], and through the launch of the novel Electrification of Heat Demonstration projects which will collectively install 750 innovative heat pumps in Newcastle and the South-East. Stakeholders were conscious of the limited manufacturing capacity in the UK to produce heat pumps at the scale needed to achieve Government ambitions. Responses to the new Government strategy have been mixed, with some concerned about insufficient scale of the planned measures.

- **Interoperable Energy Smart Appliances**: The British Standards Institution worked with BEIS to develop standards that require energy smart appliances[22] to be compatible with DSR activities. The new standard – PAS 1878 – should give consumers more choice to purchase products that can be integrated with other DSR technologies within their home, further strengthening demand for flexibility services and products.

2.3.5 Parallel initiatives

Several parallel initiatives have been launched since PFER started, indicating growing interest in SLES:

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[18] ULEVs are vehicles that are reported to emit less than 75g of carbon dioxide (CO2) from the tailpipe for every kilometre travelled. In practice, the term typically refers to battery electric, plug-in hybrid electric and fuel cell electric vehicles.
[19] https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01#ultra-low-emissions-vehicles-ulevs
[20] Department for BEIS (2021), Energy Trends, Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/997277/Energy_Trends_June_2021.pdf
[21] HM Government (2021), Heat and Buildings Strategy. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1026507/heat-buildings-strategy.pdf
[22] An appliance which is communications-enabled and able to respond automatically to price and/or other signals by modulating its electricity consumption.

- The Net-Zero pathfinder project, a proposal for a new wave of place-based programmes by the ESC, aims to drive early deployment of decarbonisation solutions.[23]
- Energy Innovation Zones across the West Midlands Combined Authorities, aiming to integrate low-carbon technologies across energy systems, and testing novel business models similar to those developed through PFER.
- Eight demonstration projects supported through Ofgem's Network Innovation Competition and Network Innovation Allowance.
- BEIS has also published plans for a flexibility innovation programme worth £65m[24]
- The NIB now offers loans to local authorities for projects of at least £5m that support delivery of net-zero goals – including the scale-up of smart local energy systems.

Future demonstration activities are likely to be influenced by other government-sponsored initiatives, such as Ofgem's Strategic Innovation Fund which will fund strategic energy system transition-related areas, such as SLES.

2.3.6 Public attitudes

PFER seeks to demonstrate novel business models that consumers find financially rewarding and easy to engage with, and the finance community wish to scale. The commercial viability of SLES will partly be determined by levels of demand from households, which in turn will be linked to their acceptance of the underlying concept and the degree to which the system meets their requirements.

In 2021, ERIS conducted a nationally representative survey of public opinion on SLES[25]. The findings suggested very few households were aware of what a SLES is, though those with strong understanding tended to display greater support. It was suggested that tailored communication strategies should be used to promote the benefits of SLES to end users, leveraging messaging that resonates strongly with the public. To maximise support for future energy systems, public trust in energy suppliers was identified as a key issue – and recent defaults of energy suppliers could have a negative effect. Going forward this means encouraging suppliers to offer open, transparent services with accurate billing will be paramount.

2.4 Evolution of PFER

PFER budget has largely been committed, and all major Challenge strands have progressed towards their completion. The programme has also been augmented:

- The critical role of digitalisation and data access has been recognised through a new programme strand to MEDA and develop applications utilising shared energy data. This builds on work of the EDT set up by the ESC.
- The role of ERIS has pivoted from a focus on support for PFER funded projects to offering services to a more diverse set of stakeholders, including local authorities and Local Enterprise Partnerships.

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[23] Energy Systems Catapult (2020), Towards an Enduring Policy Framework to Decarbonise Buildings. Available at: https://es.catapult.org.uk/policy-brief/six-steps-to-zero-carbon-buildings-step-1/

[24] https://www.gov.uk/government/publications/flexibility-innovation

[25] Energy Systems Catapult (2021), SLES User Acceptance Survey 2021: A national Representative Survey of Public Opinion. Available at: https://esc-non-prod.s3-accelerate.amazonaws.com/2021/07/ESC-User-Acceptance-2021.pdf

A central component of the new ERIS brief is the development of a toolkit to support local areas and their partners in defining, designing, and deploying Smart Local Energy Systems (SLES).

Table 2.1 provides an overview of the activities funded under PFER to date.

Table 2.1: Overview of Challenge strands, May 2021

Challenge strand	Start date	End date	No. of projects funded	PFER funding
Innovation Accelerator – Fast Starts	July 2018	April 2019	17	£3.1m
Innovation Accelerator – Key Technology Components	April 2020	March 2022	10	£4.5m
Concept and future designs	December 2018	July 2019	11	£1.5m
Detailed Designs	January 2020	March 2022	10	£20.5m
Demonstrators	April 2019	March 2022	4	£51.3m
Modernising Energy Data Access (all phases)	June 2020	August 2021	1 (in Phase 3)	£1.8m
Modernising Energy Data Applications	October 2020	June 2021	9	£2m
ERIS	September 2018	March 2022	1	£6m
EnergyREV	September 2018	March 2022	1	£9.8m[26]

[26] £9m core grant with £0.8m of additional, optional work packages.

3 Summary of Key Evaluation Metrics

This section provides a summary of key evaluation metrics at the interim stage (July 2021), drawing on the baseline metrics set out at the baseline (Table 3.1 and 3.2 in the evaluation baseline report)[27]. Separately, the PFER Programme Team have collected programme-level KPIs which have been submitted to the Programme Board for finalisation and will be available for review in the Programme Benefits documentation. These KPIs will be taken into account once they have been finalised during the final evaluation stage in March 2023.

Table 3.1: PFER – updated evaluation metrics

Outcome Area (as referenced in the Theory of Change)	Indicator	Baseline	Source	Position at Interim Stage
Smart local energy technology development and intellectual property	TRL levels associated with core assets of Demonstrator projects	6-7	Demonstrator case studies	7-9
Business models validated for local energy systems	CRL levels associated with business models underlying Demonstrator	3-6	Demonstrator case studies	5-7
Business models validated for local energy systems	CRL levels associated with Detailed Design projects	3.9 (range from 2-5)	Demonstrator case studies	4.2 (range from 2-6)
Business models validated for local energy systems	No. of non-domestic users (e.g. businesses, public organisations, EV charging point operators) signed up to Demonstrators	0	Demonstrator case studies	6[28]
Business models validated for local energy systems	No of households signed up to Demonstrators	0	Demonstrator case studies	620[29]
Roll-out /scale-up of integrated energy systems	Replication sites identified by Demonstrators at project start	45	Demonstrator proposals, Demonstrator case studies	45
Increased investment in smart local energy systems	£ of match funding committed at application stage in £	£106m	UKRI monitoring information	£88m[30]

[27] This update of baseline metrics excludes metrics which will be established through ERIS' technical evaluation retrospectively, as agreed in the interim evaluation plan. A full update of baseline evaluation metrics will be provided at the final evaluation stage.
[28] Six plug-in projects installed for the LEO Demonstrator project at non-domestic premises - one oversolar extension, three oversolar newbuilds, one hydro optimisation and on third party asset. However the Cowley battery completed for the ESO Demonstrator is directly connected to the transmission grid, allowing asset owners to trade with it through ESO's optimisation & trading engine. No statistics were available at the time of this report on the demand/usage of this service.
[29] C 560 households signed up to ReFLEX and c60 heat pumps installed in domestic premises through ESO.
[30] This decrease of match funding is due to the discontinuation of the SmartHubs Demonstrator project.

Table 3.2: Key Contextual Metrics

Contextual theme	Metric	Baseline Measure	Position at Interim Stage	Source
Wider investment in integrated energy systems	Equity finance (£) in energy systems and component technologies	£8,866m (2017)	£17,552m (2018)	PitchBook, Ipsos user-defined query
Increased investment in smart local energy systems	Private sector finance (£) in applicant firms prior to PFER funding	£151.4m (see section 5.3.2 of baseline report)	£624.29m (see section 4.1.4 of this report)	PitchBook, Ipsos user-defined query
Structural changes to energy market	Changes to energy regulation	See section 4.2.5: of baseline report**Error! Reference source not found.**	See section 2.4	
Structural changes to energy market	Changes to market structures			
Environmental benefits in UK	UK % of renewable electricity generation	29.2% (2017)	37.3% (2021)	BEIS[31]
Environmental benefits in UK	UK carbon emissions (MtCO2e, as established by CCC[32])	488 (2017)	435 (2020)	CCC[33]
Environmental benefits in UK	UK EV registrations (total/new registrations), including hybrid electric vehicles	1.5% / 4.7% (2017)	1.1% / 8.5% (2020)	DfT and Driver and Vehicle Licensing Agency[34]

[31] BEIS (2021), Energy Trends Statistical Release 30 September 2021. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1022019/Energy_Trends_September_2021.pdf

[32] Committee on Climate Change (2018), Reducing UK Emissions: 2018 Progress Report to Parliament. Available at: https://www.theccc.org.uk/publication/reducing-uk-emissions-2018-progress-report-to-parliament/

[33] Committee on Climate Change (2021), Progress in reducing emissions: 2021 Report to Parliament. Available at: https://www.theccc.org.uk/wp-content/uploads/2021/06/Progress-in-reducing-emissions-2021-Report-to-Parliament.pdf

[34] BEIS (2021), Vehicle Licensing Statistics: Annual 2020 Statistical Release. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/985555/vehicle-licensing-statistics-2020.pdf

4 Commercial Viability of SLES Business Models

This section discusses progress made by PFER in proving the commercial viability of novel, SLES-enabled business models. It draws on case study interviews for the Demonstrator projects to update the progress made in developing each overarching business model, supplemented with a review of management information collected by IUK's monitoring officers.

4.1 Key findings

- Demonstrator projects would not have materialised without substantial IUK funding – the additionality of Government funding is substantial for this part of PFER.

- Substantial progress has been made towards proving the commercial viability of underlying technological assets and business models across the portfolio of Demonstrator and Detailed Design projects. Overall, two of the initial four Demonstrators are on track to deliver 12 months of 'live demonstration' of new business models and are progressing in line with expectations given the complex technical challenges. [35]

- All three live Demonstrator projects have made strides towards more mature commercial propositions. Several Detailed Design projects have also progressed towards proving their commercial viability, formulating market and customer needs, developing financial models to commercialise core project assets, and understanding potential revenue streams.

- There is emerging evidence that PFER has helped firms to leverage further investment to support scale-up of SLES. Firms involved in three out of the initial four Demonstrators have secured growth capital to scale-up their business model, raising private equity investments to the tune of £534m. These investments were clearly made into the core assets also supported through PFER in most cases, however at this stage it has been explored to what extent the investments received were a result of PFER funding. Three technology developers that participated in PFER Demonstrator projects have been acquired by energy suppliers and a major provider of smart meter installation services, suggesting that these firms offer mature technological assets in areas such as battery storage, energy system management and carbon capture.

- Around half of the Demonstrator and Detailed Design projects have further detailed their plans for replication since the evaluation baseline – with four projects actively engaged in scaling up the work funded directly through PFER.

- Despite substantial progress, some risks to the Demonstrators and Detailed Design projects reaching the desired commercial maturity by the end of PFER remain, largely linked to COVID-19 induced delays, continued regulatory uncertainty, and engagement with DNOs.

[35] As of July 2021, when case study interviews were undertaken, three Demonstrator projects were live, and one Demonstrator project had been discontinued. One project was still live but had failed its stage gate review.

4.2 Relevant objectives

A core objective of PFER is to develop and prove the commercial viability of novel business models for SLES that span multiple energy vectors. PFER is supporting early trials and large-scale demonstration of SLES business models through the Detailed Designs and Demonstrator projects. Other competitions under PFER do not focus on actively trialling or demonstrating novel business models and are not included in the following analysis.

4.3 Progress in implementing the business models being tested through PFER

4.3.1 Demonstrator projects

Across the four Demonstrator projects, three of the underlying business models have further matured and moved towards commercial validation. By July 2021, the Commercial Readiness Levels associated with these business models had reached between 5-7. Two Demonstrator projects are on course to deliver 12 months of live demonstration before PFER funding ends. User recruitment and demonstration activities have started on all three live projects but targets on user recruitment have not been achieved yet, amidst several changes to project scope and ambition. However, projects have responded flexibly to continued challenges in implementation. Some critical risks remain to further demonstration of the proposed business models, such as continued regulatory uncertainty and issues in engaging with DNOs.

The fourth Demonstrator project, SmartHUBS, was identified by through the stage gate process set up by the PFER team as high risk, and IUK ceased funding the project in November 2020. Some important lessons can be drawn from this project, highlighting how future large-scale and complex technology demonstration projects could be designed to alleviate some of their inherent risks.

- **Staged delivery:** A staged delivery of future Government programmes could help applicants in scoping out project finance, technical and regulatory requirements in a scoping phase, with updated proposals being re-assessed before they are selected into a capital-intensive demonstration phase. The ‘stage-gate’ process used by IUK in the delivery of the programme has also helped protect the public sector from some of the more significant financial risks associated with the project.

- **Public procurement, co-funding and ownership:** There was a lack of understanding across the consortium around public procurement requirements, which resulted in lengthy explorations of different Special Purpose Vehicle which did not align with public sector procurement rules. This resulted in significant delays to installing technological assets and ultimately led to the IUK funding for the project being discontinued.

In addition to examining commercial viability, the real-life validation of SLES business models in the Demonstrator projects is also expected to bring about carbon savings at the Demonstrator sites (for instance, through the electrification of vehicle fleets in Oxford and Orkney, or an increased share of electricity generated from renewables being consumed at Demonstrator sites). Given the Demonstrator projects have only just started recruiting end-users into their projects, the extent to which carbon savings have been realised will be investigated as part of the final evaluation.

4.3.2 Detailed Designs

In addition to the four PFER Demonstrators, ten Detailed Design projects were funded at earlier stages of business model validation and trial, with real-life testing done at a smaller scale than in the PFER Demonstrators. In comparison to the Demonstrators, the Detailed Design projects have a pronounced focus on developing and trialling flexibility platforms for local and regional geographies. Many Detailed Design projects have vastly greater ambitions than the Demonstrator projects in terms of geographic coverage and technologies to be integrated into novel flexibility platforms.

Detailed Design projects vary in terms of their commercial maturity at the time they were selected for funding, and as a result have made mixed progress towards the formulation and validation of business models. Two of the ten Detailed Designs have made substantial progress towards formulating market and customer needs, developing financial models to commercialise core project assets, and understanding potential revenue streams. The remaining eight projects have not made substantial progress in developing the maturity of their business model. This was due to various reasons, but several projects have spent substantial time modelling the local energy system or target market for their solution, and others experienced delays in installing energy assets.

4.4 Barriers to progressing tests of commercial viability

Several barriers to progressing the commercial viability of projects were identified:

- **Delays in installation of energy assets** – a combination of COVID-19 induced supply chain issues and delays in obtaining planning permission meant that installation of energy assets was delayed across a majority of Detailed Design and Demonstrator projects – whilst some COVID-19 induced delays were mitigated by project extensions, delays in installation of assets reduced the time available for system demonstration and validation in a number of projects, potentially reducing their ability to test commercial propositions such as pricing strategies and validating cost of operation.

- **Changes in asset installation and capital investment plans** – Projects had to respond flexibly to the rapidly evolving energy sector which led to changes to asset installation plans. In some cases, this has fundamentally changed projects’ ability to fully test and validate their initial commercial proposition.

- **Regulatory uncertainty** – The minded-to decision on the 4-band TCR option[36] would mitigate the most serious concerns on commercial viability of flexibility trading products and services. However, continued uncertainty has delayed detailed financial planning and progress in confirming the commercial viability of novel solutions. Some major capital investments have been held back, compounding delays in installation of energy assets discussed above.

4.5 Investment in companies funded through PFER

Even though most PFER-funded activities have not concluded yet, there is emerging evidence on how PFER has helped firms to leverage further investment:

- Firms involved in three out of the initial four Demonstrators have secured growth capital to scale-up their business model, raising private equity investments to the tune of £534m. A project involved in the fourth Demonstrator was acquired by a meter installation company, indicated that the virtual power plant technology developed was sufficiently mature to attract commercial interest. Evidence

[36] Allowing four bands of costs for network maintenance to be passed down to consumers, instead of one unit cost as initially proposed. This retains some flexibility in charging users, such as households with decentralised energy generation, more for using the electricity network at certain times.

is not yet available on the importance of the Demonstrator projects in leveraging this funding, but the findings suggest participating firms have made significant progress in scaling their business models.

- Additionally, three technology developers that participated in PFER Demonstrator projects have been acquired by energy suppliers and a major provider of smart meter installation services, suggesting that these firms offer mature technological assets in areas such as battery storage, energy system management and carbon capture.

4.5.1 Private equity and Initial Public Offerings (IPO)

As of October 2021, four firms attracted private equity investment at some point after being awarded a grant through PFER. These companies (as detailed in Table 4.1:, raised a total of £822.5m over seven funding rounds and were a mixture of firms from the Demonstrator and Innovation Accelerator Fast Start competitions. Nearly 50% of the funds raised appear to be directly linked to the commercialisation of the technologies being developed by PFER. These investments were also linked to three of the four Demonstrator projects, signalling that these projects may have been successful in leveraging growth capital into flexibility systems.

Table 4.1: PFER beneficiaries raising significant private equity investment

Company	Amount raised since grant award (£m)	IUK project(s)	Investment deal purpose and attribution of PFER participation in securing funds
ITM Power – is a design and manufacturing firm specialising in integrated hydrogen systems for energy storage and clean fuel production.	£467.8m	**Smarthubs SLES** – ITM Power were involved in the fourth Demonstrator funded under PFER. **Frankenstack** – ITM Power were the lead organisation delivering a CR&D Fast Start project. This project assessed the feasibility of reusing electrolyser stack components to improve the commercial viability of hydrogen production.	ITM Power has been able to attract £467.83m in private equity investment since receiving funding through PFER. These funds were primarily used to enhance the company's manufacturing capabilities, particularly for the development and production of large scale 5MW electrolysers. The funding attracted appears linked to scale-up of the technologies involved in ITM Power's IUK project.
Nuvve Corporation – is a developer of proprietary vehicle-to-grid (V2G) technology, allowing bidirectional charging solutions that will support the next generation of electric vehicle fleets.	£44.9m	**Project LEO** – Nuvve Corporation are one of the partner firms delivering the project LEO Demonstrator project. Their role is to provide V2G capability and smart EV chargers to the network within Oxfordshire as part of the Demonstrators' testing of new products and services that create commercial opportunities for communities.	Nuvve received £44.9m in equity investment which are expected to be used by Nuvve to further develop its offerings by combining its turnkey V2G solutions with finance packages to customers, including equipment financing, V2G services, infrastructure and maintenance operations. The funding attracted appears to be linked to the scale-up and commercialisation of the firm's technology being used in Project LEO.
Invinity Energy Systems – is a producer of the vanadium flow battery that acts as a heavy-duty, stationary energy storage solution.	£20.5m	**The Energy Superhub Oxford (ESO)** – Invinity is delivering a 2MW / 5MWh battery, based on company's VS3 module. Their vanadium redox flow battery technology will sit within the total 50MW 'hybrid' Lithium/ vanadium flow battery system and enable load shifting for charging of fleet vehicles and the opportunity to provide services to National Grid and trade on energy markets.	Invinity received £20.5m in equity investment that will be used to scale up production capabilities of its vanadium flow battery to meet commercial demand, execute on sales pipeline and assist in driving down unit costs. There appears to be a direct link between funds received and the scale up of operations surrounding the firm's innovation in the ESO project.

Company	Amount raised since grant award (£m)	IUK project(s)	Investment deal purpose and attribution of PFER participation in securing funds
Ceres Power –a developer of fuel cell technologies which enable the production of clean and low-cost energy. Its core technology is the SteelCell technology which uses perforated steel sheets coupled with ceramic layers to convert fuel directly into electrical power.	£289.3m	**Low-Cost Energy Vectors for a Microwave Induced Plasma Gasification System** – Ceres Power formed part of a Fast Start project aimed at trialling a microwave plasma (MIP) technology that would improve the efficiency of Advanced Thermal Treatments (ATTs) and make them a more viable proposition to generate heat and power from increasing waste arisings.	Ceres Power has been able to attract £289.3m in equity investment over three funding rounds, with the latest round its most substantial (£181m). The latest investment was a growth capital injection, aimed at growing its power system business and entering new markets. As the outcome of the PFER-funded project was that more results were required to validate the technology in its then current use-cases, there does not appear to be a direct link between the PFER-funded project and the technology that attracted funding.

4.5.2 Mergers and Acquisitions

Twelve Merger and Acquisition deals involving PFER funded companies were completed since 2018. Deal values for four transactions were not available, but some key trends can be identified.

- **Acquisitions of innovative intellectual property:** Three deals were reported in this category, with values generally not disclosed, but focussed on acquisitions of companies that held mature technology assets in areas such as battery storage, energy system management and CO2 storage. Deals in this category are further explored in Table 4.2 below.

Table 4.2: PFER beneficiaries being acquired since 2018

Company	Amount raised since grant award (£m)	IUK project(s)
Solo Energy – was a developer of a virtual power plant (VPP) offering energy storage, blockchain and P2P functionalities. It was acquired by SMS in 2019. SMS are a smart meter installation company and are looking to strengthen their position in the market for installing carbon reduction assets.[37]	£1m	**Project ReFLEX** – Solo Energy is a partner in the ReFLEX Demonstrator project. Solo Energy is providing the battery and control software (FlexiGrid) to enable integration of the various energy assets being installed by the project (EV charging, domestic batteries, heating).
Pivot Power – is a developer of proprietary transmission-connected battery storage and electric vehicle charging network. The company was acquired by EDF Energy in 2019, helping EDF to grow in the battery storage market.[38]	Undisclosed	**Project ESO**– Pivot Power are the coordinator of the ESO Demonstrator project. The project aims to demonstrate the technical and commercial feasibility of Pivot Power's Superhub business model and plans to install energy storage adjacent to an Oxford National Grid transmission substation comprising 47.4 MW of lithium-ion technology and 2.5 MW of redox flow energy storage, in combination with EV charging solutions and an integrating energy trading platform.
Upside Energy (now KrakenFlex) is a developer of a cloud-based energy system management platform designed to aggregate and manage different types of renewable energy assets. The company's platform uses advanced algorithms	Undisclosed	**Greater Manchester Local Energy market (LEM)** – Upside Energy helped identify the requirements and strategies to set up a local energy market.

[37] https://www.sms-plc.com/insights/blogs-news/sms-enters-virtual-power-plant-market-after-solo-energy-acquisition/

[38] https://www.edfenergy.com/media-centre/news-releases/edf-group-announces-acquisition-british-start-pivot-power

and artificial intelligence to manage and monetize very large portfolios of diversified and distributed energy assets. It was acquired by Octopus Energy in 2020, to further strengthen Octopus' AI and data science capabilities underpinning its domestic home energy offering.		**Bristol Energy Smart System Transformation (BESST)** – Upside Energy supplied their energy flexibility platform to help design a digitally integrated cluster of smart homes and businesses across four wards in West Bristol.

Other deals fell into two categories:

- **Attempts at creating/increasing economies of scale or absorbing competitors to increase market shares:** Seven large deals worth a total of £8.5bn, with deal sizes between £14m and £6.7bn, focussed on consolidating the DNO or energy supplier market were recorded. This included Western Power Networks being acquired by National Grid for EUR 7.8bn, the acquisition of Bristol Energy by Together Energy, as well as a merger between battery manufacturers Avalon and redT. The merger between Avalon and redT created Invinity Energy Systems. PFER initially supported redT as part of the ESO Demonstrator and merging with Avalon will provide the necessary scale to expand on the battery systems installed in Oxford as part of the ESO project. Panoply's purchase of FutureGov, consultancy, also falls in this category.

- **Reverse merger to access capital markets:** One deal was reported in this category. V2G technology company Nuvve entered a business combination agreement with Newborn Acquisition Corporation, investing around £44.5m in the process, raising around $18m PIPE and bridge financing in the process. This deal will allow the newly formed company Nuvve Holding Corp. to be traded at the US stock exchange. Again, PFER funding is likely not to have had any influence on this deal.

4.5.3 Replication of PFER-funded SLES

Across the 13 Demonstrator and Detailed Designs projects still live, case study work and monitoring information suggests that seven have further detailed their plans for replication since the evaluation baseline – with four projects actively engaged in undertaking replication work.

Overall, the progress with replication plans is largely in line with expectations given the commercial maturity of projects as discussed above and remaining barriers to progressing commercial maturity. The remainder of projects have not reached sufficient commercial maturity to plan replication and scale up.

5 Technological development

This section provides an interim assessment of the impacts of the programme in accelerating the development and commercialisation of novel technologies. This section draws on monitoring data and case study research with projects exploring progress achieved. It should be noted that the study team have not undertaken any case study research with Fast-Start competition projects and a more in-depth follow up will be undertaken with Fast Starts at the final evaluation stage. Additionally, projects funded under the MEDApps competition started in March 2021 – this report establishes a baseline position for this group and project outcomes will be explored at the final evaluation stage.

5.1 Key Findings

In most cases, PFER-funded firms have achieved technological progress across the competitions funding technology development. There have been modest commercialisation and economic outcomes achieved among these firms during the lifetime of PFER (see Figure 5.1):

- Over the course of PFER, Demonstrator projects have been able to successfully progress their integration technology assets that underpin the delivery of their smart local energy system.

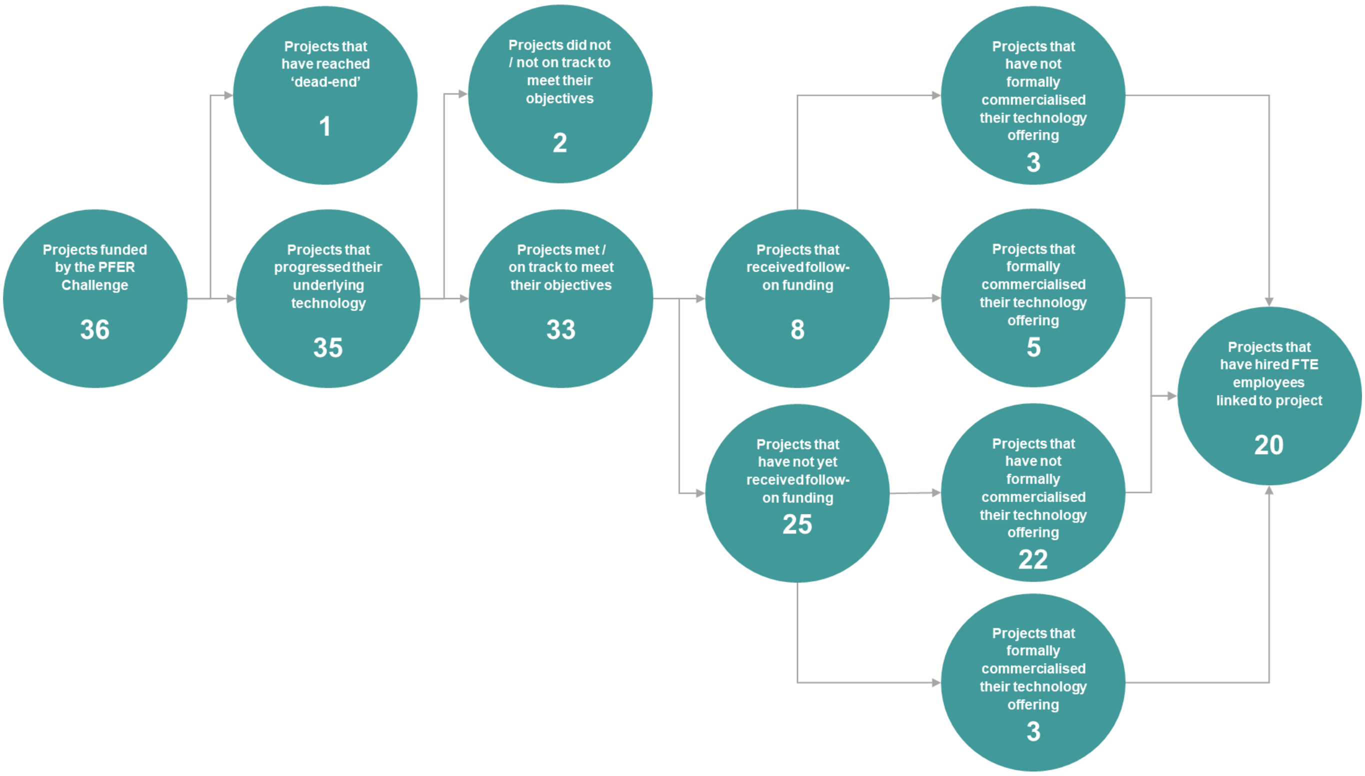
- Key Technology Component projects have so far achieved strong technological progress, in some cases reaching relatively high technology readiness levels to the point where they are able to commercialise their innovation. For those which have reached prototype development and demonstration, there are signals of market acceptance and demand, as demonstrated by direct sales of the technology and/or leveraging additional investment into the funded firm. As these projects are expected to finish by June 2022, there is still an opportunity for these technologies to achieve further technical progression and achieve positive commercialisation outcomes.

- Work undertaken via the MEDA competition has led to the creation of an open energy data architecture and platform which is now live and actively recruiting participants to share and trade energy sector data[39]. This has led to significant momentum across the energy sector and Government, with key players from across the energy supply chain having signed up to the initiative

- While Fast-start projects have progressed their underlying technology over the lifetime of PFER funding, they have not reached the stage where they were able to commercialise their outputs. There was limited evidence of any commercialisation outcomes for this cohort of projects by the end of their project. Some funded firms have however been able to leverage significant additional since being awarded PFER funding. There is a clear linkage between the focus of firms leveraging investment and applicability of their technological solutions to SLES, such as solar PV investment technology and hydrogen production to be used as an energy storage or used in industrial processes.

[39] https://openenergy.org.uk/

Figure 5.1: Outcomes for funded Demonstrator and Innovation Accelerator (Fast-Start and Key Technology Component) projects



5.2 Relevant objectives

A core objective of PFER as outlined in the business case is to create real-world proving grounds to accelerate new SLES products and services to full commercialisation. To achieve this, PFER funded firms through the Fast-Start and Key Technology Component competitions to develop technologies that can be integrated in the rollout of SLES, providing funding to 27 projects. It also funded Demonstrator projects to develop software technologies that integrate different components of a local energy system.

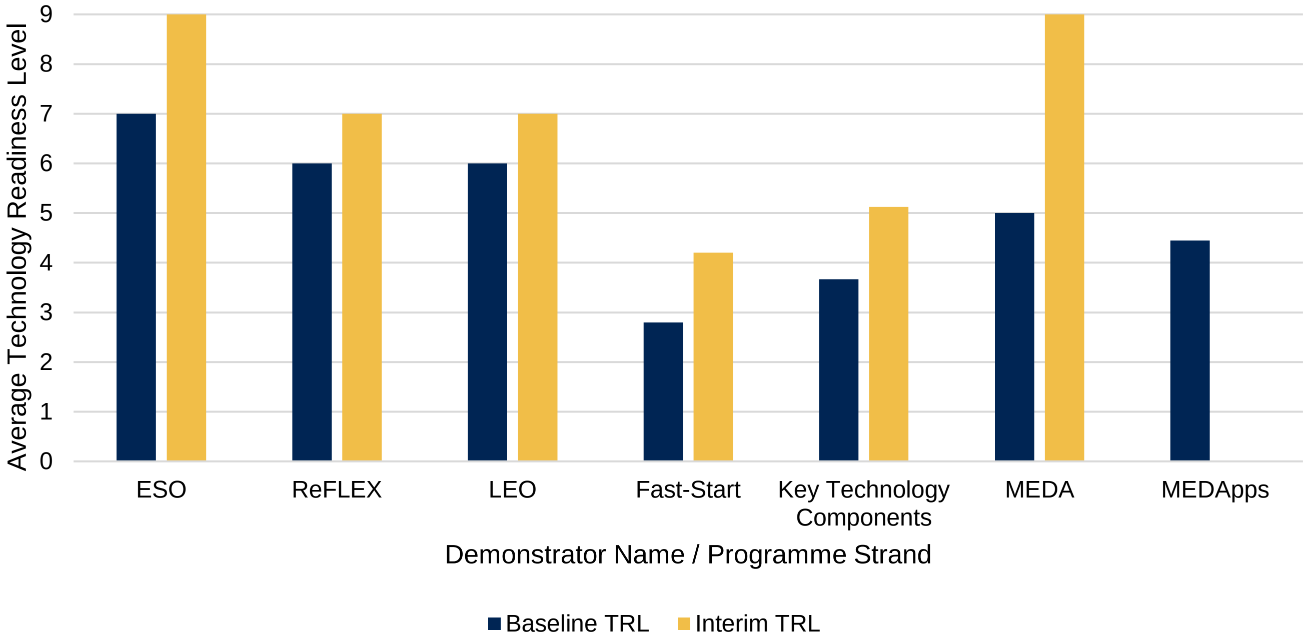
PFER also funded the MEDA competition with the aim of creating an open energy data architecture and platform for energy system organisations to share and trade energy sector data. PFER subsequently funded nine projects through the MEDApps competition to create novel SLES products and services that utilise the MEDA platform.

5.3 Technical progress in developing technologies being funded through PFER

5.3.1 Technology Readiness Levels

The majority (91%) of PFER-funded firms undertaking technology development have either met or are on track to meet their objectives. Projects have on average, progressed their technologies between one to two levels along the technology readiness level (TRL) scale since being awarded PFER funding (see Figure 5.2). Innovations supported through the Key Technology Components competition are currently at a higher technical maturity due to higher starting maturity levels and are expected to continue maturing over the remainder of their funding period

Figure 5.2: Innovation Accelerator, MEDApps and Demonstrator Baseline and Interim Technology Readiness Levels



Source: UKRI Post-completion reports (FS); Ipsos baseline data sheets, UKRI monitoring reports and case study interviews (Demonstrator); Ipsos baseline survey, UKRI monitoring reports and case study interviews (KTC); UKRI project application forms (MEDApps). Where there were multiple survey respondents from the same project, the TRL was first averaged for each project, then the project averages were averaged for that strand

5.3.2 Progress against objectives

Table 5.1 provides an overview of R&D Competitions funded through PFER and progress made against their project-level objectives.

Table 5.1: Overview of progress against technical objectives

Strand	Overview of R&D projects	Progress against objectives
Demonstrators	The Demonstrator projects involve some technology development, primarily in asset integration software technologies (such as ESOs Optimisation & Trading Engine to automate grid battery dispatch with a merchant energy trading model.	The technologies being developed were of high level of technical maturity at the start of PFER (TRL6 or 7). These technologies have since reached TRL 7-9. The case study research did not indicate that achievement of project objectives was likely to be constrained by difficulties implementing the underpinning technologies.
Fast Starts	Most Fast-Start projects were physical asset technologies aiming to offering new, intelligent ways of storing energy, generating power, or improving overall efficiency of existing processes. Examples including a novel coating for heat exchangers to be used in absorption heat pumps and a new process that extracts more power from photovoltaic modules on solar panels. The remaining projects involved software development, including a self-learning platform that helps customers reduce their energy consumption and a peer-to-peer trading platform.	Fast-start close-out reports showed projects were relatively low maturity (TRL1 to 3) when they were awarded funding. Thirteen of the 17 funded projects progressed their technologies in line with the targets outlined at the project application stage. Projects advanced an average of 1.5 TRLs. Notable successes included development of a solar energy micro-inverter able to deliver more energy than incumbent players. Some projects did not meet technical objectives due to failure of technology

Strand	Overview of R&D projects	Progress against objectives
		hypotheses. In some cases, firms were able to successfully pivot to new objectives.
Key Technology Components	Projects have a strong focus on software to support SLES delivery. Some of the more common technologies being explored included machine-to-machine communications and advanced distribution management systems. Examples included a control system for district heat networks that integrate smart consumer controls with big data and flexible energy operations and a virtual networking monitoring system based on voltage readings from EV chargers. Projects funded under Key Technology Components are still ongoing and are expected to finish by June 2022.	To date, 14 of the 16 funded projects have progressed their technologies in line with the targets outlined at the project application stage and TRLs have (on average) advanced from 3.6 on average to 5.3. Some hardware projects have faced barriers that have hindered testing of technologies in real-world environments. This was typically caused by restrictions introduced to manage the COVID-19 pandemic. In one case, COVID-19 led to the insolvency of a funded firm, resulting in early project termination.
MEDA	The MEDA Competition followed a three-phase process that ended in one project (Icebreaker One) being funded to develop the data architecture and governance framework for accessing and sharing energy sector data. Phase Three concluded in Summer 2021 and since then, there have been ongoing discussions with BEIS for potential follow-on funding for the governance solution aspect of the project that enables data access.	The MEDA project which concluded in Summer 2021 has also progressed well against its original aims. The governance and search solution were operated and tested, demonstrating functionality, and achieving TRL9.
MEDApps	**MEDApps projects** are intended to valorise the data architecture developed under the Icebreaker One/MEDA project. It follows a two-stage competition process involving an initial feasibility and a second phase to undertake prototype development and testing. Projects had a stronger focus on developing products that would support other organisations looking to deploy smart local energy system solutions and are expected to conclude in March 2022.	Based on monitoring reports provided by IUK, the average starting TRL for MEDApps projects was 4.4. These projects are working solely on digital innovation and are therefore expected to mature relatively quickly.

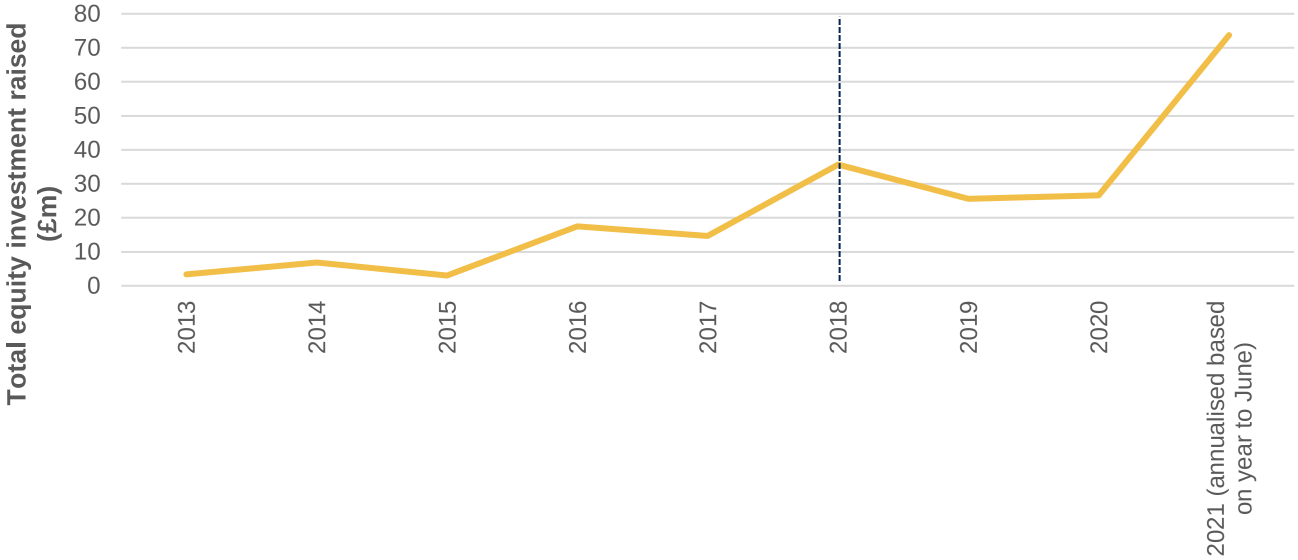
5.4 Investment in companies funded through PFER

Nineteen technology developers funded through PFER raised a total of £52m in venture capital funding to refine their technologies, scale-up business models and in some cases, access international markets. This capital has been raised by firms that operate across the supply chain for local energy systems, and the majority was raised by firms providing digital platforms to enable the type of system integration that PFER seeks to validate and demonstrate.

Though technology development was not the core focus of PFER, technology developers participated in both Demonstrator projects and CR&D competitions to help refine the technologies underpinning smart local energy systems. Data from PitchBook indicates that a total of 19 companies secured follow-on funding from angel investors, venture capital funding or other forms of private equity investment (e.g. equity crowdfunding) after being awarded grant funding through PFER (by late June 2021). These companies collectively raised a total of £52.2m in equity funding over 26 funding rounds (see Table 6.2 for more information on notable VC fundraisings).

Companies supported by the programme have been particularly effective in raising capital during 2021 (see Figure 5.3). By the end of June 2021, firms supported by the programme raised £36.9m in private funding (more than in any previous year, over a 6-month period).

Figure 5.3: Equity funding raised by companies supported by PFER from angel investors, VC funds and other private investors (e.g. equity crowdfunding)



Source: PitchBook, Ipsos user-defined query

The majority of this funding was raised by companies participating in the three Demonstrator projects (accounting for £35.1m or 67% of the total funding raised). The firms concerned were a diverse mix of smaller companies providing key technologies underpinning the Demonstrator project across the supply chain. This included developers of digital platforms underpinning the project (e.g. Origami Energy and Piclo), installers (Kensa Contracting), and developers of energy storage systems (Connected Energy, Moixa, Pivot Power).

Press releases associated with these deals suggests that funding will be deployed to fund scale-up and international growth (rather than further investment in technology development) as illustrated in Table 5.2. In some cases, investment has been leveraged through participation in the Demonstrator programme. For example, Invinity Energy Systems has been able to leverage £20.5m in investment to scale-up production of its vanadium flow battery which is a core component of the ESO Demonstrator's Lithium/vanadium flow battery system. Similarly, Nuvve Corporation has raised £44.5m in funds to develop its turnkey Vehicle-to-Grid solution which are being deployed across the LEO Demonstrator region. Hence, on the surface, it suggests that some firms have been able to demonstrate the viability of their business model.

There was also evidence that some firms funded through the Key Technology Components programme have been able to leverage further funding (with 3 firms raising a total of £12.9m in investment). The leading companies included ev.energy (a developer of a software platform for managing electric vehicle charging across the grid, which closed a £6.3m Series A deal to scale-up in USA and Australia) and Guru Systems (a developer of a software platform to improve the efficiency of heat networks).

Table 5.2: Companies raising notable levels of VC funding (£2m or more)

Company	Amount raised since grant award (£m)	Link to PFER
Origami: Developer of a trading and automation software designed to help power traders manage distributed energy assets.	£20.5m	Under project LEO, Origami is developing a market platform that will unlock new ways for participants to trade energy and flexibility locally, unlocking new revenue streams and supporting a decarbonised grid within Oxfordshire.
ev.energy: Developer of an energy intelligence software to manage EV charging across the grid by scheduling and optimizing charging times and loads, allowing drivers to reduce costs and carbon emissions through a user-friendly app.	£6.3m	Under the Key Technology Components, ev.energy is building upon its existing EV smart-charging solution to enable households to provide grid services, reducing the cost of EV ownership, improving the reliability of the electricity system and avoiding costly network investments.
Piclo: Developer of an energy management platform designed to make electricity grids efficient, reliable, and sustainable. The platform uses flexible energy markets to balance the grid from technologies such as electric vehicles and battery storage.	£4.7m	Piclo are working closely with the TRANSITION project and LEO looking at how their Piclo Flex and other digital platforms can support flexible energy trading.
Moixa: Developer and manufacturer of home battery systems intended to offer smart solar batteries. The company's energy storage systems leverage artificial intelligence to learn about each owner's energy use and develop a unique charging plan to meet their needs and maximize savings.	£4.6m	West Sussex Demonstrator – Moixa were an integral part of this Demonstrator project, developing the aggregation system for the energy assets that were planned to be installed. KTC - Moixa will use their existing GridShare platform to develop an integrated software platform that can monitor and forecast energy demand and optimise the portfolio of assets on-site.
Kensa Contracting: Operator of a specialist delivery contractor designed to install ground source heat pumps in large-scale new build and social housing retrofit programs.	£4.0m	Kensa Contracting is providing its ground source heat pump heating system to approximately 100 properties under the ESO project, which is expected to increase the cost savings to consumers whilst reducing the grid impact of electrification of heat.
PulsiV: Developer of a technology harnessing the principles of high frequency, pulsed-power extraction techniques, to establish a new, unique method of harvesting more efficient energy.	£2.2m	Fast-Start (Solar Energy Inverter Maximiser) - developed an innovative process that allows an increase in the energy extracted from photovoltaic modules by extracting energy that is currently lost through heating effects.
Guru Systems: Developer of an analytics platform intended to improve efficiency and change the future of heat. The company's platform gives complete visibility of heat networks and other utility performances to help improve the efficiency of networks and fix problems early while reducing operating costs.	£2m	KTC (Guru Engage) - Project objectives include a complete redesign of Guru's existing in-home display hardware and user interfaces to include smart heating controls, environmental sensors, language support, flexible payment, and household cost projections based on customer and system data.

In addition to the larger, later stage, deals highlighted in the table above, 11 companies closed smaller investments (often seed investments), including Connected Energy (which closed a £1.2m investment led by ENGIE partners in early 2021, following on from a £5m investment made prior to the firm's involvement in the programme).

5.4.2 Commercialisation outcomes of PFER-funded companies

There has been moderate commercialisation of the technologies developed through the various PFER competitions. Approximately 22% of projects funded through the Demonstrator and Innovation Accelerator competitions have already commercialised their technology offering, as evidenced by generation of revenues and/or entering into contractual agreements with customers.

Innovation Accelerator commercialisation outcomes have varied across projects depending on the technical maturity of the innovation being funded through PFER. Fast-Starts saw limited commercialisation of their innovations by the end of their PFER funding period, though this was likely due to projects focusing on proving the viability of the technology and less so on developing detailed exploitation plans[40]. This contrasts Key Technology Component projects, of which a third have commercialised their technology in some form (either through business-to-business or business-to-customer sales) and several more projects are currently engaging in discussions with prospective customers.

5.4.3 Economic impacts of PFER-funded companies

Early exploitation and economic impacts are reported here for funded Demonstrator, Fast-Start and Key Technology Component projects only, given their relative progress in undertaking the works funded through PFER. Due to the early stages that MEDApps projects are currently in, these impacts have not been explored and reported here. Exploitation and economic impacts will be explored in greater depth among funded and unfunded CR&D projects at the final evaluation stage through an endline survey of applicants.

Across the portfolio of PFER funded firms developing a technology to date, there has been modest economic impacts related to job creation. More than 55% of participating firms in funded projects have created at least one FTE job as a result of participating in PFER. These are predominantly within Demonstrator and Fast-Starts projects and to a lesser extent, projects funded through the Key Technology Components competition.

[40] Findings for the Fast-Starts are from Autumn 2020 and are based on three case studies undertaken with Fast Start projects, survey responses received as well as monitoring information and post-completion questionnaires shared by UKRI.

6 Broader impacts of PFER

This section deals with the broader impacts of PFER generated through PFER's key knowledge enhancement groups, including ERIS, EnergyREV and the various working groups, including the policy and regulatory working group.

6.1 Key findings

- Work undertaken by PFER has become ever more imperative to strategic policy making and regulation, with a recent National Audit Office report recognising "serious weaknesses in central government's approach to working with local authorities on decarbonisation, stemming from a lack of clarity over local authorities' overall roles, piecemeal funding, and diffuse accountabilities."

- Furthermore, PFER has undertaken work in a context of increased urgency to achieve Net Zero targets, which has helped raise the profile of the programme. Work undertaken via PFER has led to greater understanding of place-based delivery of net-zero project and programmes, which is becoming increasingly recognised as the most cost-effective routes to decarbonisation.[41]

- Results emerging from PFER have influenced Ofgem regulation, work undertaken by the new National Infrastructure Bank and BEIS initiatives on sharing and accessing data in the energy sector. Further examples of how PFER has influenced Government policy are expected as the results and knowledge produced are taken up further in Whitehall.

- Knowledge and toolkits produced by ERIS have also started to be adopted beyond PFER by local authorities planning local actions to progress towards Net Zero. EnergyREV publications have seen nascent recognition by influential thinktanks such as the Stockholm Institute.

- PFER should continue engaging with key policy and regulatory initiatives to help shape the market design and policy framework throughout the remainder of PFER to maximise the wider benefits and influence of the work undertaken.

6.2 Relevant objectives

Another core objective of PFER as outlined in the business case is to build UK leadership in integrated energy provision. Establishing the UK as a unique hub for practical smart integrated local energy systems will refocus domestic researchers and attract international research talent to the UK to develop critical missing elements of an integrated energy system. Having a more focused approach to integrated systems research should further strategically position the UK as a leader in this space, providing evidence to support new business models and improve the UKs international offering in integrated systems design and delivery.

To achieve this, PFER allocated funding to a dual-network providing essential research expertise, capability and leadership to assist Demonstrators and future designers. The network is comprised of the Energy Revolution Research Consortium (ERRC) undertaking a programme of applied research relevant to PFER, and the Energy Revolution Integration Service (ERIS) run by the Energy Systems Catapult,

[41] PwC, Strategic and Economic Analysis for Net Zero – Strategic Report (DRAFT), July 2021.

providing analytical, modelling and project support services across all funded Demonstrators and Detailed Designs projects to ensure consistency and reproducibility.

6.2.1 Policy impacts

Several specific examples of how work funded by PFER has influenced central Government policy can be identified:

- Work resulting from the EDT coordinated by ERIS and IUK[42] and launched as part of PFER has been endorsed by BEIS and Ofgem, and the final Taskforce report has been cited by several stakeholders interviewed as a critical input into a number of policy and regulatory initiatives (see below). BEIS and Ofgem have committed to implementing the five recommendations resulting from this work[43]. In July 2021, BEIS published the UK's first Energy Digitalisation Strategy[44] based on this work.

- Following on from the EDT, BEIS has now launched a new EDiT[45], focussing on:

  - Refocus the energy sector on PFER and opportunities of Digitalisation as a core component of transformation, not just an enabler.

  - Accelerate digitalisation of the energy system which enables emerging Net Zero compatible business models, markets and industry structures.

  - Develop target digital architectures and a roadmap that draw on experience from other sectors and provide the energy sector with a focal point to ensure digitalisation efforts are coordinated and effective.

  - Identify digitalisation gaps that require innovation support.

  - Identify the governance risks that digitalisation raises and present frameworks to mitigate issues.

- The updated Smart Systems and Flexibility Plan, published in June 2021, underlines the importance of integrating local solutions for low carbon power, heat and transport, and Government stakeholders highlighted how influential work undertaken by PFER has been in drafting this strategy.

- The work of the Investment and Finance Working Group has led to fruitful engagement with the novel National Infrastructure Bank, and conversation on how the Bank could support SLES initiatives in the future. A due diligence framework to aid local authorities in de-risking their project plans, developed by the Working Group, has fed into the Bank's work to develop eligibility and financing plans for energy projects.

- Work undertaken via the MEDA competition, in particular the data architecture established for search and exchange of energy data, has led to significant momentum across the energy sector and Government, with key players from across the energy supply chain having signed up to the initiative.

[42] https://es.catapult.org.uk/impact/specialisms/energy-data-taskforce/
[43] Energy Data Taskforce (2021), A Strategy for a Modern Digitalised Energy System. Available at: https://es.catapult.org.uk/reports/energy-data-taskforce-report/
[44] BEIS (2021), Digitalising our energy system for net zero: Strategy and Action Plan 2021. Available at: https://www.gov.uk/government/publications/digitalising-our-energy-system-for-net-zero-strategy-and-action-plan
[45] https://es.catapult.org.uk/news/energy-digitalisation-taskforce-launches/

Whilst no formal policy documents have referenced this work yet, the open architecture established under this strand of PFER was recognised throughout by stakeholders interviewed.

- Other specific PFER results were cited by Government stakeholders as being influential in driving forward thinking around how to achieve Net Zero – including ERIS' paper on investment in SLES[46] and outputs produced by EnergyREV.

6.3 Working with regulators

Following intensive efforts by PFER, in particular the Policy and Regulation Working Group and the ERIS team, PFER is now in regular exchange with key stakeholders at Ofgem. This engagement with Ofgem has already led to a number of critical impacts:

- Engagement with Ofgem on their RIIO-2 network price control has led to Ofgem and UKRI partnering on the Strategic Innovation Fund[47], a £450 million envelope to invest into energy network innovation from 2021-2026, which is now run by IUK's energy innovation team.
- Based on the work undertaken by the EDT, Ofgem are now obliging networks to abide by best practice guidance developed by the Taskforce[48].
- The work undertaken by the EDT has also led to Ofgem requesting and publishing digitalisation strategies of DNOs and other network actors, to facilitate development of novel services and business models using energy data[49].

Engagement with Ofgem on the TCR and its implications for revenue stacking is ongoing and has been acknowledged by stakeholders attempting to develop business models based around novel flexibility services. A recent minded-to decision communicated a four-band option for Transmission Demand Residuals, a solution that had been advocated by PFER.[50] This has enabled multiple SLES projects' business models, including that of the Energy Superhub Oxford Demonstrator – however uncertainty remains as the policy is currently classed as minded-to, and it is unclear when it will be implemented. Where originally a flat fee connection was the incumbent model (costing smaller energy asset owners the same as large power stations), the four-band option support business models with smaller energy assets.

6.4 Equity investment in SLES

6.4.1 International trends in equity investment in SLES relevant companies

Figure 6.1 illustrates the trends in equity investment (spanning venture capital, growth capital from private equity funds, and fundraising from capital markets) in energy systems and smart energy companies from the UK, US, France, and Germany between 2010 and 2021. Equity investment has risen substantially

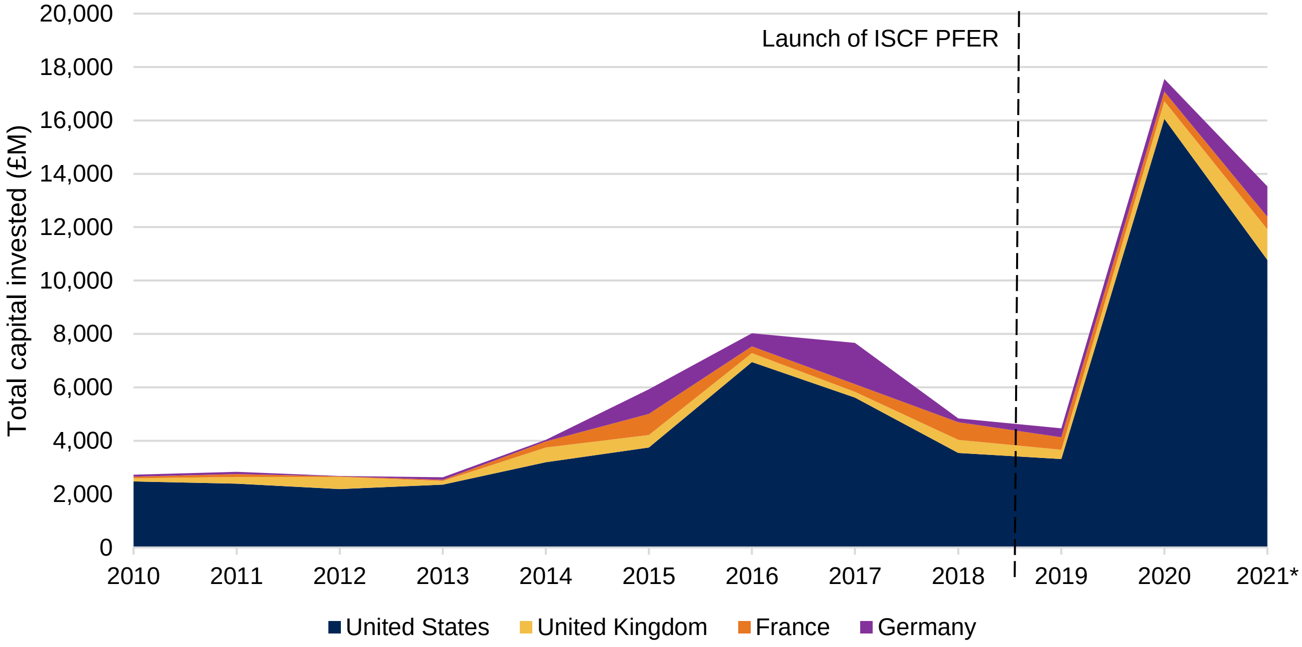
[46] https://es.catapult.org.uk/comment/scaling-up-investment-in-smart-local-energy-systems/
[47] https://www.ofgem.gov.uk/energy-policy-and-regulation/policy-and-regulatory-programmes/network-price-controls-2021-2028-riio-2/riio-2-network-innovation-funding/strategic-innovation-fund-sif
[48] Ofgem (2021), Data Best Practice Guidance. Available at: https://www.ofgem.gov.uk/sites/default/files/docs/2021/05/data_best_practice_guidance_v0.3_0.pdf
[49] https://www.ofgem.gov.uk/publications/digitalisation-strategies-modernising-energy-data
[50] This decision was under public consultation until July 2021, with implementation of the new TCR regime delayed to April 2023: https://www.ofgem.gov.uk/publications/cmp343-consultation-minded-decision-and-impact-assessment

since the launch of PFER in 2018, rising to £17.5bn across these four leading countries by 2020, primarily driven by an expansion in PIPE[51] and 2PO[52] investment.

The US maintains a leading position and accounted for 81% of the capital raised since 2010. The rise in US equity investment in 2020 is mainly driven by significant funding raised by individual companies, including:

- **Tesla:** Tesla – a vertically integrated sustainable energy company which also aims to transition the world to electric mobility by making electric vehicles – raised £3.8bn and £1.6bn in two 2POs.
- **NextEra Energy:** NextEra Energy – a power distributor to roughly 5m customers in Florida and a leader of innovative energy storage solutions in the US – attracted £1.5bn and £1.9bn in two separate PIPE investments.

Figure 6.1: Total equity investment (venture capital, growth capital via private equity and public fundraisings), UK, US, France, and Germany, 2010 to 2021



*Source: PitchBook, Ipsos user defined queries. Search criteria used: see Annex II. Only companies headquartered in respective countries. *2021 data is incomplete – inclusive up to 18th October 2021.*

There are indications that UK competitiveness in attracting investment in smart energy systems has risen relative to European competitors. Prior to 2018, the UK attracted a smaller share of investment (compared to France and Germany) in SLES relevant companies (6% during 2010-2018, lower than both Germany and France). However, since the programme was launched in 2018, this share has risen to 7% (inclusive of all investment between 2010-2021), equalling Germany and surpassing France (5%). More than a third (40%) of the £2.2bn total equity investment in the UK between 2019-2021 was generated by firms funded by PFER, further highlighting the influence of the programme on UK investment competitiveness.

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[51] Private Investment in Public Equity (PIPE) is the purchase of stock in a public company by a private investor, usually for less than the current market price.

[52] A Second Public Offering (2PO) refers to the sale of shares owned by an investor to the public on the secondary market. These are shares that have already been sold by the company in an Initial Public Offering (IPO).

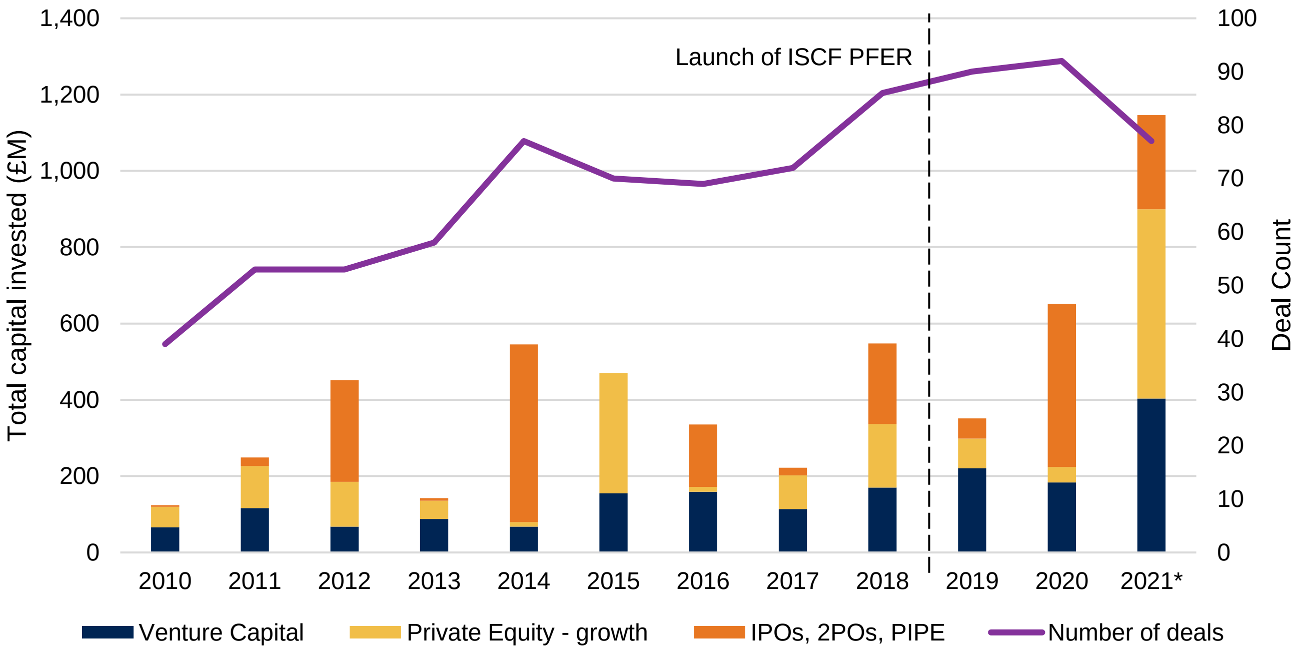
6.4.2 Investments in UK headquartered companies

Equity investment in UK headquartered companies relevant to SLES increased markedly following the launch of the PFER, driven by substantial growth in venture capital and PIPE funding, particularly in 2021 (see Figure 6.2). This rise was predominantly driven by significant fundraisings of single companies, including:

- **Octopus Energy:** a producer and supplier of renewable solar energy intended to enable customers to switch to green energy online – raised £475.6m in 2021 through PE growth/expansion funding.
- **Ceres Power:** a technology solutions provider and one of the foremost developers of fuel cell technology, enabling the production of clean and low-cost energy – attracted £181m of PIPE investment in 2021.
- **Onto:** an electric car subscription platform intended to offer ownership of electric vehicles without having to purchase them – raised £175m of early-stage venture capital (Series B)[53] in 2021.

Although data on the number of deals in 2021 is incomplete (up to 18th October 2021), a marked decline in deal numbers is seen between 2020 and 2021, from 92 to 77 deals, respectively. This is indicative of a shift in investors' preferences in 2020/2021 following the COVID-19 pandemic, as during this time it was more difficult to secure an IPO[54], and venture capital funds focused more on extending the cash runways for their existing investment portfolios.

Figure 6.2: Trends in in venture capital and growth capital via Private Equity investments and public fundraisings in UK-headquartered firms, 2010 to 2021



*Source: PitchBook, Ipsos user defined queries. Search criteria used: see Annex II. Only companies headquartered in the UK. *2021 data is incomplete – inclusive up to 18th October 2021.*

[53] Follows seed and Series A funding rounds where private investors fund businesses past their development stage to expand market reach and meet higher levels of demand.
[54] An Initial Public Offering (IPO) refers to the first time a private company's stock is available to the public.

6.5 Collaborative Research in Integrated Energy Provision

PFER aims to contribute to enhancing the UK position in emerging global markets for SLES. EnergyREV plays a pivotal role in these efforts by enhancing applied research and research partnerships within academia that take a whole-systems focused approach to research that considers the interdisciplinary aspect of smart local energy systems. EnergyREV has been actively collaborating and producing outputs on SLES since its inception in April 2018.

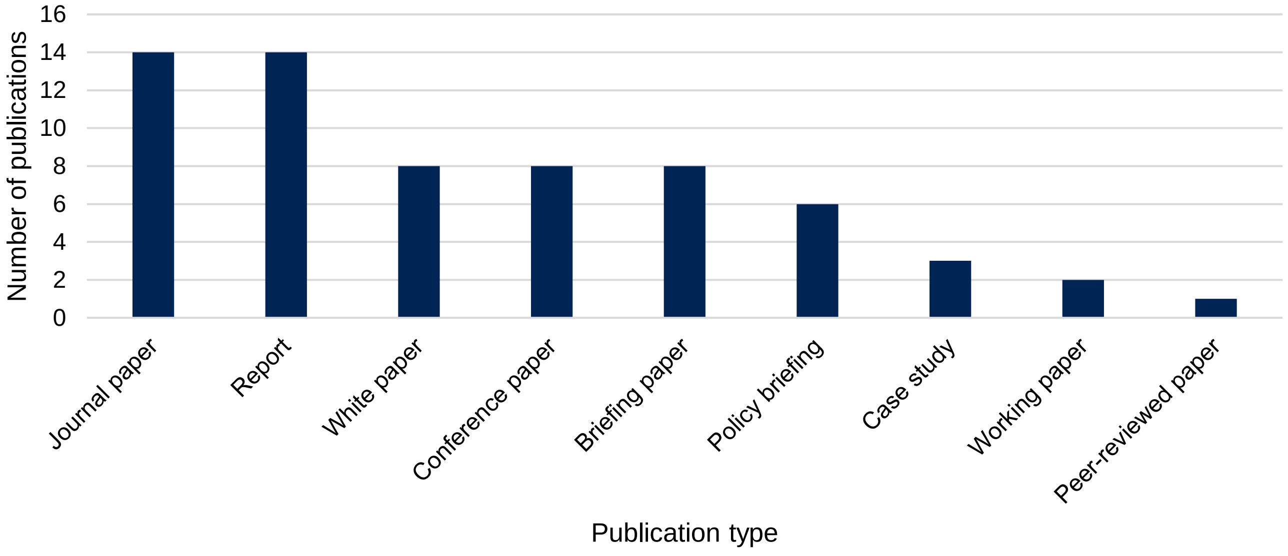
Overall, EnergyREV is delivering well against its specified objectives and supporting the objectives of PFER. To date, EnergyREV has delivered knowledge and insights across a variety of stakeholders. The programme has and will continue to produce a broad range of outputs across the six main themes/work packages that EnergyREV covers. Broadly, the consortium has now established itself and is looking to deliver on its plans to deliver stakeholder focused research and outputs. The end of the funding period is expected to be a period of significant acceleration in outputs.

In addition to the knowledge outputs it has created, EnergyREV has supported the leverage of c.£400k of funding (data available to August 2021) and has undertaken engagement with stakeholders across a variety of platforms (including website content creation, social media, podcast, conference presentations and seminars, public outreach, and media engagements). Research and knowledge creation, synthesis and management has been focused on how EnergyREV can be useful to external stakeholders, requiring activities to ensure that the delivery of work packages differs from academic business-as-usual (e.g. flexibility in reacting to emerging research questions). The mechanisms in place are still imperfect and subject to the risks of rapid obsolesce inherent in research of this kind.

6.5.1 Uptake of EnergyREV publications

Since 2019, the consortium has produced 64 outputs in various formats (See Figure 6.3). Existing outputs provide evidence of PFER, opportunities, and successful models (or unsuccessful models) for scaling up SLES. A core strand of EnergyREV work and outputs has been dedicated to understanding what SLES are, what success in a SLES might look like, and how this can measured. The consortium has also prioritised the development of knowledge management to link work packages to one another and ensure focus remains on activities and outputs focused on SLES. Where possible, EnergyREV has created thematic/topic led consultations with PFER projects using a variety of engagement mechanisms. These have been both collaborative work (e.g. with Demonstrators during lifetime of their project to date) and shorter targeted forms (e.g. request to all PFER projects to complete a survey).

Figure 6.3: EnergyREV outputs published since the end of 2020 or currently planned for publication during the remainder of the project

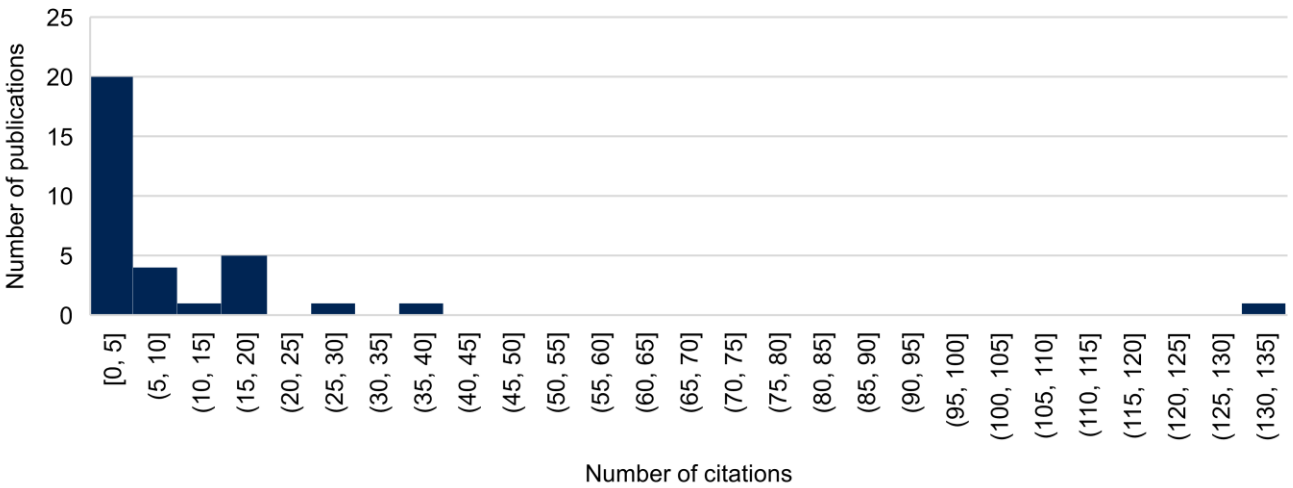


Source: EnergyREV

6.5.2 Number of citations and Field-Citation-Ratio (FCR)

In order to track the progress of PFER in promoting applied research, the study team have sourced number of citations and field-citation ratio scores for EnergyREV publications. It should be noted that here the limited number of publications and relatively short timeframe that they have been in circulation. The majority of EnergyREV outputs have had limited citations per output to date, reflecting the short timeframe they have been in circulation (see Figure 6.4).

Figure 6.4: EnergyREV publication citations



Source: Dimensions data, Ipsos queried

Six of the seven EnergyREV publications that have an FCR[55] have ratios higher than one, meaning the publications have a higher-than-average number of citations for their field. FCR scores for other publications will be reported at the final evaluation stage once they have been in circulation for two years.

[55] Only publications that are at least two years old and have at least one citation are given an FCR.

There is growing recognition of EnergyREV outputs in policy making, through citations by international organisations such as the Stockholm Environment Institute. EnergyREV's Hepburn et al (2020) review of COVID-19 fiscal recovery packages on climate change progress has been widely cited, reflecting on national climate change strategies that can be implemented to recover from the effects of the COVID-19.

6.6 Uptake of systems approach and local area energy planning

By using robust data analysis to create integrated local energy plans, decarbonisation can be driven through coordinated investment in energy infrastructure from a whole systems perspective, avoiding isolated action. The ESC, through the ERIS programme funded by PFER, has contributed directly to the wider uptake and understanding of such a systems approach.

Since 2018, the activities of ERIS pivoted from supporting PFER projects to disseminating knowledge generated by PFER to a broader audience. The PFER team played a key role in repositioning ERIS activities, showing awareness of changes in the wider programme context and recognising significant capacity gaps at the local authority level which presented critical barriers for wider replication and scale-up of any SLES technologies or business models across the UK.

Current ERIS activities focus on supporting local authorities to help implement systems-based approaches to local area energy planning and SLES projects (in response to key reports from the Climate Change Committee and Public Accounts Committee) suggesting a focus on building capacity and capabilities of local authorities to deliver local action against the national Net Zero targets.[56][57] A number of ERIS activities since the baseline have helped to build capacity and capability in the sector:

- **Capacity building and support offer for local authorities** – working with Oxford Country Council to apply the SLES toolkit and Local Energy Asset Representation model for local area energy planning – this will help Oxford Country Council to identify potential SLES projects to implement, taking account of the building stock, existing energy networks, heating technologies available, electrification of transport, and local spatial constraints. Further engagement with the capacity building offer was evidenced through workshops and events, including Oxford City, Peterborough, Orkney, Greater London Authority and Greater Manchester Combined Authority. Feedback was not sought from local authorities for this report but will be explored in the final evaluation.

- **Engaging a group of institutional investors in the development of a due diligence framework** for system level investment propositions and supporting local authorities in using this framework to develop proposals. This framework is now being used to structure investment propositions using a common approach, facilitating engagement with potential investors for SLES projects.

- **Continued engagement with projects** –the Local Energy Asset Representation modelling tool was used to help Demonstrator and Detailed Designs projects to plan demonstration activities and identify potential areas for scaling up roll-out of the integration and flexibility solutions developed.

[56] Climate Change Committee (2020), Local authorities and the Sixth Carbon Budget. https://www.theccc.org.uk/publication/local-authorities-and-the-sixth-carbon-budget/

[5757] Public Accounts Committee (2021), Achieving Net Zero. https://publications.parliament.uk/pa/cm5801/cmselect/cmpubacc/935/93502.htm

7 Conclusions

This section presents the conclusions and recommendations from the interim evaluation of PFER. It highlights key points of interest from the assessment of the programme and early outcomes identified, which will be reviewed again at the final impact evaluation stage.

7.1 Progress to programme objectives

PFER has been designed around a complex and innovative premise, tackling the system-level requirements and approaches needed for a transition towards Net Zero rather than the development of individual technologies. At the interim stage, we found that PFER has progressed the funded demonstration activities towards commercial maturity, started to materialise some of the aspired system level value and has started to shape system-level change through influencing discussions and policy decisions around the broader design of the energy market and how it should be regulated to facilitate progress towards Net Zero. IUK stopped funding a fourth Demonstrator project in West Sussex, largely due to significant delays in scoping finance and procurement arrangements across the project.

The PFER team has proven flexibility and agility in navigating change in the programme context and challenges to the implementation of funded activities, thus maximising the potential for PFER to materialise the expected outcomes. Examples of this include:

- Stage gating key projects, which has been invaluable in identifying critical issues early.
- Introduction of specific workstreams outside of the core PFER funding to enable the commercial viability of PFER projects, such as working groups on finance, regulatory and policy aspects.
- Introducing funding on energy data and digitalisation through the MEDA and MEDApps competitions.
- Pivoting the ERIS workplan to provide tools & capabilities for the wider adoption of SLES business models.

7.1.1 Prove investable, scalable local business models

Overall, PFER has facilitated progress towards the validation of new SLES business models and has been working towards shaping the wider market design determining their commercial viability.

Substantial progress has been made towards proving the commercial viability of underlying technological assets and business models across the portfolio of Demonstrator and Detailed Design projects. Overall, two of the initial four Demonstrators are on track to deliver 12 months of ‘live demonstration’ of new business models and are progressing in line with expectations given the complex technical challenges.

Several Detailed Design projects have made substantial progress towards formulating market and customer needs, developing financial models to commercialise core project assets, and understanding potential revenue streams.

PFER has actively addressed some barriers to progressing the commercial maturity of projects:

- PFER has continued engagement with regulators and policy makers to ensure that future market design and regulation facilitates the wider roll out of SLES business models, providing evidence into key policy initiatives at BEIS and Ofgem.

- Results of the Icebreaker One project has led to the creation of an open energy data architecture and platform[58]. This has led to significant momentum across the energy sector and Government, with key players from across the energy supply chain having signed up to the initiative – this initiative will have substantial enabling effects on the development and testing of SLES business models.

User recruitment and demonstration activities have started on all three live Demonstrator projects, amidst several changes to project scope and ambition, indicating that projects have responded flexibly to continued challenges in implementation – it therefore remains unknown at this interim stage to what extent business models will be able to generate sufficient revenues and demonstrate a sufficiently attractive IRR to be commercially viable beyond PFER funding.

Despite the efforts of PFER, the current national regulatory and market design landscape is limiting the commercial viability of SLES business models and the extent to which these business models attract investor interest. It incentivises large-scale deployment of large assets without consideration of local needs and preferences – this poses some systematic challenges for PFER projects to quantify and access benefits of consumer flexibility. The TCR minded-to decision to prefer 4-band options has provided some clarity for envisaged revenue streams, projects have also experienced regular changes to rules on cost allocation and charging – for instance, it is currently unclear how forward-looking network charges will be set.

Lessons can also be drawn from the Demonstrator project which IUK stopped funding towards the end of 2020. Issues with this project suggest that future programmes funded large-scale and complex technology demonstration should be staged into a scoping and implementation phase, to reduce some of the inherent risks of such projects.

Other residual risks to the demonstration of commercially mature business models remain – delays induced by COVID-19 are in most cases temporary risks to commercial viability of projects. Some revenue streams anticipated by projects have been threatened by insufficient scoping – for instance required FCA approval and insufficient early engagement with DNOs.

7.1.2 Unlock investment in local integrated energy systems

PFER-funded firms have been able to collectively raise £874.29m in funding from external investors since receiving PFER funding. Hence, more than a third (40%) of the £2.2bn total equity investment in the UK between 2019-2021 was generated by firms funded by PFER, further highlighting the influence of the programme on UK investment competitiveness. These investments have been categorised using the following IUK investment types and reported in Table 7.1 below:

- **Type 1**: Upfront, committed co-investment (match funding) in Research and Innovation activity part funded through PFER.[59]

- **Type 2**: Additional funding raised that's purpose is directly related to further progressing development or commercialisation of the technology or business model developed under PFER.

[58] https://openenergy.org.uk/

[59] This funding type includes the match funding commitments made as part of project proposals submitted against an ISCF PFER competition. Given the focus of this report is on investments made after a given firm started receiving PFER funding, there are no Type 1 investments reported here or in the table below.

- **Type 3**: Funding that has been raised to progress development or commercialisation of a business model of technology aligned with the PFER-funded technology or business model.

- **Type 4**: All other funding raised by PFER funded firms.[60]

Table 7.1: PFER investment outcomes

IUK Investment Category	Amount raised since grant award (£m)
Type 2	£75.4m
Type 3	£323.4m
Type 4	£475.5m

There is also some emerging evidence that PFER has helped firms to leverage follow on investment:

- Firms involved in three out of the initial four Demonstrators have secured growth capital to scale-up their business model, raising private equity investments to the tune of £534m.

- Three technology developers participated in PFER Demonstrator projects have been acquired by energy suppliers and a major provider of smart meter installation services, suggesting that these firms offer mature technological assets in areas such as battery storage, energy system management and carbon capture.

A further 19 technology developers funded through a variety of PFER competitions have raised a total of £52m in venture capital funding to refine their technologies, scale-up business models and in some cases, access international markets. Several developers of digital platforms and energy storage systems underpinning the Demonstrator projects have received investment to fund scale-up and international growth.

Beyond the investments into firms supported by PFER, the work of the Investment and Finance Working Group has led to fruitful engagement with the novel National Infrastructure Bank, and conversation on how the Bank could support SLES initiatives in the future. A due diligence framework to aid local authorities in de-risking their project plans, developed by the Working Group, has fed into the Bank's work to develop eligibility and financing plans for energy projects and its local lending function.

Since 2018, the activities of ERIS pivoted from supporting PFER projects to disseminating knowledge generated by PFER to a broader audience. The PFER team played a key role in repositioning ERIS activities, showing awareness of changes in the wider programme context and recognising significant capacity gaps at the local authority level which presented critical barriers for wider replication and scale-up of any SLES technologies or business models across the UK.

Activities undertaken by ERIS have helped to build capability at the level of local authorities, helping them to plan and finance local solutions to reach Net Zero. ERIS has contributed to wider learning and knowledge sharing across PFER and beyond, raising awareness of system level approaches and solutions across the sector.

[60] Fundraising amounts are inclusive of those not directly attributable to the technology/service being funded by PFER.

7.1.3 Create real world proving grounds to commercialise new products and services

PFER has made substantial progress towards large-scale demonstration of flexibility and energy system integration products and services. Two of the four Demonstrators are on track to deliver 12 months of 'live demonstration' and are progressing in line with expectations given the complex technical challenges. User recruitment and demonstration activities have started on all three live projects, amidst several changes to project scope and ambition, indicating that projects have responded flexibly to continued challenges in implementation. Highlights include the connection of a 50MW lithium-ion battery energy storage system in Cowley, the first battery storage in the UK to directly connect and trade with the transmission system. All three projects that are still live have made good progress in the technical development of their core technological assets.

PFER has also influenced the facilitation of proving grounds outside the activities funded – for instance:

- The £65m Flexibility Innovation Programme, set up to implement BEIS' novel Smart Systems and Flexibility Plan. Government stakeholders highlighted how influential work undertaken by PFER has been in drafting plan.
- A due diligence framework to aid local authorities in de-risking their project plans, developed by the PFER Investment and Finance Working Group has fed into the NIBs work to develop eligibility and financing plans for energy projects.

7.1.4 Build UK leadership in integrated energy provision

PFER is also expected to aid the UK in establishing a leading role in designing, financing and supply of local energy systems technology – generating UK business growth across the local energy systems supply chain. To this end, PFER funded a number of smart local energy technology development projects through innovation accelerator and MEDApps competitions.

Some early commercial exploitation of project results from this portfolio of CR&D projects was observed – with many projects still ongoing, three core assets have been commercialised, including a battery optimisation solution developed by Powervault, a wireless household metering solution by Hypervolt, and technology developed by EV Dot Energy to maximise grid services from electric vehicles.

There is also growing recognition of the publication outputs of PFER – for instance, EnergyREV papers have been cited by international organisations such as the Stockholm Environment Institute.

7.2 Recommendations

Table 7.2: Recommendations

Evaluation finding	Recommended action	Responsible parties
Group A: Improvements to on-going programmes		

Evaluation finding	Recommended action	Responsible parties
Despite the progress made since the launch of PFER, there is still uncertainty around the long-term energy market design model and policy framework and how this should evolve in order to achieve net-zero targets. This uncertainty is preventing commercially viable business models of SLES to be fully tested – holding back wider investment, scale-up and replication.	PFER should continue to engage with key policy makers and regulators to help shape a future market design conducive for the wider scale up of SLES business models – in particular: 1. Feeding into a consultation on Ofgem's strategic priorities, with regards to how Ofgem can support the Governments Net Zero and related innovation objectives. 2. Feeding into Ofgem's supply market review 3. Invite Ofgem to finalise its work programme to implement the smart systems and flexibility plan 4. Invite Ofgem to recognise the open energy standard for data sharing developed by Icebreaker One to further facilitate data sharing across the sector. 5. Invite BEIS to follow up on last year's call for evidence on the Licence Exemptions Regime 6. Inviting Ofgem to draft proposals on more flexible licensing and use of derogations and exemptions in support of SLES 7. Inviting Ofgem to provide certainty on costs and revenues from offering flexibility services 8. Ensure results of PFER are fed through to other innovation programmes such as the RIIO-2 Strategic Innovation Fund and BEIS' Flexibility Innovation Programme.	PFER team, ERIS
Results of the MEDApps project portfolio are not yet available – but it is anticipated that these could help accelerate progression of business model development and local area planning activities funded through Demonstrator and Detailed Design projects	UKRI should explore possible opportunities to link outputs from the MEDApps portfolio into programmes of Detailed Design and Demonstrator projects – potentially aiding the commercial viability of business models and local energy area planning through access to novel energy data	IUK
Group B: Issues for future UKRI intervention		
The complexity and ambition of PFER Demonstrators imply the importance of scoping out in detail the technological, commercial, regulatory and financial aspects of their 'real-life' implementation.	Future Government programmes funding large-scale demonstration of energy system innovation should be phased into a scoping phase, with Government providing seed funding to detail out financing and partnership arrangements as well as regulatory requirements, and an implementation phase, focussing on the 'real-life' demonstration of technological and commercial viability. This would allow Government to maximise return on investment by selecting the most viable detailed plans from results of the scoping phase, instead of committing upfront so significant capital investments on potentially unviable demonstration activities.	IUK, BEIS
The PFER practice of stage-gating large projects with high levels of risk has clear advantages for project quality. Adoption of these practices was not commonplace in historic CR&D competitions.	IUK may wish to consider the possible merits of diffusing these practices more widely. Stage-gating does, however, have implications for programme integration as changes in direction in individual projects may make it more challenging to plan cross-cutting programme activities to exploit project-specific results.	IUK

Evaluation finding	Recommended action	Responsible parties
The TCR minded-to decision to prefer 4-band options has provided some clarity for envisaged revenue streams, projects have also experienced regular changes to rules on cost allocation and charging – for instance, it is currently unclear how forward-looking network charges will be set.	Future Government programmes funding large-scale demonstration of energy system innovation should be undertaken in a regulatory sandbox environment by default, allowing projects to trial their commercial viability against agreed regulatory options without disruption.	IUK, BEIS, Ofgem
Some PFER projects have encountered issues in proving their commercial viability which could have been avoid by more extensive scoping of the requirements.	UKRI could consider adapting its assessment process for future competitions funding large scale demonstration activities to include a review of plans and arrangements for network access. The process should also be adapted to review evidence on local demand for the specific energy assets they plan to install and consider any requirements around FCA approval. This would help prevent some of the specific access issues that have held back part of the PFER demonstration activities funded.	IUK

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8 Future evaluation work

Following this interim report, the evaluation will conclude with the final evaluation. This will include an update on the data collected during the baseline and interim evaluation with the aim of establishing any attributable outcomes and impacts associated with PFER. A final report delivered at the end of PFER – we understand this has been extended by up to 6 months so are currently assuming a final report for Q1/2023.

Table 8.1 outlines the proposed research methods to be employed during Phase II of the evaluation.

Table 8.1: Evaluation task by research method

Research Method / Evaluation Task	Phase II: Programme Evaluation	
Timeline	Interim Report / Q2 2021	Final Report / Q1 2023
Analysis of Monitoring records		
Secondary data analysis		
Bibliometrics & patent analysis		
End-user/business/applicant Survey		
Econometrics & CBA		
Stakeholder Consultations		
Case studies		

Source: Ipsos (2021).

Table 8.2 maps the evaluation questions against the proposed research tasks employed to answer them as set out in the initial evaluation framework.

Table 8.2: Evaluation questions mapped to research tasks

Research question	Analysis of Management Information	Bibliometrics and Patent analysis	Secondary data analysis	Survey	Econometrics	Stakeholder consultations	Case Studies
Was the programme able to demonstrate cleaner, cheaper energy models?							

To what extent did the programme demonstrate positive stakeholder engagement, including from business and finance communities?						
To what extent did the programme contribute to prosperity improvements in local communities?						
To what extent did the programme demonstrate UK Business growth from proof of new products, services and systems?						
To what extent did the programme lead to investability, scalability and replicability of new models created?						
To what extent did the programme contribute to UK leadership in integrated energy systems?						

Annex I – SLES Sector Groupings

Sector groupings	Role in SLES
Households	Traditionally utility grids would consume energy from the utility provider and charged based on their level of consumption. Under a smart local energy system where smart grids beginning to replace traditional grids, energy users can generate, store or trade energy with other users in the grid.[61] The available literature identifies three proposed categories of prosumer roles in the smart grid based: • the "Engineer" who value new technologies and innovation. • the "Green User" who are concerned with environmentally sustainable solutions; and, • the "Value Seeker" who are interested in the economic benefits and product performance, quality and security.[62]
Local authorities / community groups	Local authorities and community groups are essential actors in the SLES design and delivery. Using the framework mentioned, local authorities and community groups would be responsible for making a SLES 'local', incorporating local interests into SLES design. Seen as key players in brokering relationships between different other actors in SLES delivery, facilitating installation of large-scale infrastructure (through planning permits, for example), and occasional ownership of SLES assets. Each PFER Demonstrator has at least one local authority in their delivery team.
Power generation assets	Smart local energy systems are at the fore of the transition from a centralised power system that currently relies on fossil-fuelled energy sources to one of decentralisation that harnesses greater renewable (low-carbon) power generation. Furthermore, given a SLES provides the environment for consumers to become prosumers, power generation is likely to be small-scale and/or at household-scale. While existing fossil-fuelled generation assets still generate power for smart local energy systems, this proportion is expected to diminish over time as the UK progresses towards its fifth carbon targets.
Distribution Network Operators (DNO) and Distribution	Distributed Network Operators are owners of regional networks that transport power from generators to customers. They are responsible for maintaining and monitoring distribution networks, such as local power lines and substations that

[61] Rathnayaka, A.D.; Potdar, V.M.; Dillon, T.; Kuruppu, S. Framework to manage multiple goals in community-based energy sharing network in smart grid. Int. J. Electr. Power Energy Syst. 2015, 73, 615–624.
[62] Kotilainen, K.; Järventausta, P.; Aalto, P. Prosumer centric co-creation in Smart Grid innovation ecosystem. In Proceedings of the Innovative Smart Grid Technologies-Asia (ISGT-Asia), Melbourne, Australia, 28 November–1 December 2016; pp. 884–889.

System Operators (DSO)		transform the voltage of power to transport it to homes efficiently. We are currently witnessing a transition of DNOs to DSOs across the distribution network.
Physical infrastructure providers		
Power	Generation	Given the transition towards local, low-carbon generation assets, infrastructure providers might be best classified as those hardware technology developers and manufacturers of hardware technology components of a smart local energy system (see below). In particular, technology components that would generate power for prosumers and therefore be eligible for the Smart Export Guarantee (i.e. are eligible to receive payment for exported electricity). This includes owners and operators of anaerobic digestion, hydro, onshore wind and solar photovoltaic (PV) generators with a total installed capacity up to 5 MW and micro-combined heat and power up to 50kW.[63] There is also a case to include owners/operators of other renewable generation that may exceed SEG eligibility, but which are too small to take advantage of Contracts for Difference (CfDs) due to the financial capability needed to deal with them. This might include combined heat and power plants, biomass plants, solar and wind farms that might be considered 'local energy producers', i.e. produce power between 5-50 MW.[64]
	Distribution	Distribution networks are made up of substations, overhead power lines and underground cables that transport electricity from National Grid's transmission network and small-scale generators and delivers it to the homes and businesses and each DNOs designated region. The majority of the electricity distribution network is built, owned and operated by distribution network operators, with some parts of the network owned by Independent Distribution Network Operators.
	Supply	Electricity and gas suppliers would remain important players in the energy system under SLES design. Over time, their role in smart local energy systems would be better adapted to the needs of prosumers, including compulsory offering of smart tariffs that allow consumers to consume energy during off-peak demand at low prices and avoid consumption of energy during peak periods of demand and high prices.
Transport		As the process of electrification of transport takes place, as does the need for expansion of existing and development of new electric vehicle charging networks. The core physical infrastructure considered within EV charging networks are the charging points, typically installed either at individual households, workplaces, public car parks or on-street parking. Key players to consider in this sector grouping include those organisations that install, own or maintain the physical EV charging

[63] https://www.ofgem.gov.uk/environmental-programmes/smart-export-guarantee-seg/about-smart-export-guarantee-seg#:~:text=The%20smart%20export%20guarantee%20(SEG)%20is%20an%20obligation%20set%20by,force%20on%201%20January%202020.

[64] House of Commons Energy and Climate Change Committee, Local Energy: Volume I. (2013). Available at: https://publications.parliament.uk/pa/cm201314/cmselect/cmenergy/180/180.pdf

	network infrastructure, i.e. charging point operators. There are also digital infrastructure providers who are responsible for monitoring the networks, managing energy requirements, and providing billing services to end-users.
Heat	Heat infrastructure providers would be responsible for installing and maintenance of domestic heating systems (including Ground Sourced Heat Pumps (GSHP) and Air Sourced Heat Pumps (ASHP)), large-scale hydrogen fuel cells (for heating purposes) and heat networks (series of thermally insulated pipes that distribute hot water from an energy plant and connect buildings and homes within the network to provide reliable heat and hot water supply).
Developers / manufacturers of hardware	Developers and manufacturers of Key Technology Components that enable deployment of a SLES. This includes developers and manufacturers of DERs, such as solar panels, combined heat and power plants, electricity storage (such as batteries), small natural gas-fuelled generators, electric vehicles and controllable loads, such as Heating, Ventilation, and Air Conditioning (HVAC) systems and electric water. This sector grouping would also include developers and manufacturers of Internet of Things (IoT) devices that enable local energy systems to be ‘smart’. As a minimum, this would include manufacturers of smart meters that connect consumers in virtual marketplaces; and smart applications (for example, smart thermostats that can be remotely switched in response to price signals) that enable demand-side response – this is an important instrument for increasing the flexibility of an energy market. This group would also include developers and manufacturers of assets across the mobility and heat vectors that would be incorporated into a SLES, including Ground Sourced Heat Pumps (GSHP), Air Sourced Heat Pumps (ASHP), H2 fuel cell (for heating) and electric vehicle charging points.
Software providers	Developers of software that intelligently link the various energy vectors and players making up a SLES. Given the ‘smart’ component of a SLES, software providers could potentially provide a wide range of services to customers, harnessing the use of smart meter data. This may include Distributed Energy Resources Management Services (DERMS) that support DSOs with voltage management of the grid, optimisation of the power flow within a grid or local grid local management. Software providers may also develop Virtual Power Plant (VPP) applications (as in the case of the ReFLEX Demonstrator) that offer grid frequency stabilisation, energy trading, portfolio management and peak load/demand management. This sector grouping may also include software platforms that: enable demand side response (including algorithmic smart tariffs); and offer electric vehicle charging and energy management platforms, providing bespoke billing, operations management and energy management. Within the transport vector of a SLES, software providers might also include developers of digital apps tailored more

	towards end-users that wish to use, for example, public charging facilities, or find the nearest charging point.

Annex II – SLES industry Pitchbook investment search terms

(Energy > Energy Services > Energy Infrastructure AND CleanTech NOT Business Products and Services (B2B) > Commercial Services > Consulting Services (B2B) AND Energy > Exploration, Production and Refining > Energy Production) OR (Energy > Energy Equipment > Alternative Energy Equipment AND Infrastructure AND CleanTech) OR (Energy > Exploration, Production and Refining > Energy Exploration AND CleanTech NOT Oil & Gas) OR (Energy > Exploration, Production and Refining > Energy Production AND CleanTech NOT Oil & Gas) OR ((Energy > Energy Equipment > Alternative Energy Equipment AND (CleanTech AND Manufacturing) NOT Mobile) OR (Consumer Products and Services (B2C) > Consumer Durables > Electronics (B2C) AND Information Technology > IT Services > Systems and Information Management AND CleanTech) OR (Energy > Energy Services > Energy Storage AND Manufacturing NOT Energy > Exploration, Production and Refining > Energy Refining)) OR (Energy > Energy Equipment > Alternative Energy Equipment OR Business Products and Services (B2B) > Commercial Products > Electrical Equipment AND CleanTech AND Manufacturing NOT Industrials) OR (Information Technology > Software > Business/Productivity Software AND Energy > Energy Services > Energy Storage NOT Oil & Gas) OR (Energy > Energy Services > Energy Storage AND Information Technology > Software > Vertical Market Software AND Cryptocurrency/Blockchain) OR (heat network NOT SaaS) OR ((Energy > Energy Services OR Energy > Utilities > Electric Utilities OR Energy > Utilities > Gas Utilities OR Energy > Utilities > Multi-Utilities) AND (Information Technology > Software OR SaaS OR Artificial Intelligence & Machine Learning AND CleanTech)) OR (Energy > Energy Services > Energy Traders and Brokers AND CleanTech) OR (((CleanTech AND LOHAS & Wellness AND Mobility Tech) AND (Consumer Products and Services (B2C) > Transportation > Other Transportation OR Consumer Products and Services (B2C) > Transportation > Automotive OR Business Products and Services (B2B) > Commercial Services > Environmental Services (B2B) OR Business Products and Services (B2B) > Commercial Services)) NOT Manufacturing NOT Micro-Mobility NOT Car-Sharing NOT Ridesharing) OR (Business Products and Services (B2B) > Commercial Services > Other Commercial Services AND Information Technology > Software > Other Software AND CleanTech) OR (Business Products and Services (B2B) > Commercial Services > Consulting Services (B2B) AND Business Products and Services (B2B) > Commercial Products > Other Commercial Products AND CleanTech AND Manufacturing AND TMT) OR (Consumer Products and Services (B2C) > Transportation > Other Transportation AND Consumer Products and Services (B2C) > Other Consumer Products and Services AND CleanTech NOT LOHAS & Wellness) OR (Business Products and Services (B2B) > Commercial Transportation > Road AND Information Technology > Software > Social/Platform Software AND Car-Sharing) OR (Energy > Utilities > Electric Utilities AND Energy > Energy Services > Energy Marketing AND CleanTech).

Annex III – Commercial Readiness Level (CRL) scale

	CRL Summary
1	Knowledge of applications, use-cases, & market constraints is limited and incidental, or has yet to be obtained at all.
2	A cursory familiarity with potential applications, markets, and existing competitive technologies/products exists.
3	A more developed understanding of potential applications, technology use-cases, market requirements/constraints, and a familiarity with competitive technologies and products allows for initial consideration of the technology as product.
4	A primary product hypothesis is identified and refined through additional technology-product-market analysis and discussions with potential customers and/or users. Potential suppliers, partners, and customers are identified and mapped in an initial value-chain analysis. Any certification or regulatory requirements for product or process are identified.
5	A deep understanding of the target application and market is achieved, and the product is defined. A comprehensive cost-performance model is created to further validate the value proposition and provide a detailed understanding of product design trade-offs. A basic financial model is built with initial projections for near- and long-term sales, costs, revenue, margins, etc.
6	Market/customer needs and how those translate to product needs are defined and documented (e.g. in market and product requirements documents). Product design optimization is carried out considering detailed market and product requirements, cost/performance trade-offs, manufacturing trade-offs, etc.
7	Product design is complete. Supply and customer agreements are in place, and all necessary certifications and/or regulatory compliance for product and production operations are accommodated. Comprehensive financial models and projections have been built and validated for early stage and late-stage production.
8	Customer qualifications are complete, and initial products are manufactured and sold.
9	Widespread deployment is achieved.

Annex IV – Technology Readiness Level (TRL) scale

	TRL Summary
1	**Basic principles have been observed and/or formulated:** Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.
2	**Developing hypothesis and experimental designs:** Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3	**Specifying and developing an experimental Proof of Concept (PoC):** Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4	**PoC demonstrated in test site/initial evaluation of costs and efficiency produced:** Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5	**Technology/process validated in relevant environment:** Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components.
6	**Technology/process validated in operational environment**: Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.
7	**System complete and qualified:** Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, in a vehicle, or in space).
8	**Product/technology in manufacture/process being implemented:** Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications.
9	**Product/service on commercial release/process deployed:** Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.
10	**Dead end and reached.**

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Ipsos' standards and accreditations provide our clients with the peace of mind that they can always depend on us to deliver reliable, sustainable findings. Our focus on quality and continuous improvement means we have embedded a "right first time" approach throughout our organisation.

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ISO 9001

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ISO 27001

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