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Review of UK Energy System Demonstrators

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Introduction to UKERC

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Executive Summary

A review of energy systems demonstrator projects in the UK has been undertaken for the UK Energy Research Centre (UKERC) by the Energy Systems Research Unit (ESRU) at the University of Strathclyde. The review consisted of two phases 1) the identification of demonstrator projects and 2) an analysis of projects and their outcomes.

For the purposes of project identification, an energy systems demonstrator was defined as "the deployment and testing of more than one technology type that could underpin the operation of a low-carbon energy infrastructure in the future". Only projects post-dating 2008 were considered. A search using a wide range of resources yielded a total of 119 projects that met these criteria.

Information on each project was recorded using a common template. The collected data was used to develop a GIS layer of UK demonstrators, available at: http://ukerc.rl.ac.uk/TOOLS/EnergyDemonstrators/map.html.

Analysis of the collected project data led to the following findings.

Most demonstration projects had budgets in excess of £1M, with an average budget of £5.7M. The largest project funder (by number of projects) was the LCNF.

Projects were spread across the UK, with SE England and Scotland hosting the largest portion of projects respectively. Most projects were located in urban areas.

The majority of projects were electricity-related and the target sector of many projects was the built environment, particularly the domestic sector. Some duplication between projects funded by different bodies was evident. The technology type most frequently appearing in demonstrations was smart controls followed by PV, batteries and active network management.

Under a quarter of projects featured some form of direct engagement with consumers. The scale of engagement varied hugely from a handful of participants through to tens of thousands.

Approximately 54% of the projects reviewed were classed as completed: this was where the stated project end date had expired. Of these completed projects, 87% had produced an identifiable final report. Note that where a project is recorded as completed it does not imply that the objectives were achieved.

The quality of final reports reviewed varied considerably; some funding schemes such as the Low Carbon Network Fund (LCNF) and EU-H2020 had set reporting requirements and this was reflected in the quality and content of the final reports. Project reports from other funding schemes were generally less informative.

Approximately 85% of projects had a website, or at least there was evidence that a website had existed. However, persistence of information was an issue, as several project websites (e.g. for older FP7 projects) could not be found. This could be problematic if a web site was the sole public dissemination point for a final report and other project outcomes. Few projects were found with readily accessible datasets.

Information on demonstrators was culled from a range of different sources and was frequently difficult to track down. There is a case that findings and learning from projects should be adequately disseminated through a common, accessible and persistent repository.

A review of the project outcomes found that most were positive, highlighting technology specific learning derived from the project work. A significant number of findings quantified or provided a qualitative statement of the beneficial impact that a technology or system had on energy performance. It was noted that project outcomes were self-reported.

Some common problems were reported including high costs of trialled systems and issues in engaging and recruiting participants.

Given that most project reports were written immediately after the completion of a project, there was little evidence of wider policy impacts, as these would be expected to occur later.

Finally, the report is intended to provide strategic information on the current demonstrator landscape with a view to guiding and focusing future demonstration calls.

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1 Background

The Energy Systems Research Unit (ESRU) at the University of Strathclyde has been tasked with identifying and reviewing recent UK energy systems demonstration projects, the work was commissioned by the EPSRC via the UK Energy Research Centre (UKERC).

1.1 About ESRU

ESRU is a multi-discipline research group formed in 1987 and based in the Department of Mechanical and Aerospace Engineering. The group comprises some 15 researchers with a primary focus on low carbon energy systems, particularly those associated with the built environment – the group operates the BRE centre of Excellence in Energy Utilisation. The team at ESRU has extensive experience in evaluating energy systems demonstrators: reviewing zero carbon housing demonstrators for BRE Ltd (on-going); reviewing the efficacy of energy efficient housing stock refurbishments for Glasgow City Council; reviewing heat pump demonstrators for EON and assessing hydrogen demonstration projects for the International Energy Agency's Hydrogen Implementing Agreement.

2 Aim

The aim of the work was to identify and document recent, UK energy systems demonstrator projects; and to review their reported outcomes.

This involved two phases of activity:

Phase 1 - identification and documentation of demonstration projects, involving a systematic search to identify and record the details of projects.

Phase 2 - a review of project outcomes and outputs, particularly end-of-project evaluations, covering technical, economic and social outcomes where available.

The review of outcomes was not intended to be a technical appraisal of each demonstrator project, rather, the available outcomes and outputs from projects were identified, recorded (where available) and analysed.

2.1 Outputs

The work led to the following outputs:

- 119 demonstrator project summaries, featuring all the information collected on each project in Phase 1 - http://ukerc.rl.ac.uk/TOOLS/EnergyDemonstrators/phase1attributetables.html.
- a QGIS map and database, showing the location of the demonstrators and with a layer holding a subset of the demonstrator information - http://ukerc.rl.ac.uk/TOOLS/EnergyDemonstrators/map.html.
- 119 demonstrator output analyses, highlighting the outputs and key outcomes from projects; http://ukerc.rl.ac.uk/TOOLS/EnergyDemonstrators/phase2attributetables.html.
- this final report supersedes previous interim reports.

2.2 Use of this Report

The work reported here predominantly involved identification of projects and recording of their details, followed by wider analysis of their characteristics and outputs. The report provides details such as the types of projects undertaken, their location and scale, the sectors targeted (e.g. transport, heat), the technologies demonstrated, funding level, etc. Specific information on projects including links to final reports and datasets for those requiring more information is available in each if the 119 project summaries.

The report, attendant project summaries and GIS data is intended to provide policy makers and funding bodies with an overview of the existing demonstrator "landscape", enabling decisions on future demonstrator calls and the focus of those calls to be made with a clearer knowledge of what has already been done: this may (for example) allow future calls to target technologies and techniques that have not been well covered by energy systems demonstrations to-date.

The report does *not* provide an exhaustive synthesis and appraisal of technical findings – that has been done elsewhere, for example Frame et al (2016) provide an analysis of the outcomes from Low Carbon Network Fund projects. Consequently, this work cannot provide guidance the applicability or otherwise of technologies and systems, indeed given the range of demonstration systems viewed and myriad outcomes, performance appraisal is most appropriately done through more targeted reviews.

3 Phase 1 - Identification and Documentation of Projects

The scope of the project identification process was defined through discussions with UKERC. The definition of an energy system was kept deliberately broad and was defined as "the deployment and testing of more than one technology type that could underpin the operation

of a low-carbon energy infrastructure in the future"; this was to try and capture as diverse a range of projects as possible and gain a comprehensive picture of the UK demonstrator landscape. The search therefore captured a wide range of demonstrator types: from part energy systems such as an electrical load management scheme to full, multi-vector systems encompassing heat, power and transport. Tests of single technologies were not included.

It was also agreed that demonstration projects identified should be relevant to the contemporary vision of a decarbonised UK energy system: so, only demonstrators that post-date the 2008 Climate Change Act were included.

3.1 Search Process

The search for demonstrator projects was iterative. Initially, the websites of bodies likely to have funded demonstration projects were searched for candidate projects.

The following were the primary information sources for UK-based projects or those with a significant UK-located demonstration element:

- ENA Smarter Networks Portal (http://www.smarternetworks.org/) - this Energy Networks Association portal consolidates all related information for projects funded under the Low Carbon Network Funds, Network Innovation Allowance, and Network Innovation Competition funding mechanisms and covers the majority of major demonstration projects carried out by the major UK network operators for electricity and gas supply.
- Additional information for the LCNF projects was available on the Ofgem website and the major network operators also have project information on their own websites.
- EU Cordis (https://cordis.europa.eu/home_en.html) -this portal consolidates information for all EU-funded R&D initiatives, including the FP7 and Horizon 2020 funded projects which are relevant for the demonstrator project search. These projects typically have demonstrator sites in multiple EU countries, and can be filtered to determine those with a UK-located demonstrator element. FP7 and Horizon 2020 also typically have a detailed project website, which can be accessed from the relevant Cordis webpage.
- Gateway-To-Research (http://gtr.ukri.org/) - a central repository for all UK research council funded projects. Narrowing the search criteria to reliably find large-scale energy system demonstrator projects was, however, challenging as a significant number of projects were identified with the key search terms (see below).
- InnovateUK (https://www.gov.uk/government/publications/innovate-uk-funded-projects) provide a spreadsheet of all InnovateUK projects that can be filtered by theme to identify energy-related projects. The majority of included projects are single technology focused and a final manual search was required to identify candidate projects.

- Low Carbon Infrastructure Transition Programme (http://www.gov.scot/Topics/Business-Industry/Energy/Action/lowcarbon/LCITP) has consolidated project kickoff information at the above link. Additional information on the majority of these projects is limited, with only a few major projects having dedicated websites.

It was noted that there were significant variations between funding bodies with regard to how ongoing and final project information was archived and disseminated, with only those accessed via the Smarter Networks and Cordis portals having reliably comprehensive archiving - these sites tended to yield good quality information on projects and it was straightforward to determine key project details such as scope, timeline, project partners, and budget.

A substantial number of projects were not recorded in any centralised repository, so a subsequent more wide-ranging search was undertaken, which relied on the use of a range of search engines (Web of Knowledge, Engineering Village, Scopus, Google Scholar and Google, etc.) using and a variety of keywords relating to energy systems demonstrations: 'energy', 'system(s)', 'demonstrator', 'multi-vector', 'network', 'project', 'test', 'trial', 'low-carbon', 'smart', 'grid', 'hub', 'village', 'community', 'city' and 'renewable'. In addition, UK region names were used to find area-specific projects. Specific project type terms were also used: 'active network management', 'demand response', 'smart grids', 'smart controls', 'storage', 'district heating', 'distributed generation', 'electric vehicles', 'EV charging', 'ecovillage', 'virtual power plant', 'smart building', 'private wire' and 'microgrid'.

This search yielded information on of projects from academic papers and other "grey" sources including:

- Individual university websites (for projects funded and/or hosted by universities)
- Energy Systems Catapult (https://es.catapult.org.uk/)
- Community Energy Hub (http://hub.communityenergyengland.org/)
- Energy Research Accelerator (http://www.era.ac.uk/home.html).
- Community Energy Scotland (http://www.communityenergyscotland.org.uk/innovation.asp).

The search process is illustrated in Figure 1.

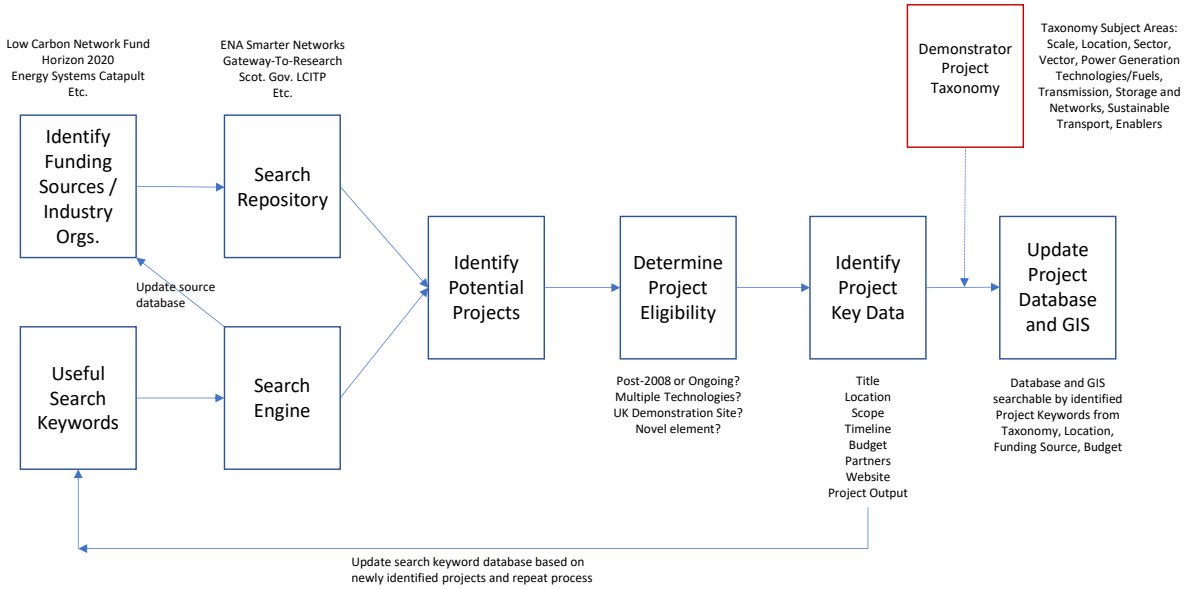

Figure 1: Search process and generation of outputs

3.2 Project Selection

To determine whether a project emerging from the search met the criteria for inclusion in the dataset, several manual filtering questions were required (which align with the scope outlined in section 3):

- Did the project commence after 2008 (for completed projects) or is the project currently ongoing?
- Does the project incorporate multiple generation, storage, network/grid management, and/or demand management technologies or mechanisms?
- Is there a physical demonstration at one or more UK sites?
- Is there a novel element to the project in terms of aim, location, scale or technology combination that identifies it specifically as a demonstration?

A project was selected if it met all of these criteria. A list of all of the 119 demonstration projects identified is given in the Appendices.

3.3 Project Data Collection

The following information was collected for each project:

- Project name
- Description (as provided in project documentation)
- Location
- Concepts demonstrated
- Economic sector
- Energy vectors
- Project partners
- Funding sources and budget
- Engagement with industry and consumers
- Links to project reports, websites, datasets, etc.

- Project status and dates of operation
- Primary data sources

These details were recorded using a common template, shown in **Table 5** at the end of the document.

3.4 Demonstrator Mapping

To augment the collected project records, a subset of the data has been used to develop a GIS layer for the Open Source QGIS tool (www.qgis.org); this provides a means of visualising and accessing the collected project summaries. The map is viewable at: http://ukerc.rl.ac.uk/TOOLS/EnergyDemonstrators/map.html. **Figure 2** shows the map generated by the on-line tool.

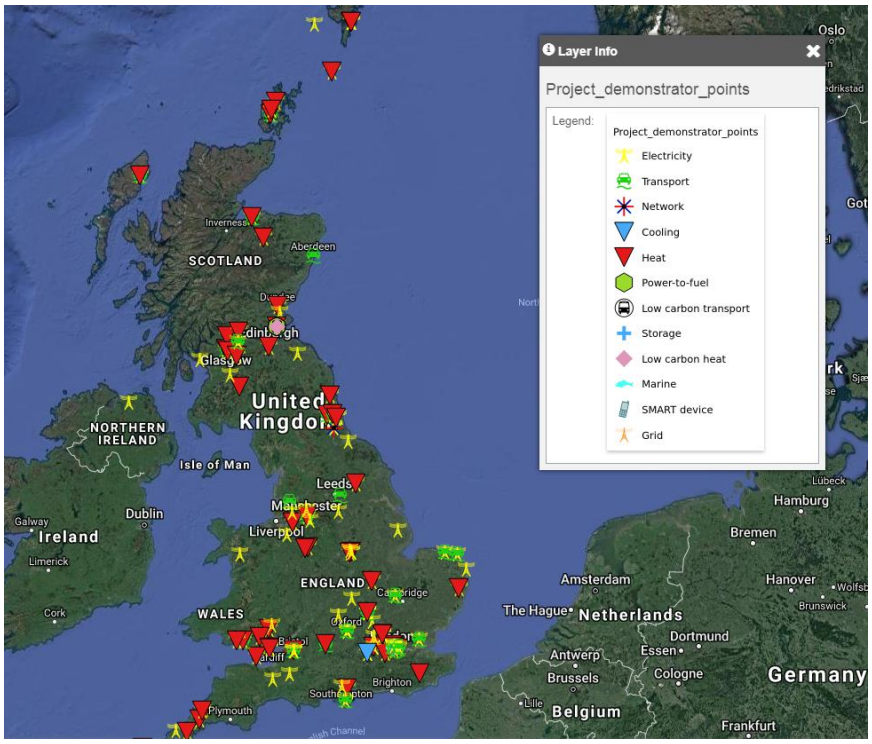

Figure 2: Demonstration projects plotted on QGIS online tool

4 Phase 2 - Project Analysis

As an aid to the planning and commissioning of future demonstration projects, the summaries of the identified projects have been analysed to determine the characteristics of the current demonstrator portfolio.

All of the project summaries are available at: http://ukerc.rl.ac.uk/TOOLS/EnergyDemonstrators/phase2attributetables.html.

4.1 Project Type

As part of the data collection and GIS mapping process, a series of keywords were assigned to each identified project, based on the project description. In the tree map of Figure 3, the relative size of each tile indicates the number of occurrences of a keyword.

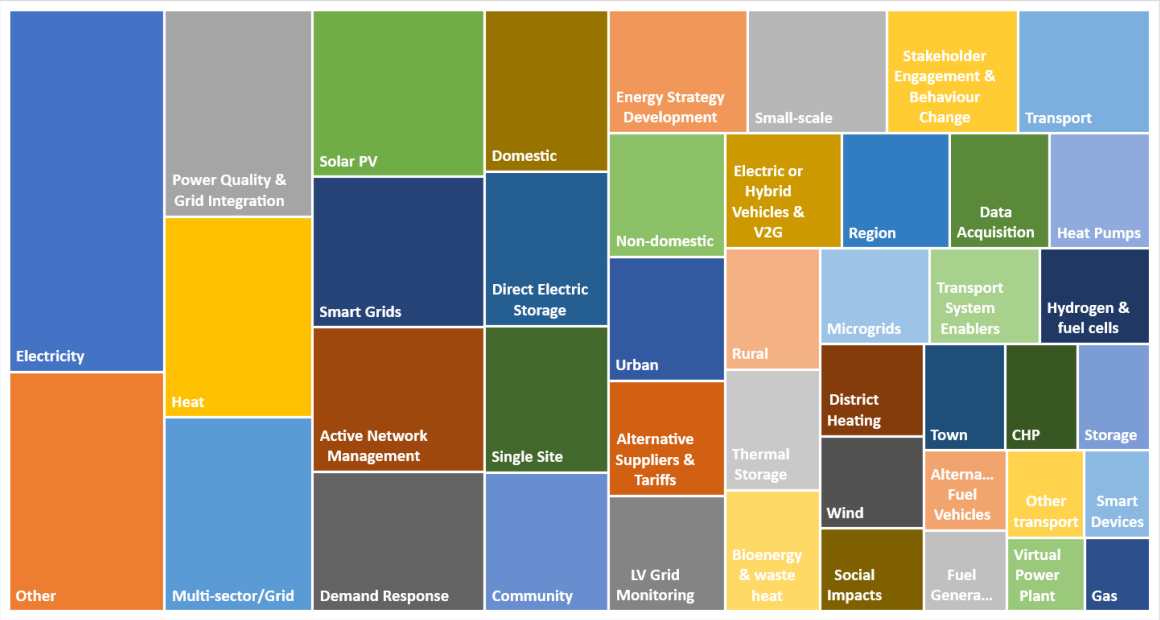

Figure 3: Prevalence of keywords associated with all projects

The most common keyword appearing was electricity, there are also a wide range of electricity-related terms including smart grids, demand response, solar PV, etc. Heat and transport related terms are less prevalent. Whilst not a quantitative assessment, this does indicate qualitatively that the bulk of demonstrator projects are concerned with electricity supply, transmission, distribution and demand.

4.2 Project Focus

Figure 4 shows the distribution of projects by the principal energy component or components. Three broad categories were defined: electricity, heat (also including cooling) and transport.

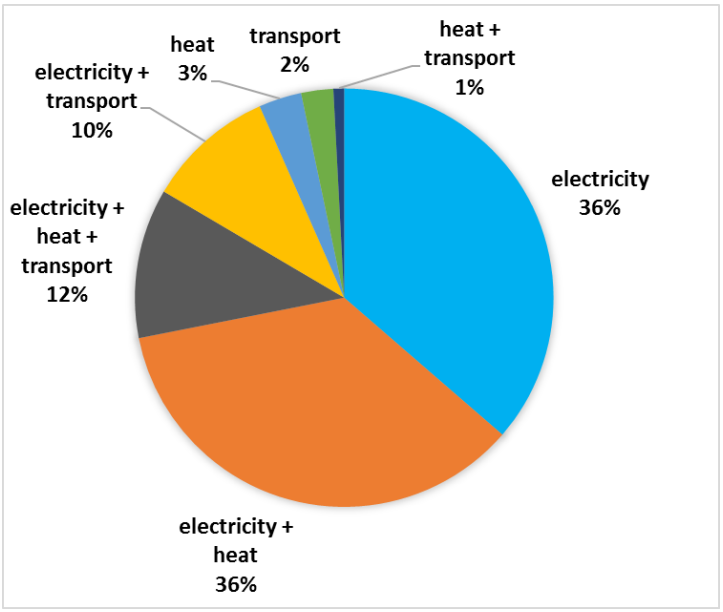

Figure 4: breakdown of projects by principal components

The figure corroborates the keyword analysis and illustrates that the majority of demonstration projects identified focused on electricity, either as the sole energy component or combined with other elements such as transport or heat. Electricity was the sole component in 36% of projects and featured in over 90% of projects. There were relatively few projects focusing solely on heat or transport, however heat featured in almost 50% of projects. Transport featured in approximately 23% of projects. Just over half of projects feature two or more principal energy components.

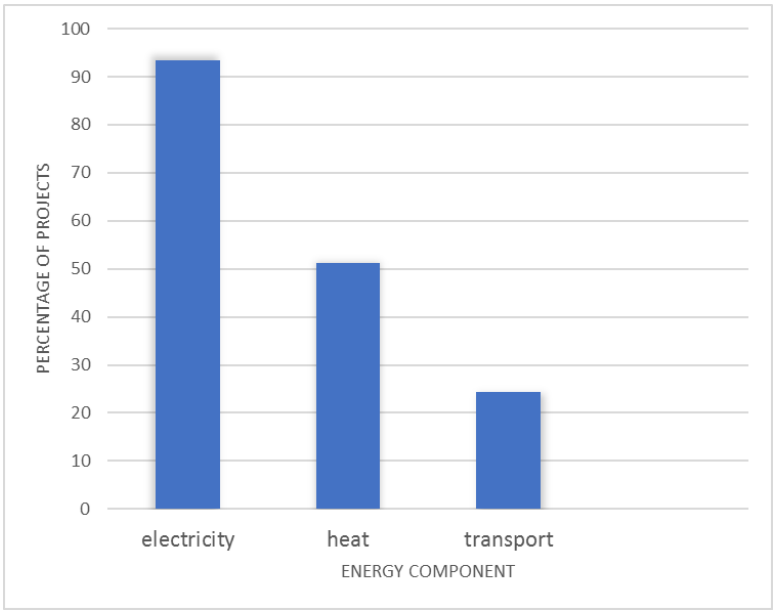

Figure 5: Occurrence of principal component in projects

Many projects identified had similar scopes (e.g. household demand or grid-scale storage projects), perhaps indicating a lack of co-ordination or visibility of projects between the different funding bodies.

4.3 Project Funders and Value

The majority of projects were funded or part-funded via OFGEM through the Low Carbon Network Fund (LCNF), Network Innovation Allowance (NIA) and Network Innovation Competition (NIC); by the EU through its FP7 and H2020 programmes; by the Scottish Government through its Low Carbon Infrastructure Technologies Programme - LCITP) and by InnovateUK.

The LCNF/NIC funded distribution-level electricity projects to support Distribution Network Operators (DNOs) in trialling new technologies, operating strategies and commercial arrangements that would lead to carbon and cost savings. The NIA funded smaller-scale projects or supported bids for larger NIC projects.

The EUs Horizon 2020 programmes and previous FP 7 research programme funded energy demonstration projects are typically demonstration at scale featuring at least 3 sites in different EU member countries.

The Scottish Government's Low Carbon Infrastructure Transition Programme funded Scottish local authority community-scale energy projects which had the potential to reduce carbon emissions.

InnovateUK projects were industry-led and mostly focused on specific technology development, but also funding a small number of broader energy systems demonstrations.

The full range of funding sources for the demonstration projects identified is shown in **Figure 6**.

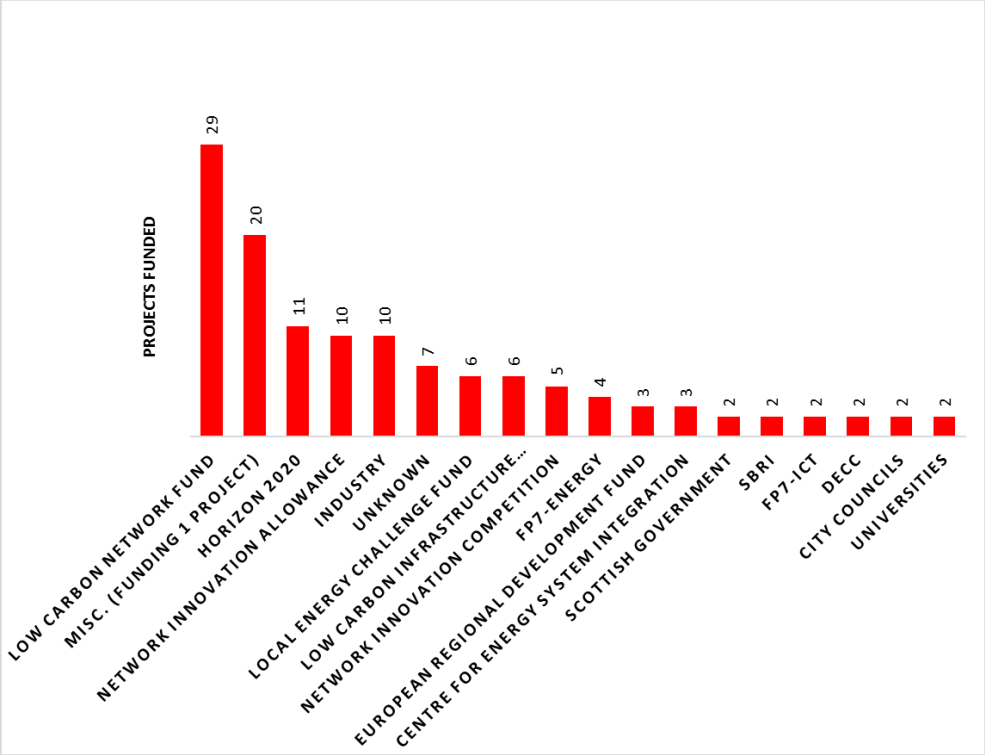

Figure 6: project funding sources

Most of the projects identified have an element of direct or indirect government funding. Few projects solely funded by industry were found, which may suggest that this type of project is not happening or that this type of project typically has no public dissemination either during or after the project.

The distribution of project budgets (where a total project budget was identified) is illustrated in Figure 7. The large majority demonstrator project budgets were more than £1 M and the mean budget was £5.7 M.

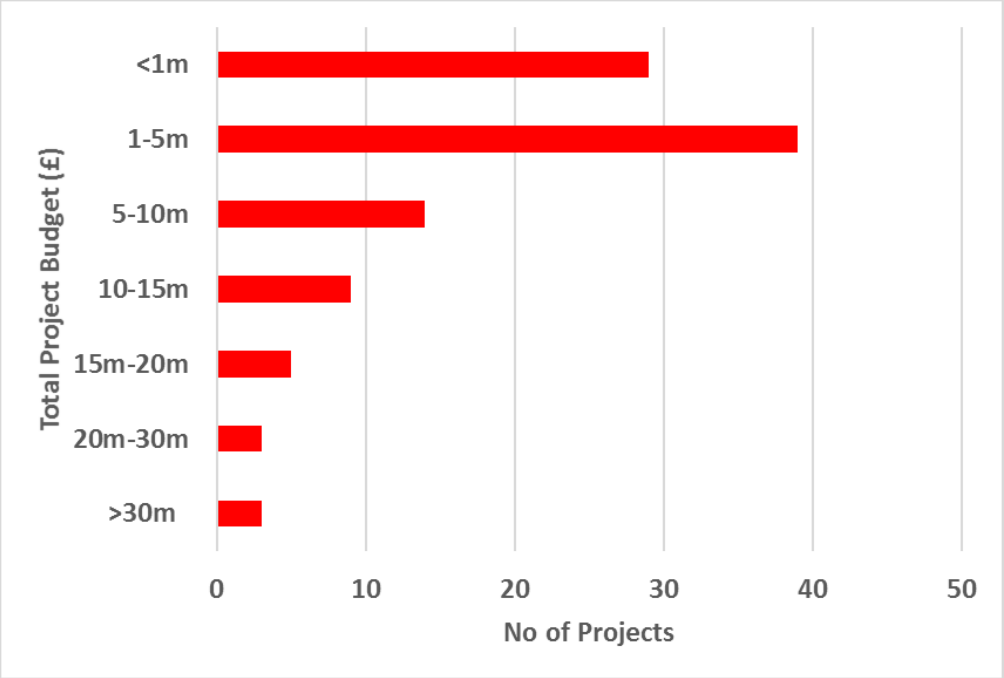

Figure 7: Range of total project budgets

Most of the larger projects funded by government had multiple partners, with some academic support. No reference in the output documentation is made to how the partnerships were developed. There is limited discussion in some reports about the benefits of trusted partners for project participant identification.

4.4 Technology

Figure 8 shows the occurrence of different technology types in the projects reviewed. Whilst a wide range of technologies have been demonstrated, so-called “smart controls” feature in just under half of projects; this is a catch-all term that encompasses many different individual technologies, which would explain its high occurrence in project summaries. The most frequently appearing specific technology types demonstrated were solar PV and battery storage.

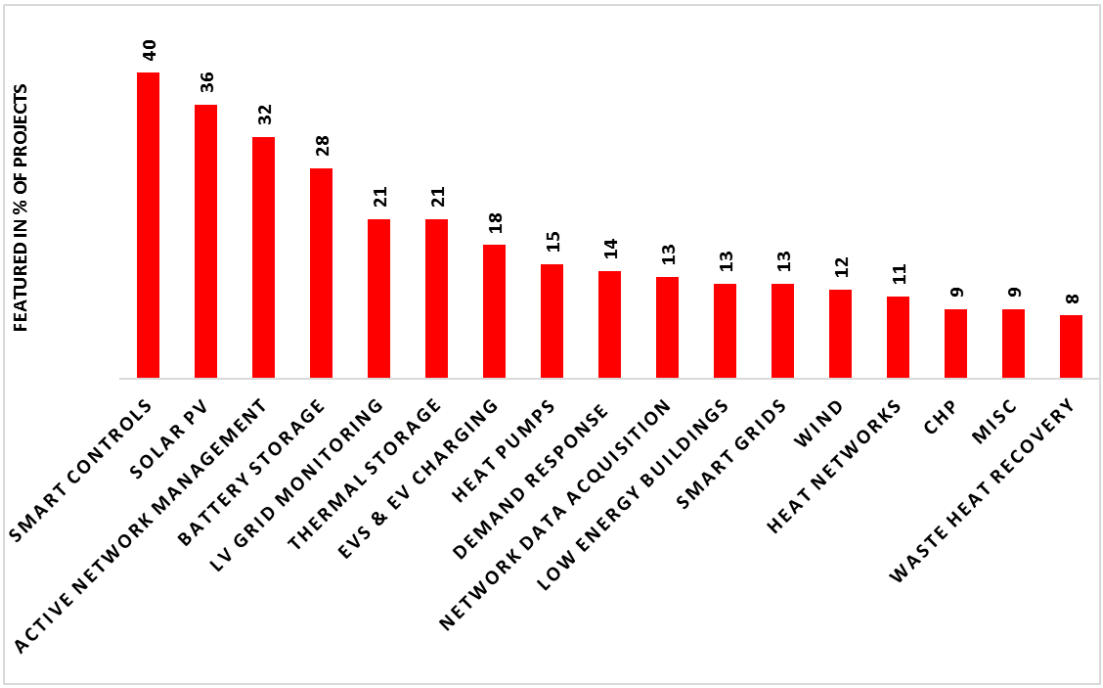

Figure 8: most common technologies trailed in projects

4.5 Target Sector

The distribution of projects by target sector is illustrated in Figure 9. The built environment featured in around 64% of projects, with the domestic sector being the principal focus of some 36% of all projects. Projects focused on the grid (HV & LV) accounted for 16% of projects. Transport or projects involving transport accounted for some 12% of projects. This would indicate that there is a bias in projects towards electrical demand. Very few of the projects reviewed targeted the industrial sector.

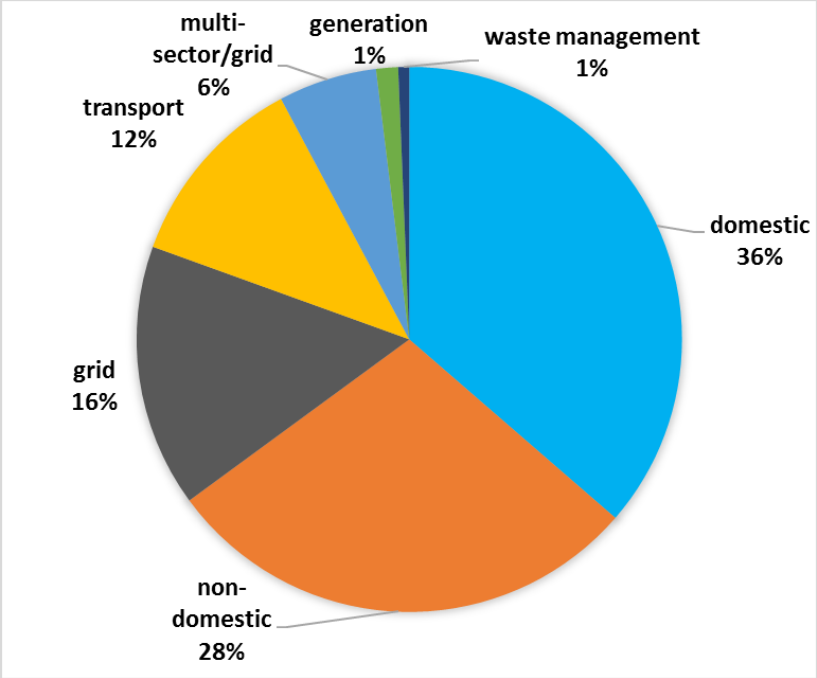

Figure 9: Projects by target sector

4.6 Physical Scale

The majority of projects reviewed were relatively small in scale, with most being focused on a single building or single site. Relatively few projects were larger than community scale. Table 1 describes project scales and Figure 10 shows their distribution.

Table 1: Project scales

Lab	Small test-bed demonstration
Site	Demonstration at a single location (e.g. building, hydrogen filling station, etc.)
Small	Demonstrator with select locations in an area (e.g. housing estate, industrial complex).
Community	Demonstrator spread across a village, town or part of a city.
Region	Demonstrator spread across a local authority area or areas.
National	Demonstrator spread across UK.

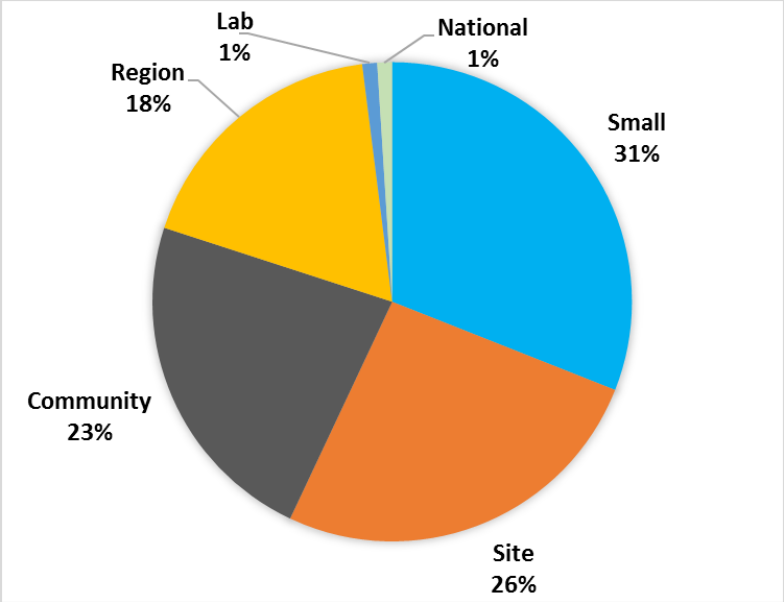

Figure 10: Physical scale of projects

4.7 Consumer Engagement

Given the prevalence of projects featuring the built environment, it is interesting to note that only 23% of all projects identified had some form of direct consumer engagement.

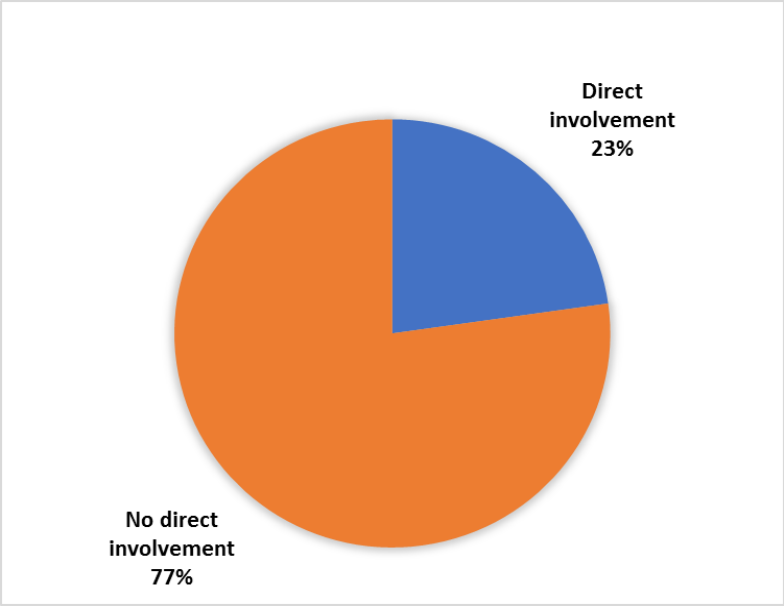

Figure 11: Consumer engagement in projects

Projects involving consumers varied hugely in scope with between 20 and 67,000 households engaged. Figure 12 shows the distribution of the numbers of consumers engaged in projects. The majority of projects featured between 10-500 consumers, with just two projects targeting very large numbers (10,000+) of end-users.

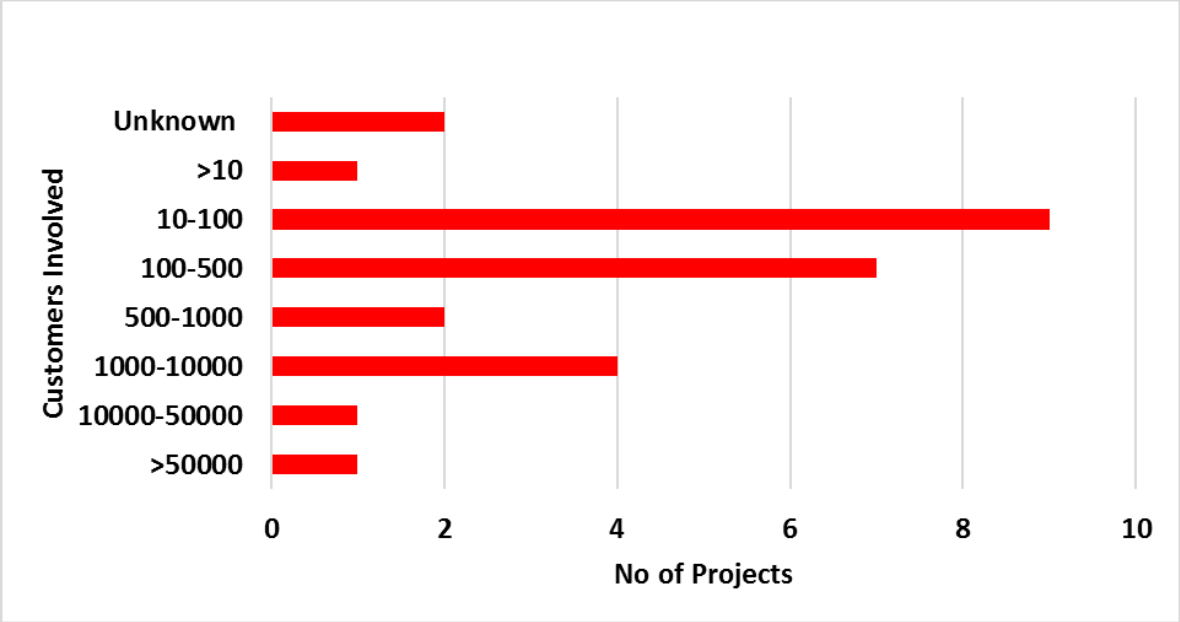

Figure 12: Number of consumers engaged by projects

Very few projects which engaged consumers as participants published feedback from the participants on either the direct project impact or the engagement process, unless participant response was a primary objective (e.g. Shift & Save [DIP087]). Most project reports focused on technical outcomes rather than user perceptions.

4.8 Location

The breakdown of projects by country and locality are shown in Figure 13 and Figure 14. Demonstrators are located throughout the UK, with 66% of the projects identified located in England. Half of these in the South East. Approximately 7% of identified projects were in the Midlands. Scotland hosted 24% of projects with Wales and Northern Ireland accounting for 2% and 1% of projects, respectively.

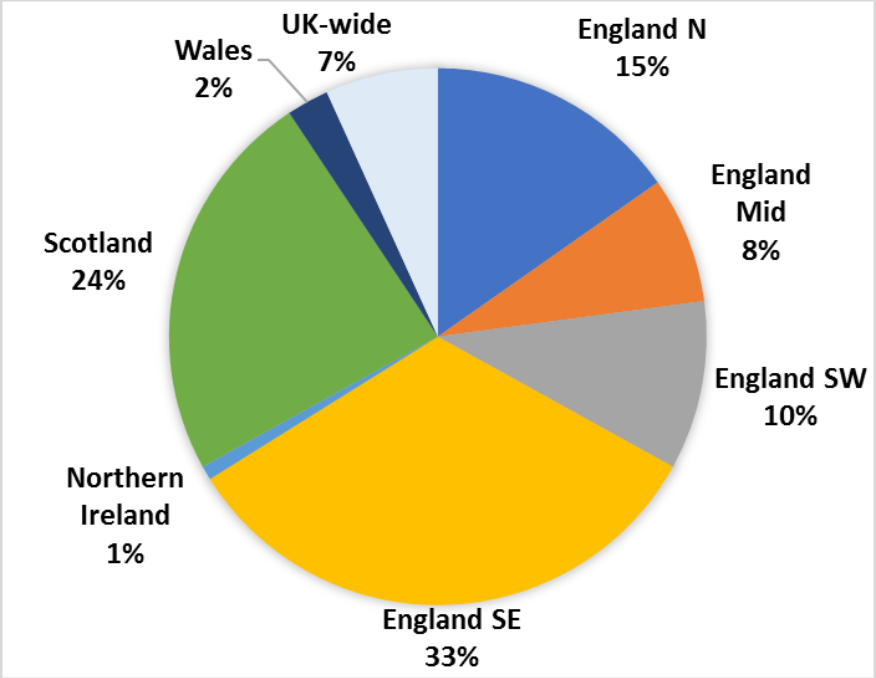

Figure 13: project distribution by area of the UK

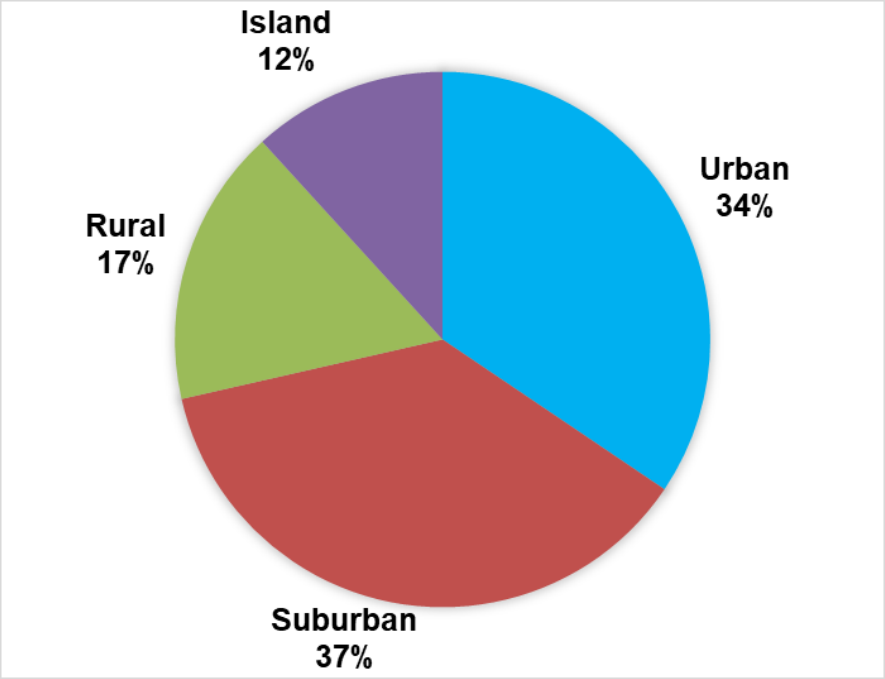

Figure 14: Project distribution by locality

The bulk of projects (71%) are in urban or suburban areas, with 17% of projects in rural areas. Demonstrators based on relatively isolated island energy systems proved popular, accounting for approximately 12% of projects. Note that whilst many rural energy projects were

identified during this work, few of these were identified as demonstrating innovative energy systems.

4.9 Status of Projects Identified

Of the projects for which information was collected, 54% were identified as completed and 45% were still active, with the status of the remainder unknown. Completed projects were those where the stated end date of the project had expired; however, this does not imply that the objectives were met.

4.10 Project Outputs

Analysis was undertaken to identify and quantify outputs from projects such as reports and datasets. Where projects were completed, the project literature was reviewed to identify final conclusions. The output information is intended to augment that held in the project summaries of Phase 1 - providing more details on the nature of the outputs.

It should be noted that this activity was not a comprehensive technical review of demonstrator project outputs and no attempt was made to verify if the stated outcomes could be substantiated.

Whilst the review focused primarily on whether a project delivered a final report, brochures, website case studies and videos were also used to disseminate information. These provide a useful format to summarise basic scope and findings that can be difficult to discern from a cursory review of a detailed report. This may also be useful for smaller projects were a detailed report might not be practical.

The additional information collected on each demonstrator is shown below. This information was collated in a set of project output summaries available at: http://ukerc.rl.ac.uk/TOOLS/EnergyDemonstrators/phase2attributetables.html.

4.10.1 Project Reports

Of the projects identified as completed, 87% had an identifiable final report. For the remainder, no final report was found.

Many of the projects investigated had a lack of evident outputs and this was noted in the data summaries as “n/a” or “none”. This does not mean that those outputs do not exist, rather it indicates that the outputs could not be located following an extensive internet search.

Of the projects reviewed, LCNF/NIA/NIC and EU projects had a clear requirement for public outputs. For example OFGEM require a project close-down report and that learning from projects is disseminated to other DNOs (https://www.ofgem.gov.uk/ofgem-

publications/93538/lcnf-gov-doc-v7-pdf). However, despite a formal output requirement, the form and quality of LCNF closedown reports was found to be variable.

InnovateUK and LCITP projects were often poorly documented, with no apparent set output criteria, or requirement for a website. The Fintry project (DIP090) is an exception with a clear report and evidence of dissemination. Comparison between LCNF, NIA and EU projects and those funded by other means would suggest that demonstrator funding should come with set requirements for reporting and dissemination.

Dissemination via dedicated events or participation in conferences, at least in terms of publicly available reports or uploaded presentations, was limited and tended to be restricted to those projects featuring academic partners.

4.10.2 Websites and Datasets

Approximately 85% of projects had websites, which varied in quality. Further, persistence proved to be an issue, as links to some of the older FP7 project websites were found to be broken.

Only four projects had readily identifiable and accessible datasets:

Table 2: Output datasets

Project	Description	Dataset Link
Customer Led Network Revolution (DIP017)	Detailed household time-of-use data for multiple demands. Includes total electricity use, use of immersion heaters, ASHPs, washing machines and EVs under different tariffs.	http://www.networkrevolution.co.uk/resources/project-data/
Low Carbon London (DIP060)	Time-of-use tariff trial data, smart meter consumption data, EV charging data and heat pump load profiles.	TOU Tariff Trial Data: https://discover.ukdataservice.ac.uk/catalogue/?sn=7857&type=Data%20catalogue Smart Meter Consumption Data: https://data.london.gov.uk/dataset/smartmeter-energy-use-data-in-london-households Electric Vehicle Charging Data: https://data.london.gov.uk/dataset/low-carbon-london-electric-vehicle-load-profiles Heat Pump Load Profiles: https://data.london.gov.uk/datase

		t/low-carbon-london-heat-pump-load-profiles
Smart Street (DIP096)	Grid voltage and power quality data before and after the implementation of smart grid controls.	https://www.enwl.co.uk/innovation/smart-street/smart-street-trials/
Thames Valley Vision (DIP110)	Household consumption data and substation performance data.	http://www.thamesvalleyvision.co.uk/project-library/research-data/ (registration required)

4.10.3 Outcomes vs Objectives

Performance against objectives, where documented, was self-reported and with few exceptions, objectives were met.

4.11 Project Findings

A review of all of the key project findings outlined in the output summaries was undertaken, yielding some on 270 separate outcomes. There were analysed and categorised as shown in Figure 15.

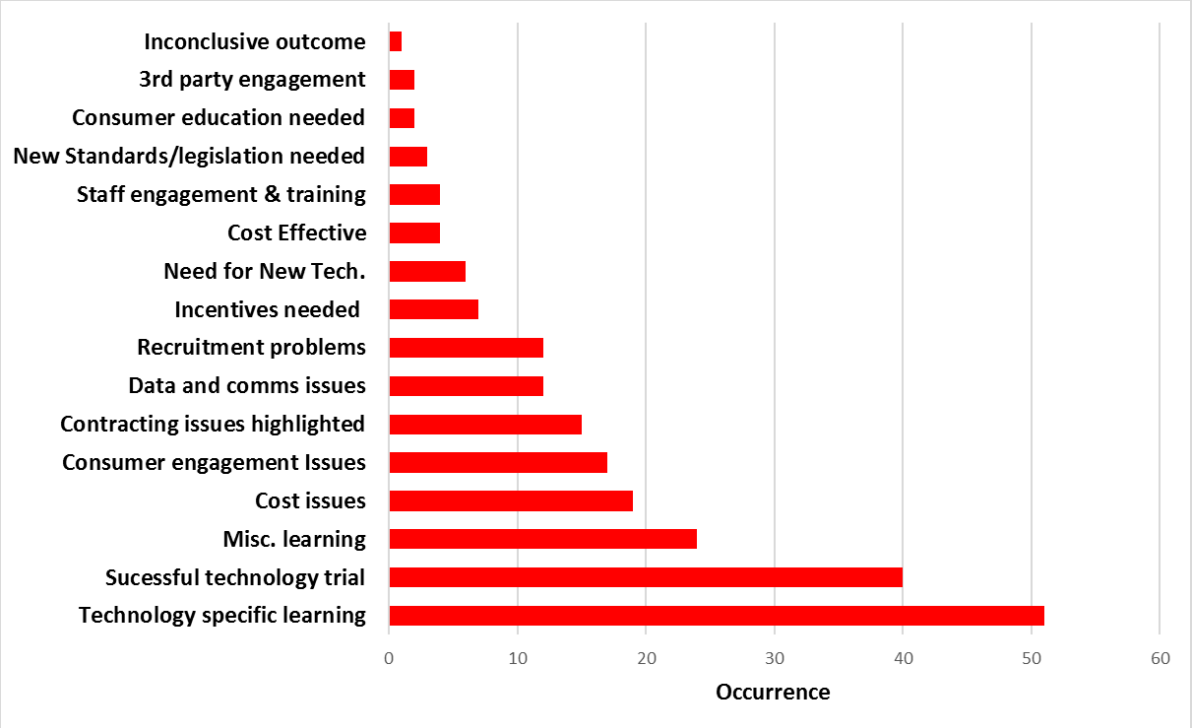

Figure 15: Analysis of key project findings

Most self-reported project findings were positive, highlighting a diverse range of technology specific learning emerging from the project work.

A significant number of projects findings quantified or provided a qualitative statement of the beneficial impact that a technology or system had on performance, however, there was little commonality between them, so general conclusions on technology effectiveness could not be drawn.

4.11.1 Common Findings

However, given the wide range of projects focused on the built environment and the domestic sector, some common lessons emerged, particularly relating to consumer engagement.

A number of projects reported difficulty in engaging consumers and/or recruiting participants and a number of solutions were suggested.

- Using trusted project partners such as local councils or universities as seen be of benefit in the recruitment of customers into projects.
- Providing adequate financial inducements was deemed to be important in encouraging wide-spread participation in demand-side manipulation schemes.
- Engaging consumers face-to-face and clearly outlining the direct financial benefits of participation in a trial scheme were seen to be key to successful recruitment for demand management schemes.
- New tariff arrangements would be required to support end-user load shifting and make it cost-effective.

Measured diversity was seen to be greater than initial assumptions – this was highlighted particularly in the case of PV, where aggregate PV output was seen to be less than predicted due to diversity in the orientation of installed systems. In the Photovoltaic Impact on Suburban Networks project (DIP074) 20% more PV could be installed than was initially anticipated.

A number of projects reported on the difficulty in recruiting skilled staff, particularly with experience in monitoring. Further, some project findings highlighted shortcomings in the capabilities of monitoring equipment, particularly in relation to the electrical network.

The cost of trialled solutions was highlighted in several project findings. For example, the Aberdeen Hydrogen Project (DIP002) reported that costs of hydrogen busses would need to reduce by a third to be competitive with diesel alternatives.

Communication problems were prevalent in some project findings, particularly relating to the unreliability of the mobile network for the collection of data from remote monitoring sites.

4.11.2 Policy and Standards

Few projects considered wider policy implications in their final outputs as most were primarily focused on the specific technical goals and directly related policy and regulation limitations.

The only evidence of findings relating to standards was found in hydrogen projects, specifically relating to hydrogen safety requirements or the implications of a hydrogen grid replacing natural gas.

4.11.3 Tertiary Outcomes - Follow-on Projects

Evidence of follow-on projects or activities was limited and were usually identified by explicit references to previous projects in project reports. Details are shown in Table 3 below.

Table 3: Follow on projects and activities

Project	Follow On
DIP001 (1MW Shetland Battery)	Learnings used for DIP068 (NINES).
DIP002 (Aberdeen H2 Bus)	A follow-on EU project (JIVE2).
DIP005 (Active Classroom)	Same concept used for other building, including offices and homes.
DIP006 (Ashton Hayes SV)	Learning used in DIP004 (ACE).
DIP017 (CLNR)	Learnings used for DIP021 (DSSS).
DIP019 (ADR)	Learning used in DIP110 (Thames Valley Vision).
DIP024 (Early Learning)	Learnings used for DIP074 (PV Impact on Suburban Networks).
DIP034 (Entire)	Learnings used for Western Power Distribution initiative 'Flexible Power'.
DIP043 (Glasgow Future Cities)	Learning used for DIP084 (Ruggedised) H2020 project.
DIP044 (GoGreenGas)	Scale up from pilot to commercial plant.
DIP049 (Hybrid Bus Charging)	Additional routes added.
DIP052 (HyHouse)	Learning used for HyDeploy (DIP050) and H2020 projects.
DIP061 (LV Storage)	Learnings used for DIP110 (TVV) and DIP045 (Greenwatt Way).
DIP063 (Mull Access)	Developed technology used for DIP047 (Heat Smart Orkney).
DIP064 (MyEA)	Learnings used for the collaborative project 'Management of plug in vehicle uptake on distribution networks'.

DIP066 (Network Management)	Learnings used for larger scale Smart Islands project (DIP094).
DIP070 (Origin)	Multiple follow on projects.
DIP071 (Orkney SnT)	Larger follow on the EU 'BIG HIT' project.
DIP074 (PV Impact on Suburban Networks)	Learnings used for 'LV Network Sensors' project.

5 Conclusions

A comprehensive review of UK energy systems demonstration projects has been undertaken and 119 projects were identified that met the search criteria outlined in Section 3.2.

An information sheet and record of outputs was prepared for each project http://ukerc.rl.ac.uk/TOOLS/EnergyDemonstrators/phase1attributetables.html; key details of each project were also used to develop a GIS layer, the map is available at http://ukerc.rl.ac.uk/TOOLS/EnergyDemonstrators/map.html.

Analysis of the data collected on projects indicated the following.

The overwhelming majority of projects were electricity-related, either as the sole energy vector or in a multi-vector system. Similarly, the target sector of many projects was the built environment, particularly the domestic sector. Consequently, there was considerable overlap and duplication between projects funded by different bodies.

The technology type most frequently appearing in demonstrations was smart controls followed by PV, batteries and active network management. It was noted that smart control was a catch-all term that encompasses a range of technologies and so that may be the reason for its prevalence in project summaries.

Just under a quarter of projects featured some form of direct engagement with consumers, typically with consumers as participants in projects. The scale of engagement varied hugely from a handful of participants through to tens of thousands.

Most demonstration projects had budgets in excess of £1M, with an average budget of £5.7M. The largest project funder (by number of projects) was the Low Carbon Networks Fund (LCNF). More than half of projects were small-scale focusing on a single site or building.

Projects were spread across the UK, with SE England and Scotland hosting the largest portion of projects respectively. Most projects were located in urban areas, but there were a surprisingly large number of projects located on small island sites.

Approximately 54% of the projects reviewed were identified as completed and of these 87% had produced an identifiable final report.

The quality of final reports reviewed was variable. Some funding schemes such as LCNF and EU H2020 have strict reporting requirements and this was reflected in the final report, though quality varied even in these cases. Reports from other finding schemes were less well documented.

Approximately 85% of projects had a website, or at least there was evidence that a website existed. However, their persistence was an issue as several reported project websites (e.g. for older FP7 projects) could not be found. This could be problematic if a project web site was the sole public dissemination point for a final report and other project outcomes.

Documentation on demonstrators was spread across a range of different sources and was frequently difficult to track down. This indicates a need to ensure that findings and learning from projects are adequately disseminated through a common, accessible, persistent repository.

Very few projects were found with readily accessible datasets.

A review of key project findings found that most project outcomes were positive, highlighting technology specific or wider learning derived from the project work. A significant number of findings quantified or provided a qualitative statement of the beneficial impact that a technology or system had on performance.

It was noted that most outcomes were self-reported, only a limited number of projects were subject to independent evaluation of results.

Some common problems were evident including high costs of trialled systems and problems in engaging and recruiting participants.

Given that most project reports were written immediately after the completion of a project, there was little evidence of wider policy impacts or follow-on projects.

6 References

References for individual projects are contained in each project summary at http://ukerc.rl.ac.uk/TOOLS/EnergyDemonstrators/phase1attributetables.html.

Frame D, Bell K, McArthur S, A Review and Synthesis of the Outcomes from Low Carbon Networks Fund Projects, UKERC Report. Available at: http://www.ukerc.ac.uk/asset/93F0B513-2199-437C-82550108C4292663/ Accessed 04/10/18.

7 Appendices

7.1 Demonstrator Projects Identified

Table 4: Demonstration project list

Project ID	Title	Location (Town, Region, Country)
DIP001	1MW Shetland NaS Battery	Lerwick, Shetland, Scotland
DIP002	Aberdeen Hydrogen Bus Project	Aberdeen, Scotland
DIP003	Accelerating Renewable Connections	East Lothian / Borders, Scotland
DIP004	Activating Community Engagement	Durham, County Durham, England
DIP005	Active Classroom	Swansea, West Glamorgan, Wales
DIP006	Ashton Hayes Smart Village	Ashton Hayes, Cheshire, England
DIP007	Balanced Energy Network	London, England
DIP008	Bus2Grid	London, England
DIP009	Cambridgeshire Solar Carport	St. Ives, Cambridgeshire, England
DIP010	Celsius Smart Cities – Waste Heat Capture from the Underground	London, England
DIP011	Cockle Park Farm	Morpeth, Northumberland, England
DIP012	Combined Heat System by using Solar Energy and Heat Pumps	Corby, Northamptonshire, England
DIP013	Community Energy at Trent Basin	Nottingham, England
DIP014	Coupling Renewable, Storage and ICTs, for Low carbon Intelligent Energy management at district level	Ebbw Vale, Blaenau Gwent, Wales
DIP015	Cranbrook Solar Thermal District Heating	Cranbrook, Devon, England
DIP016	Creative Energy Homes	Nottingham, England
DIP017	Customer Led Network Revolution	Northeast, England
DIP018	Demand Response in Blocks of Buildings	Middlesborough, Tyne and Wear, England
DIP019	Demonstrating the Functionality of Automated Demand Response	Bracknell, Berkshire, England

DIP020	Distributed Storage and Solar Study	Barnsley, South Yorkshire, England
DIP021	Domestic Energy Storage and Control	England
DIP022	Dundee Low Carbon District Energy Hub	Dundee, Scotland
DIP023	e4Future	Rickmansworth, Hertfordshire, England
DIP024	Early Learning of Low Voltage Network Impacts from Estate PV Cluster	Crickhowell, South Wales, Wales
DIP025	Edinburgh and Surrounding Towns Heat Energy Action through Thermal Storage	East Central, Scotland
DIP026	E-FLEX: Real-world Energy Flexibility through Electric Vehicle Energy Trading	London, England
DIP027	Electric Boulevard	Milton Keynes, Buckinghamshire, England
DIP028	Electric Nation (previously CarConnect)	Bristol, England
DIP029	Electricity and Heat	Warrington, Cheshire, England
DIP030	Electrou	London, England
DIP031	Energy Local Storage Advanced System	Sunderland, Tyne and Wear, England
DIP032	Energy Resources for Integrated Communities	Oxford, Oxfordshire, England
DIP033	Enhanced Frequency Control Capability Project	National
DIP034	Entire	East Midlands, England
DIP035	EV-elocity	London, England
DIP036	Fair Isle Unified Low Carbon Electricity Storage and Generation Project	Fair Isle, Scotland
DIP037	Flexible Approaches for Low Carbon Optimised Networks	Milton Keynes, Northumberland, England
DIP038	Flexible Integrated Energy Systems	Swansea, West Glamorgan, Wales
DIP039	Flexible Networks for a Low Carbon Future	3 locations
DIP040	Flexible Residential Energy Efficiency Demand Optimisation and Management	South Wales, Wales
DIP041	Foula Community Energy Phase 2	Foula, Shetland, Scotland
DIP042	Fusion	Northeast, Fife, Scotland
DIP043	Glasgow Future Cities – Demand Side Management	Glasgow, Scotland
DIP044	Go Green Gas	Swindon, Wiltshire, England

DIP045	Greenwatt Way	Slough, Berkshire, England
DIP046	H-Disnet (Integration with existing district energy network and with smart grid)	Newcastle, England
DIP047	Heat Smart Orkney	Rousay, Orkney, Scotland
DIP048	Hunterston Energy Storage Project	Hunterston, North Ayrshire, Scotland
DIP049	Hybrid Bus Charging Technology	Cumbernauld, Scotland, London, England
DIP050	HyDeploy	Keele, Staffordshire, England
DIP051	Hydro Active Network Management	Snowdonia, Gwynedd, Wales
DIP052	HyHouse	Sanqhuar, Dumfries & Galloway, Scotland
DIP053	Integrated Energy Management Demonstrator	Carnmenellis, Cornwall, England
DIP054	Integrated Transport Electricity Gas Research Laboratory	Gateshead, Tyne and Wear, England
DIP055	IODiCUS - Interoperable Open Digital Control Unit System	South East, England
DIP056	Kingston Heights	Kingston, Surry, England
DIP057	Levenmouth Community Energy Project	Levenmouth, Fife, Scotland
DIP058	Local Energy Market / Visibility Plugs and Sockets	Cornwall, England
DIP059	Low Carbon Hub	East Lindsey, Lincolnshire, England
DIP060	Low Carbon London	London, England
DIP061	Low Voltage (LV) Network Connected Energy Storage	Slough, Berkshire, England
DIP062	LV Connect and Manage	Milton Keynes and Nottingham, England
DIP063	Mull Access	Garmony, Mull, Scotland
DIP064	My Electric Avenue (Innovation Squared)	UK
DIP065	Network Equilibrium	Devon/Somerset, England
DIP066	Network Management on the Isles of Scilly	Isles of Scilly, England
DIP067	Newcastle Helix	Gateshead, Tyne and Wear, England
DIP068	Northern Isles New Energy Systems	Shetland, Scotland
DIP069	Open Dynamic System for Holistic energy Management of the dynamics of energy supply, demand and storage in urban areas	Manchester, England

DIP070	Orchestration of Renewable Integrated Generation in Neighbourhoods	Findhorn, Moray, Scotland
DIP071	Orkney Surf-n-Turf / BIG HIT	Orkney, Scotland
DIP072	Outer Hebrides Local Energy Hub	Stornoway, Western Isles, Scotland
DIP073	Owen Square Community Energy Project	Bristol, England
DIP074	Photovoltaic Impact on Suburban Networks	Aspley, Nottingham, England
DIP075	Pilsworth Liquid Air Energy Storage	Pilsworth, Greater Manchester, England
DIP076	Power Saver Challenge	Stockport, Greater Manchester, England
DIP077	Powerloop: Domestic V2G Demonstrator Project	London, England
DIP078	PowerVault (Domestic Energy Storage - Technical Demonstration Project)	London, England
DIP079	Pumped Heat Energy Storage	Fareham, Hampshire, England
DIP080	RE:NEW London – Solar Energy and Battery Storage Trial	London, England
DIP081	Retrofitting Solutions for Services for the enhancement of Energy Efficiency in Public Edification	Conventry, West Midlands, England
DIP082	Revolutionising Transport	Leyland, Lancashire, England
DIP083	ROGER	Amersham, Buckinghamshire, England
DIP084	Ruggedised	Glasgow, Scotland
DIP085	Sciurus	Bristol, England
DIP086	Sharing Cities	Greenwich, London, England
DIP087	Shift & Save	Coleraine, Cty. Londonderry, Northern Ireland
DIP088	Short-term discharge energy storage	Hemsby, Norfolk, England
DIP089	Smart Building Potential Within Heavily Utilised Networks	Glasgow, Scotland
DIP090	Smart Fintry	Fintry, Stirling, Scotland
DIP091	Smart grid storage and system integration technologies enabling an increase in renewables	Isle of Wight, England

DIP092	Smart Home	Watford, Hertfordshire, England
DIP093	Smart Hooky	Hook Norton, Oxfordshire, England
DIP094	Smart Islands	Isles of Scilly, England
DIP095	Smart Operation for a Low Carbon Energy Region	Cardiff, South Glamorgan, Wales
DIP096	Smart Street	Wigan, Lancashire, England
DIP097	Smarter Network Storage	Leighton Buzzard, Bedfordshire, England
DIP098	SmartHubs	Huntingdon, Cambridgeshire, England
DIP099	SMILE Orkney	Orkney, Scotland
DIP100	SoLa Bristol	Bristol, England
DIP101	Solar Storage	Butleigh, Glastonbury, England
DIP102	Solar Yield Network Constraints	England
DIP103	Solent Achieving Value from Efficiency	Southampton, Hampshire, England
DIP104	Step-Up – Energy Planning for Cities	Glasgow, Scotland
DIP105	Stirling Renewable Heat Project	Stirling, Scotland
DIP106	Storage Enabled Sustainable Energy for Buildings and Communities	Nottingham, England
DIP107	Sunderland Low Carbon Energy Demonstrator Project	Washington, Tyne and Wear, England
DIP108	Sunshine Tariff	Wadebridge, Cornwall, England
DIP109	Tackling Fuel Poverty & Grid Balancing with Smart Electric Storage Heat	Motherwell, Lanarkshire, Scotland
DIP110	Thames Valley Vision	Bracknell, Berkshire, England
DIP111	The City CNG Project	Leeds, England
DIP112	Thinking Energy	Milton Keynes, Buckinghamshire, England
DIP113	Tidal Energy Storage System	Bluemull Sound, Shetland, Scotland
DIP114	Towards Building Ready for Demand Response	Cardiff, South Glamorgan, Wales
DIP115	Trial Evaluation of Domestic Demand Side Management (DDSM)	Lerwick, Shetland, Scotland

DIP116	V2GO: Vehicle-To-Grid Oxford	Oxford, England
DIP117	ZEDpod	Watford, Hertfordshire, England
DIP118	Zero Bills House	Watford, Hertfordshire, England
DIP119	Zero-Plus	York, Yorkshire, England

7.2 Example of Data Collected on a Project

Table 5: example of information gathered on each project

Project ID	DIP012		
Long Title	Combined Heat System by using Solar Energy and Heat Pumps		
Short Title	Chess		
Keywords	Small-scale; Town; Domestic; Electricity; Heat; Solar PV; Solar Thermal; Heat Pumps; Thermal Storage; Seasonal Storage;		
Location (Town, Region, Country)	Corby	Northamptonshire	England
Latitude and Longitude	52.51N	0.64W	
OSGB code	SP 924 908		
Status	Ongoing		
Start Date	2016		
End Date	2019		
Description	"The project objective is to design, implement and promote a reliable, efficient and profitable system able to supply heating and hot water in buildings mainly from renewable sources. The proposed system is based in the optimal combination of solar thermal (ST) energy production, seasonal heat storage and high efficient heat pump use. Heat pumps will be improved technically in order to obtain the best performance in the special conditions of the CHESS-SETUP system. The used solar panels will be hybrid photovoltaic and solar thermal (PV-ST) panels, which is a promising solution for also producing the electricity consumed by the heat and water pumps of the heating system and part of the electricity consumed in the building. Hybrid solar panels are a key element to achieving energy self-sufficiency in buildings, especially in dense urban areas where the roof availability is one of the most limiting factors. Also will be considered the integration of other energy sources as biomass or heat waste, to make the system suitable for any climate conditions. The project will also explore the possibility to integrate the system with other		

	electricity or cooling technologies (solar cooling, cogeneration). The system operation will be optimized according to some external factors, as electricity price or user requirements by using a smart control and management systems developed specifically for the project. This proposal will be materialized in three pilot experiences: a small-scale prototype in Lavola's headquarters (Spain), 50 new dwellings located in Corby (England) and a new sport centre located in Sant Cugat (Spain).”
Sectors	Domestic
Funding Sources	Horizon 2020
Budget £	€3.7 million
Partners	University of Ulster, Electric Corby
Energy vectors	Electricity, Heat
Scale (lab/site/small /community/region/national)	Small
Technologies demonstrated	Solar thermal, season thermal storage, solar PV, heat pumps, low energy buildings
Economic models demonstrated	
Other concepts demonstrated	
Industry engagement	Industry partners
Consumer engagement	50 homes
Project Reports (incl. links)	https://www.chess-setup.net/documentation
Datasets (incl. links)	
Website/social media	https://www.chess-setup.net/corby
Information sources	https://cordis.europa.eu/project/rcn/203231_en.html

7.3 Example of Additional Data Collected on Project Outputs

Table 6: example of additional information gathered on project outputs

Activating Community Engagement (ACE) Dedicated website – Yes Organisation webpage – Yes Centralised portal - ENA Smarter Networks Objectives/Success Criteria - Yes Closedown/final report – No (just completed, yearly progress reports) Open-source data – No Peer-reviewed academic output (Primary Subject / Referenced) - 1 / 0 Brochures/Case Studies/Videos - No On-line major conference/event presentations - 0 Dissemination Event(s) / Output available – 1 / 0 Follow-on project – No (just completed) Consumer Engagement Consumer Participation – Yes Consumer Feedback – No Output Summary Progress reports – Yes Detailed and objective final report – No, simple format only Project method detailed – Limited Performance to objectives detailed – Limited Lessons learned identified – Limited Policy/Regulation implications reviewed – No No closedown report (yet) available, but yearly progress reports using standard LCNF/NIA template available on ENA portal. Progress reports restate objectives and success criteria and provide a brief assessment of current performance to objectives and any challenges. Lessons for future projects section not completed for final progress report. Outcomes vs. Objectives/Targets Performance to objectives – mostly achieved

Most recent progress report states main objectives being met at this stage with some challenges with the technology and recruitment of participating households. No useful detail on the challenges met.

Key Finding

N/a, project only recently completed.