REPORT

Summary of the Low Carbon Networks Fund learning

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Executive summary

This review has sought to establish the learning that has been derived from Low Carbon Network Fund (LCNF) projects and the extent to which this learning is now being adopted into business as usual (BAU) by Distribution Network Operators (DNOs) to drive benefits to stakeholders.

The key findings are as follows:

- LCNF projects have shown that a number of innovative technologies and approaches can provide benefits to customers. Examples of these technologies include those associated with active network management, demand side response and voltage management;

- A number of technologies have the potential to deliver further benefits, but certain economic or external barriers exist and therefore this potential cannot be realised immediately. For example, some demand management techniques can only deliver benefit when smart meters are fully deployed, or controlled electric vehicle charging technology will only realise its potential when uptake of electric vehicles reaches a certain threshold;

- A number of the technologies trialled within LCNF projects have already been transferred into BAU and are forming part of DNO activities in the current regulatory period. Examples of these include the use of flexible connections, the dynamic reconfiguration of the network to meet demand and restore outages, and demand side response techniques. A large body of the remaining learning from LCNF is in the process of making the transition from innovation into BAU;

- Learning from LCNF projects has contributed to many areas of DNO business activities, including all six of the key RIIO Outputs;

- A wide range of learning has been achieved through LCNF and this is informing ongoing strategy within DNOs regarding which projects to pursue next. The LCNF results provide a solid foundation upon which to build future innovation projects;

- Learning from projects regarding new customer technologies, such as electric vehicles, has assisted DNOs in preparing to meet the future challenges that these technologies will pose and hence to improve their state of readiness to meet the longer term needs of both customers and the network;

- The greatest benefits are observed in improving network performance and flexibility. Improvements in this area are likely to have direct consequential improvements such as the satisfaction of customers as a more reliable network, or shorter durations of interruptions.

Across the LCNF Tier 1 and Tier 2 projects, a wide range of smart technologies and approaches have been trialled. The nature of these smart interventions include:

- System solutions for voltage and network management more widely; network simulation and modelling;

- Technological solutions such as electrical energy storage and specific fault level management devices;

- Process changes stemming from updates to engineering codes and also the development of new commercial arrangements.

This learning has led to some approaches making the transition to BAU for a number of DNOs in RIIO-ED1. However, there are in some cases barriers (economic, technical and regulatory) which prevent the immediate adoption of the innovative approaches. A brief summary of the state of adoption into BAU of a number of innovative techniques and technologies is presented below.

- **Demand Side Response (DSR)** – all DNOs are building on the learning of LCNF projects to include DSR as part of their approach to network investment. The precise form that this DSR takes varies form one DNO to another, demonstrating that there is no 'one-size-fits-all' approach in this field and that each company is adapting the learning to meet its own needs;

- **Active Network Management (ANM)** – all DNOs are using some form of ANM within their business, although this varies by the precise technology and the area of the network in which it is deployed. For example, some DNOs are using smart fuse devices at LV, while others are looking at automatically re-configuring the network at HV to meet demand. As for DSR, this shows a flexibility to be able to cater for the needs of individual networks and means there is healthy competition in this area for DNOs to look at different equipment manufacturers and service providers;

- **Electrical Energy Storage** – this has been trialled by several DNOs, but is not fully adopted into BAU. Storage is difficult to justify economically to solely manage network demands (although they can be cost-effective in particular cases, such as island networks). Additional revenue streams can be leveraged to improve the economic case, such as selling services to the System Operator for balancing and frequency purposes;

- **Dynamic Ratings** – the ability to flex the rating of assets has been shown to have merits in several areas, such as overhead lines and transformers. This now forms BAU whereby some DNOs will consider the use of dynamic ratings alongside conventional approaches when examining the options for a particular project;

- **Voltage Management** – a range of voltage management devices have been deployed through LCNF to more actively manage the voltage deeper in the network than previously. This has also been used to help with demand management, something which is currently under consideration for BAU implementation by a number of DNOs;

- **Flexible Connections** – DNOs have explored ways to accelerate the connection of renewable generation to the network. As such, there is greater engagement with those wishing to connect and several DNOs now offer as standard flexible connections, rather than traditional connections that would require a significant amount of network enabling works and would take many months. The flexible connections allow generation to connect in a faster, less costly way and in exchange have their connection more actively managed by the DNO.

A key feature of the learning from all of the approaches described is that they are geared towards improving the flexibility of the network to meet new types of demand. In turn this increases customer engagement levels and hence contributes to both customer satisfaction and improving access for more efficient and cost-effective customer connections. Improvements in these areas are therefore the main beneficial outcomes from the portfolio of LCNF projects.

This report summarises the learning that has been accrued through LCNF projects, split by RIIO Output area and by technology type as appropriate. It is clear that learning has moved forward in several areas thanks to the LCNF program. However, this report does not attempt to estimate the value for money of this program as a separate cost benefit assessment is planned to be performed.

More detailed information on the individual projects is included as an Appendix, should the reader wish to further understand the specifics associated with a particular approach or project.

Contents

Appendices

1. Introduction

1.1 Context

The Office of Gas and Electricity Markets (Ofgem) established the Low Carbon Networks Fund (LCNF), ahead of the 2010-2015 regulatory period for electricity distribution networks (DPCR5), to encourage Distribution Network Operators (DNOs) to innovate to efficiently deliver the networks that users will need in a low carbon economy. The Low Carbon Network Fund (LCNF) aimed to stimulate: the real-world trialling of new technologies and services; knowledge and learning exchange amongst the electricity industry and a culture change among the DNOs so that innovation could become a core part of their business.

1.2 Aims and objectives

As a result of a study of each LCNF project and conversations with the six GB DNOs, this report aims to summarise the learning that has been achieved and also to demonstrate some of the benefits, particularly for the customer, of the LCNF funded projects in the RIIO[1] Output areas of:

- Customer satisfaction
- Safety
- Reliability and availability
- Conditions for connection
- Environment, and
- Social obligations.

It should be noted that all project business cases and benefits stated in this document are as reported by the DNO conducting the project and as part of this work these figures have not been validated or endorsed by either Ofgem or EA Technology.

Furthermore, this report does not set out to evaluate to what extent the various activities conducted under LCNF represent value for money. It should in no way be construed as an assessment of the costs and benefits of the projects, but instead provides a factual summary of the learning that has been derived and the level to which this learning has been adopted into Business As Usual (BAU). All information concerning whether or not the innovative approaches trialled have made the transition into BAU is taken from the business plans of the various DNOs.

1.3 Report Structure

Section 2 contains a matrix diagram showing the relevance of each LCNF Tier 1 and Tier 2 project to the RIIO Outputs. This is followed by a narrative on the most relevant developments in each Output area, showcasing the learning detailed in the Closedown Reports of completed projects and, where appropriate, disaggregating this learning by technology type (Table 3). To further aid the reader, this section also incorporates a table mapping the various technology types to projects in which they have been trialled.

Brief conclusions on this work are provided in Section 3.

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[1] RIIO is the regulatory framework introduced by Ofgem and is an abbreviation for Revenue = Incentives + Innovation + Outputs

For further reference, an overview of each of the 23 Tier 2 projects and a number of Tier 1 projects is provided in the Appendix, along with more detailed information relating to the various RIIO Outputs.

2. Summary of learning from the Low Carbon Networks Fund projects

This section summarises the key learning delivered, to date, by the innovation projects awarded LCN funding. The report will support industry stakeholders in understanding and drawing on this learning. It will provide an indication of the extent to which DNOs are already making use of learning to deliver cost-effective and reliable networks. The summary is structured to translate the key learning from the innovation projects into the six Output categories that the network companies are expected to deliver under the regulatory RIIO-ED1 framework. (Definitions of the six key Output areas can be found in Appendix I.)

The size of the bars in Tables 1 and 2 represent a subjective view on the scale of the learning generated in each of the RIIO Output areas attributable to a certain project. The colour of the bars represents the fact that projects are at different stages in their life cycle as follows:

- Green – projects that have completed and can be considered to be confident in the learning achieved
- Yellow – projects that are currently in flight and are yet to fully document their learning
- Blue – projects that have only recently commenced. These are assessed based on their expected outcomes as articulated in project proposals

The information presented in these tables is based on EA Technology's interpretation of publicly available material from project close-down reports and similar. It is not intended to be a quantifiable means of judging economic benefits of different projects, but provides a high-level qualitative view of the areas (in terms of the RIIO Outputs) in which the greatest benefits are being accrued. It should be noted that while a large amount of learning from LCNF projects has made the transition into BAU (or is to some degree informing current DNO thinking), there are some technologies and approaches that are not yet ready to be adopted by DNOs. There are three main reasons for this:

- Economics
    - It may not make economic sense to invest in the approach at this time. For example, the learning associated with demand management of electric vehicle charging is valuable, but the value can only be realised when the uptake levels of electric vehicles make investment in this approach worthwhile. Hence it is likely that the true value of this learning will be realised in ED2 and beyond.
- Technology (performance and/or availability)
    - Some solutions require technology to be at a certain level to facilitate their deployment. An example of this is the use of dynamic pricing incentives which requires the wide-scale roll-out of smart meters. This roll-out is in progress but not yet ready for adoption into BAU within DNOs.
- Regulatory environment
    - Some solutions need to take account of the regulatory landscape. For example, electrical energy storage is a costly solution to deploy purely to manage demand and a cost-benefit case sometimes requires additional revenue streams to make it positive. Such revenue streams exist (such as providing frequency response services). As energy storage is a competitive market participation by the DNOs is restricted but they can provide sufficient market signals to third parties to provide storage.

Table 1: LCNF Tier 2 projects and associated Outputs of the regulatory RIIO-ED1 framework.

Distribution network operator	Project name	Safety	Reliability & availability	Environment	Connections	Customer satisfaction	Social obligations
Electricity North West Limited	Capacity to Customers		🟩🟩🟩 3	🟩🟩	🟩🟩🟩 3	🟩🟩🟩 3	
	Customer Load Active System (CLASS)		🟩🟩🟩 3	🟩🟩	🟩	🟩🟩	
	Smart Street (eta)	🟧🟧	🟧🟧🟧 3	🟧🟧	🟧	🟧	
	Respond (FLARE)	🟦🟦🟦 3	🟦🟦	🟦🟦	🟦	🟦🟦	
Northern Powergrid	Customer-Led Network Revolution (CLNR)		🟩🟩🟩 3	🟩🟩🟩 3	🟩🟩🟩 3	🟩🟩🟩 3	🟩🟩
Scottish and Southern Energy Power Distribution	Thames Valley Vision		🟧🟧🟧 3	🟧🟧	🟧🟧	🟧🟧🟧 3	
	My Electric Avenue		🟩🟩🟩 3	🟩🟩🟩 3	🟩🟩	🟩🟩🟩 3	
	Solent Achieving Value from Efficiency (SAVE)		🟧🟧🟧 3	🟧🟧		🟧🟧🟧 3	🟧🟧🟧 3
	Low Energy Automated Networks (LEAN)		🟦🟦🟦 3	🟦🟦		🟦🟦	
Scottish Power Energy Networks	Flexible Networks for a Low Carbon Future		🟩🟩🟩 3	🟩🟩	🟩	🟩	
	Accelarating Renewable Connections (ARC)		🟧🟧	🟧🟧	🟧🟧🟧 3	🟧	
UK Power Networks	Low Carbon London (LCL)		🟩🟩🟩 3	🟩🟩🟩 3	🟩🟩	🟩🟩🟩 3	🟩
	Flexible Plug and Play Low Carbon Networks		🟩🟩🟩 3	🟩🟩	🟩🟩🟩 3	🟩🟩🟩 3	
	Smarter Network Storage (SNS)		🟧🟧🟧 3	🟧🟧	🟧🟧	🟧	
	Flexible Urban Networks - Low Voltage	🟧	🟧🟧🟧 3	🟧🟧🟧 3	🟧🟧🟧 3		
	Vulnerable Customers and Energy Efficiency		🟧🟧	🟧🟧		🟧🟧🟧 3	🟧🟧🟧 3
	Kent Active System Management (KASM)		🟦🟦🟦 3	🟦🟦	🟦		
Western Power Distribution	LV Network Templates		🟩🟩🟩 3	🟩🟩	🟩	🟩	
	SoLa Bristol		🟩🟩🟩 3	🟩🟩	🟩🟩🟩 3	🟩🟩🟩 3	
	Flexible Approaches for Low Carbon Optimised Networks (FALCON)		🟩🟩🟩 3	🟩🟩	🟩	🟩	
	Lincolnshire Low Carbon Hub		🟩🟩🟩 3	🟩🟩	🟩🟩	🟩	
	Advanced Fault Level Management in Birmingham (FLEXDGRID)	🟧🟧🟧 3	🟧🟧🟧 3	🟧🟧	🟧🟧		
	Network Equilibrium		🟦🟦🟦 3	🟦🟦	🟦		

Completed Project	🟩 1
Ongoing Project	🟧 1
Future Project	🟦 1

Table 2: LCNF Tier 1 projects and associated Output of the regulatory RIIO-ED1 framework.

Distribution network operator	Project name	Safety	Reliability & availability	Environment	Connections	Customer satisfaction	Social obligations
Electricity North West	The Bidoyng Smart Fuse	🟩	🟩🟩🟩				
	Voltage Management of LV Busbars		🟩🟩🟩			🟩	
	Low Voltage Network Solutions		🟩🟩			🟩🟩	
	Low Voltage Integrated Automation (LoVIA)		🟩🟩🟩		🟩	🟩	
	LV Protection and Communications (LV PAC)	🟩	🟩				
	Combined On-Line Transformer Monitoring	🟦🟦					
	Fault Current Active Management (FCAM)	🟧🟧🟧					
	Fault Sense	🟦🟦	🟦🟦			🟦	
Northern Powergrid	33kV SC Fault Current Limiter	🟩🟩	🟩🟩				
Scottish Power Energy Networks	Real-Time Thermal Ratings			🟩	🟩🟩		
	Ashton Hayes Smart Village			🟩🟩	🟩	🟩🟩	
	Clyde Gateway		🟩🟩🟩	🟩🟩	🟩	🟩	
	Hydro Active Network Management		🟩🟩		🟩🟩		
	Windfarm Cable Circuits		🟩🟩	🟩🟩	🟩🟩		
	Smart Building Potential			🟩🟩🟩	🟩🟩	🟩🟩	
	Digital Substation Platform - Phase 1	🟩🟩	🟩				
Scottish & Southern Energy	1MW Shetland NaS Battery		🟩🟩				🟩
	Benefits of Monitoring LV Networks					🟩	
	Trial Evaluation of Domestic Demand Side Management (DDSM)			🟩			
	Honeywell I&C ADR - Demand Response		🟩🟩	🟩		🟩	
	LV Network Modelling & Analysis		🟩				
	Orkney Energy Storage Park (Phase 1)		🟩			🟩	🟩
	LV Network Storage	🟩🟩	🟩	🟩			
	Trial of Orkney Energy Storage Park (Phase 2)		🟩🟩		🟩	🟩	🟩
	Impact of Electrolysers on the Network		🟩				

Distribution network operator	Project name	Safety	Reliability & availability	Environment	Connections	Customer satisfaction	Social obligations
UK Power Networks	Digital Substation Platform	🟩	🟩				
	Short Term Discharge Energy Storage		🟩	🟩			
	Distribution Network Visibility		🟩				
	Smart Urban Low Voltage Network		🟩				
	Validation of PV Connection Assessment			🟩	🟩		
	Power Transformer Real Time Thermal Rating		🟧	🟧	🟧		
Western Power Distribution	Interconnection of WPD and NGC SCADA		🟩				
	Network Management on the Isles of Scilly		🟩	🟩	🟩	🟩	
	Voltage Control System Demonstration Project		🟩				
	Early Learning of Low Voltage Network Impacts from Estate PV Cluster				🟩		
	Seasonal Generation Deployment*						
	LV Current Sensor Tech Evaluation	🟩	🟩				
	Implementation of AFLM Scheme	🟩					
	Community Energy Action					🟩	🟩
	Electric Boulevards			🟩	🟩		
	PV Impact on Surburban Networks		🟩	🟩	🟩		
	Hook Norton Low Carbon Community Smart Grid			🟩	🟩	🟩	
	Energy Control for Household Optimisation (ECHO)			🟩		🟩	

*project closed early

Of the LCNF Tier 1 projects listed above only those that represented significant independent learning are considered in detail. As over half of the Tier 1 projects can be regarded as foundations for further innovation projects, such as Tier 2 or NIA (Network Innovation Allowance) projects, the benefits of these projects were not considered separately so as to avoid double counting the benefits or learning. Six Tier 1 projects could not be considered as, at the time of writing they were not complete or had no closedown reports available. Further information on the mapping of LCNF Tier 1 projects to the Tier 2 projects, illustrating the 'flow' of learning arising as the initial Tier 1 projects lead into larger, more wide-ranging Tier 2 projects can be found in Appendix II.

The key intended outcome of the learning generated from the innovation projects is that it can be applied to bring benefits to the customer. Confidence in the learning within a solution area tends to grow from numerous projects. Cross-DNO interaction, facilitated through regular dissemination activities, stakeholder engagement initiatives and working groups, ensures that the learning points build on one another and complementary approaches are adopted. This means that it is often difficult to attribute a particular innovation to one project or DNO. It is therefore considered useful to group the projects by the solution areas to which they have contributed learning.

The following table illustrates the correlation between a number of key solution areas investigated through the LCNF Tier 2 projects and the respective projects that had these areas as their focus. It should be noted that a number of the projects are wide-ranging, and this table does not seek to capture all activity associated with projects, but rather to focus on those area that were most central to the objectives of the project.

Table 3: Mapping LCNF Tier 2 projects to solution areas.

Solution Area	DNO	LCNF T2 Project
Network Management	ENWL	Customer Load Active System Services (CLASS)
	ENWL	Capacity to Customers (C2C)
	ENWL	Smart Street (eta)
	NPg	Customer Led Network Revolution (CLNR)
	SPEN	Accelerating Renewable Connections (ARC)
	SSEPD	Low Energy Automated Networks (LEAN)
	SSEPD	My Electric Avenue (MEA)
	SSEPD	Low Energy Automated Networks (LEAN)
	UKPN	Flexible Plug & Play (FPP)
	UKPN	Low Carbon London (LCL)
	UKPN	Flexible Urban Network - Low Voltage (FUNLV)
	WPD	SoLa BRISTOL
	WPD	Flexible Approaches to Low Carbon Optimised Networks (FALCON)
	WPD	Low Carbon Hub (LCH)
Voltage Management	ENWL	Customer Load Active System Services (CLASS)
	ENWL	Smart Street (eta)
	NPg	Customer Led Network Revolution (CLNR)
	SPEN	Flexible Networks for a Low Carbon Future (FNLCF)
	SSEPD	New Thames Valley Vision (NTVV)
	UKPN	Flexible Plug & Play (FPP)

Solution Area	DNO	LCNF T2 Project
	UKPN	Flexible Urban Network - Low Voltage (FUNLV)
	WPD	Low Carbon Hub (LCH)
	WPD	Kent Area System Management (KASM)
Fault Level (Monitoring &) Management	ENWL	Fault Level Active Response (FLARE)
	WPD	FlexDGrid
	WPD	Low Carbon Hub (LCH)
Dynamic Ratings	NPg	Customer Led Network Revolution (CLNR)
	WPD	Flexible Approaches to Low Carbon Optimised Networks (FALCON)
	WPD	Low Carbon Hub (LCH)
Network Simulation and Modelling	NPg	Customer Led Network Revolution (CLNR)
	UKPN	Flexible Plug & Play (FPP)
	WPD	LV Network Templates
Electrical Energy Storage	NPg	Customer Led Network Revolution (CLNR)
	SSEPD	New Thames Valley Vision (NTVV)
	UKPN	Smarter Network Storage (SNS)
	WPD	SoLa BRISTOL
	WPD	FALCON
Demand Side Response/Management	ENWL	Capacity to Customers (C2C)
	ENWL	Customer Load Active System Services (CLASS)
	NPg	Customer Led Network Revolution (CLNR)
	SPEN	Accelerated Renewable Connections (ARC)
	SPEN	Flexible Networks for a Low Carbon Future (FNLCF)
	SSEPD	New Thames Valley Vision (NTVV)
	SSEPD	My Electric Avenue (MEA)
	SSEPD	Solent Achieving Value for Efficiency (SAVE)
	UKPN	Flexible Plug & Play (FPP)
	UKPN	Low Carbon London (LCL)
	WPD	SoLa BRISTOL
Energy Efficiency	ENWL	Customer Load Active System Services (CLASS)
	SSEPD	Solent Achieving Value from Efficiency (SAVE)
	UKPN	Vulnerable Customers and Energy Efficiency (VCEE)
Smart Meters and Time of Use Tariffs	NPg	Customer Led Network Revolution (CLNR)
	UKPN	Low Carbon London (LCL)
	WPD	SoLa Bristol
New Connections Process & Procedure	ENWL	Capacity to Customers (C2C)
	SPEN	Accelerating Renewable Connections (ARC)

Solution Area	DNO	LCNF T2 Project
	UKPN	Flexible Plug & Play (FPP)
	UKPN	Kent Area System Management (KASM)
New/Updated Code/Standard	ENWL	Capacity to Customers (C2C)
	NPg	Customer Led Network Revolution (CLNR)

In order to demonstrate the level of project effort that has been expended in some of the critical solution or technology areas, the following graphic (Figure 1) has been produced, which illustrates how the projects, on the right hand side, are mapped to the key solution areas (on the left hand side) with the relative sizes of the bars for each project indicating how much of the project was focused on each of these solution areas. For the purpose of this graphic, only five of the most prevalent solution areas are displayed, but clearly a number of projects have contributed in other solution areas, as evidenced by the contents of Table 3 above.

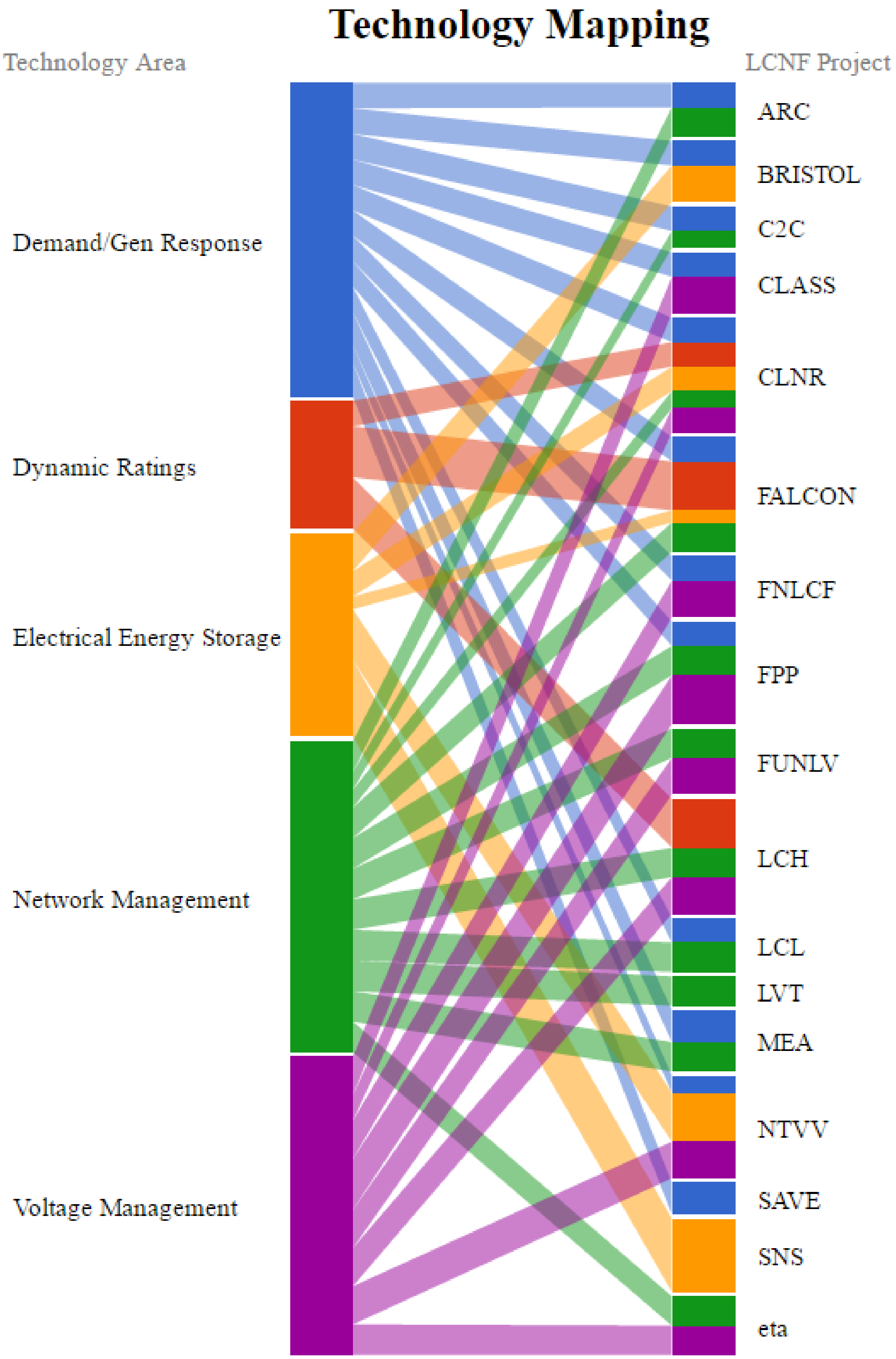

Figure 1: Graphical representation of the correlation between key solution areas and LCNF Tier 2 projects.

The following sections take each of the RIIO Outputs in turn and provide examples and commentary on the way in which LCNF projects have benefitted these areas and where techniques have been adopted into BAU to drive value to stakeholders.

2.1 Customer satisfaction

LCNF projects have afforded unprecedented opportunities for DNOs to engage with their customers and explore the possibilities of working with them to achieve the aims of secure, affordable and low carbon electricity.

Learning has been generated in understanding customer response to mechanisms such as Demand Side Response (DSR) and the willingness of customers to engage in using some of their demand at times of day that may avoid the need for expensive reinforcement work. This has led to DSR being integrated into BAU for several DNOs and has also provided a significant body of evidence to assist DNOs in beginning to plan strategically for a future where a greater proportion of the heating and transport requirements of their customers are provided electrically.

The opportunity to work with customers through engaged communities and also to explore the potential cost savings that can be achieved through energy efficiency have all led to significant learning around customer satisfaction.

In the UK electricity customers expect a steady, reliable supply of electricity. Ageing assets and new demand and generation profiles are likely to have an adverse effect on the supply of electricity to customers should their effects go unchecked. **A key part of customer satisfaction is ensuring the continued reliability and availability of the network.** ENWL's Tier 1 project with 200 Smart Fuses was aimed at reducing the impact of transient faults on customers. Before this technology ENWL's average interruption was approximately 60 minutes. ENWL found that **the Smart Fuse restores supplies in under 3 minutes** effectively eliminating 'Customer Interruptions' (based on an average number of customers connected to low voltage feeders) and 60 minutes of 'Customer Minutes Lost' penalties. It is estimated by ENWL that an average penalty of £500 is avoided with every Smart Fuse low voltage feeder supply restoration[2].

In times of change customers need to be engaged to aid the adoption and continued development of novel solutions. This is particularly true of projects such as ENWL's 'Customer Load Active System Services' (CLASS) which ran four trials on 60 primary substations in 2014, representing 17% of their network and around 485,000 customers. Survey findings from the 496 domestic and 200 industrial and commercial (I&C) customers who repeatedly engaged with the project showed that the CLASS method (of controlling voltage in different ways) **had no adverse effect on customers' perception of power quality**[3].

A key part of the 'Capacity to Customers' project was seeing if customers were willing to adopt new forms of commercial arrangements which allow the DNO to action demand and/or generation response in the event of a network fault. **The participants' satisfaction with the commercial arrangements led to support of the idea of extending the contracts beyond the pre-agreed 18 months.** This may have been due in part to the neutral or positive difference noted in all three key

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[2] ENWL (2015) The Bidoyng Smart Fuse Closedown Report. (Online). Available: http://www.smarternetworks.org/Files/The_Bidoyng_Smart_Fuse_140701155713.pdf Last Accessed: 4 March 2016

[3] ENWL (2015) Customer Load Active Systems Project Closedown Report. (Online). Available: http://www.smarternetworks.org/Files/CLASS_151127094432.pdf Last Accessed: 1 March 2016

power quality measures: frequency, duration and dips and spikes.[4] This perception was echoed amongst priority service registered customers who are sometimes more sensitive to changes in the supply.

Beyond maintaining the quality of supply, certain customer segments want to engage in the development of a low carbon economy. Customer satisfaction particularly where LCNF projects are concerned can be related to the level and quality of engagement employed by the DNO. In some instances the projects were built around a community aim of being 'low carbon', such as at Hook Norton. The network monitoring applied in 'Hook Norton Low Carbon Community Smart Grid' (WPD Tier 1 project), has delivered a high level of confidence in the performance of the network and its capacity to absorb additional technology as it comes on line. The monitoring capability also provides a strong basis to evaluate the connection of low carbon technologies adopted across the community as part of the ongoing carbon reduction plans of the village.[5] SPEN's Tier 1 project with Ashton Hayes Smart Village, similarly engaged locals who commented on the usefulness of the DNO providing reports to the community. In the closedown report SPEN write 'while proxy indicators such as anecdotal evidence suggested that the focus on engagement produced very positive results, it is difficult to measure the impact more rigorously and affected by factors outside the control of the project'[6].

As part of the Tier 2 project CLNR (Customer-Led Network Revolution) 13,000 customers took part generating learning on a suite of smart technologies (including energy storage, voltage control, demand side management and dynamic ratings) that are 'helping lead the way to a low carbon world'. Within the CLNR outputs, Northern Powergrid state that the learning generated is expected to bring about a reduction of between £3.25bn and £17.7bn on distribution network reinforcement costs from 2020 to 2050, dependent on the uptake rate of Low Carbon Technologies (LCTs)[7]. This is expected to translate to savings for electricity customers as a portion of the household electricity bill comes from network costs. **CLNR has also quantified the primary financial benefit to customers from the payments associated with Demand Side Response flexibility.** Between 2020 and 2050, Northern Powergrid expects the payments to Industrial and Commercial (I&C) customers to be between £1.3bn and £7bn[4]. This figure takes into account that the viability of I&C DSR is site specific and significantly influenced by the value of the counterfactual reinforcement costs.

There have been a number of other projects investigating the various ways in which generation or load related constraints can be overcome with the help of customers. The Tier 2 project SoLa Bristol investigated the combination of home energy storage coupled with new variable tariffs and integrated network control. Households participating in the trials made a modest saving on their energy bills[8]. However, as the sample size was small (11 houses) it is difficult to extrapolate these findings to broader effects for customers on different tariffs.

My Electric Avenue tested the customer acceptance and technical effectiveness of 'Esprit', a technology aimed at controlling EV charging to protect the network. The findings suggest that control of EV charging was acceptable to the majority of participants. Most of the domestic

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[4] ENWL (2015) Capacity to Customers. (Online). Available: http://www.enwl.co.uk/docs/default-source/c2c-key-documents/c2c-closedown-report-aug-2015.pdf?sfvrsn=4 Last Accessed: 4 March 2016

[5] WPD (2013) LCN Fund Tier 1 Close Down Report. Smart Hooky. (Online). Available: http://www.smarternetworks.org/Files/Hook_Norton_Low_Carbon_Smart_Grid_140618123740.pdf Last Accessed: 29 March 2016

[6] SPEN (2014) Ashton Hayes Smart Village Closedown Report. (Online). Available: https://www.ofgem.gov.uk/sites/default/files/docs/2014/02/ashton_hayes_cdr_v3_0.pdf Last Accessed: 29 March 2016

[7] NPG (2015) Customer-Led Network Revolution Project Closedown. (Online). Available: http://www.networkrevolution.co.uk/wp-content/uploads/2015/03/CLNR-G026-Project-Closedown-Report-FINAL-V2.pdf Last Accessed: 1 March 2016

[8] WPD (2016) SoLa Bristol SDRC 9.8 Final Report (Online) Available: http://www.westernpowerinnovation.co.uk/Document-library/2016/WPDT2003_SoLa-Bristol_SDRC9-8-v1.aspx Last Accessed: 3 March 2016

participants in the trial whose charging was curtailed were either not aware of the curtailment, or were not impacted by it.[9]

2.2 Safety

Safety has not tended to be the primary driver of LCNF project learning. However, a number of techniques have been trialled to either improve network performance or delay expensive reinforcement schemes that also serve the purpose of improving network safety.

Examples of this include the use of reclosing devices at low voltage which negate the requirement for DNO staff to physically insert fuses live on the network. The use of such devices has been fully integrated into BAU.

There are also examples of using equipment to limit fault currents to safe levels as an alternative to replacing expensive assets. While not yet BAU, further trials are taking place in this area.

Finally, the development of innovative technologies and approaches requires the appropriate use of policies and procedures to ensure their safe operation. Some of the work conducted under LCNF has led to the development of processes for handling such technologies safely, particularly for electrical energy storage.

There are a limited number of LCNF projects relating directly to the area of improved safety. These projects: FlexDGrid, Flare, Smart Street and Flexible Urban Networks are still ongoing. Indirectly the projects working to improve the reliability of the electricity network (discussed in Section 2.3); particularly the smart interventions looking at **automation, sensing and protection, inherently also improve the safety of the system.** Fast fault detection and use of automated, fast-response protection reduces the risk of negative knock-on effects. It protects the assets from being operated outside the ratings for which they have been designed.

The safety metrics identified in Appendix I: compliance with health and safety law; reducing accidents; substation security and theft of equipment and educating the public on electricity safety matters represent incremental improvements to BAU. The main area where new safety processes have been developed is in the **implementation of Electrical Energy Storage (EES)**, particularly with the work involved in the installation of a 1MW system in Orkney (SSEPD LCNF projects). **The time and funds expended in producing these will be saved on all future installations of the technology.** Of particular relevance to the Safety Output are the well documented safety cases for NaS (Sodium Sulphur) and lead-acid batteries. A number of LCNF projects also led to the establishment of the Energy Storage Operators Forum (ESOF); a resource used by a range of stakeholders to continue the conversation on the operation and management of storage, which in turn led to the **production of a Good Practice Guide for Energy Storage.**

Another area where safety can be regarded as improved due to LCNF projects is that of **fault level management**, and this is discussed in more detail in the following section.

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[9] Fisher, J., Gammon, R. and Irvine, K. (2015) SDRC 9.6: An assessment of the public acceptance of Demand Side Response of EV charging using Esprit. (Online). Available: http://myelectricavenue.info/sites/default/files/MEA%20SDRC%209%206%20Issue%202.pdf Last Accessed: 6 March 2016

2.3 Reliability and availability

Improving the reliability and availability of the network has received significant attention through LCNF projects and there are many ways in which this Output can be addressed.

Numerous technologies and processes have been trialled and since been adopted into BAU. Some examples of these include: demand side response, dynamic ratings, voltage management and active network management.

There are other cases where important learning has been gained, but further work is still being undertaken in order to fully deploy this into BAU, or where there are external factors that mean this cannot be taken forward at this time. Some examples of this include: fault level management, electrical energy storage, advanced network simulation and time-of-use incentives.

Some of the areas described above are fairly broad and there may well be individual examples where the learning is already adopted hence, as a consequence of the broad nature of the learning in this area, this section contains various subsections where the individual technologies are discussed in more detail.

The Reliability and Availability Output is related to the delivery of improvements in the performance of the network that enabled electricity customers to have **fewer and shorter interruptions** to their electricity supply. Table 1 suggests that all Tier 2 innovation projects have contributed, to different extents, to the delivery of this regulatory Output. Accordingly, new learning has been generated in the following technology areas, in some cases enabling DNOs to start adopting the solutions into BAU:

- Network management – many different examples of this now in BAU;
- Voltage management – widely adopted into BAU and evolving to incorporate new technologies;
- Fault level (monitoring &) management – not yet mature enough to be BAU, further trials in progress;
- Dynamic ratings – adopted and being used in BAU as and where appropriate;
- Network simulation and modelling – many approaches being trialled, yet to be fully adopted although some techniques (such as modelling new customer demands) are now forming part of BAU assessments;
- Electrical energy storage – suitable for deployment in specific cases, but economic barriers to wide-scale adoption exist;
- Demand side management/response – widely adopted into BAU, but in different forms across DNOs;
- Energy efficiency – further work in progress in this area;
- New connections process & procedure – widely adopted into BAU;
- Smart meters and time of use pricing – not yet BAU as this is largely dependent on availability of smart meter data.

Each of these is discussed in more detail in the following section.

Network management

Innovation activities have led to the implementation of Active Network Management (ANM) solutions supporting the flexible management of network constraints through the monitoring and control of smart grid devices and distributed generators. The deployment of ANM has tested and proved the scope for integration and interoperability of various smart grid solutions and enabling technologies,[10] in real distribution networks, to address network operational challenges and improving redundancy and resilience. A range of network challenges and associated smart grid solutions and enablers trialled in LCNF projects with ANM applications are described below:

- Thermal constraints: new distributed generation (e.g. renewable energy resources) connecting to networks with already limited spare capacity may be constrained, for instance, at times of low demand and high generation output. Smart grid solutions, such as dynamic line rating, trialled in projects including Northern Powergrid's Customer-Led Network Revolution, have the potential to allow the relaxation of existing constraints and obviate the need for prescribed seasonal limits to export to the distribution network.

- Reverse power flows: in areas of relatively low demand, the connection of distributed generators may need to be constrained as it could result in power flowing in the reverse direction, i.e. from lower to higher voltages. This can cause network protection equipment to operate as protection settings in traditional network operation consider a reverse flow to be an indication of a fault. Adaptive protection such as modern protection relays and intelligent tap changer relays trialled in UKPN's Flexible Plug and Play Low Carbon Networks and ENWL's Capacity to Customers should alleviate problems resulting from reverse power flows.

- Voltage constraints: distributed generation raises voltage levels on distribution networks. Modification to the operation of transformer tap changers during times of high generation output and/or the management of generator active and/or reactive power enables the connection of higher levels of generation while maintaining network voltages within acceptable limits. Several projects have trialled different automatic voltage control schemes, notably ENWL's Customer Load Active System Services.

- Flexible network configurations: during network outages certain circuits of the distribution network may experience thermal overloads whilst other circuits with spare capacity remain underutilised. The deployment of innovative network switches designed for frequent operation, in contrast to the standard switches, together with ANM will enable more flexible network configurations to reduce or remove network constraints. Similarly, on interconnected circuits, active management of power flows using a phase shifting transformer will maximise overall network capacity.

- Generator control mechanisms: the connection of distributed generation can be further limited by the absence of smart generator control mechanisms (i.e. smart generator controllers) that enable an adequate management of the generator active and reactive power. Traditionally, DNOs have adopted a limited form of active control over generators (i.e. on or off, or to a number of pre-set seasonal power export levels) that does not allow the generation export to track to the real-time export capacity available on the network. LCNF projects including UKPN's Flexible Plug and Play Low Carbon Networks have trialled sophisticated forms of ANM that provide greater refinement in the control of generator export and enable a closer match to available network capacity.

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[10] 'Enabling technologies' refers to those elements of the smart grid system that are required to allow the system to function, but do not, themselves, help to alleviate network constraints or improve performance. For example, network monitoring is required to determine demand on a network in order for an appropriate decision to be made, but the monitoring equipment in itself does not provide a benefit.

The testing of ANM solutions within LCNF projects has also led to significant learning on the design and implementation of appropriate communication infrastructures and interoperability. Both are required to facilitate the integration of smart grid solutions and enablers into the operation of distribution networks. For instance, UKPN's Flexible Plug and Play Low Carbon Networks project implemented vendor agnostic communication platforms based on open standards (e.g. IEC 61850) and internet protocol (IP) systems to enable end-to-end communication between distributed smart network technologies and distributed generation.

Projects have explored other network solutions for the development of smarter active (rather than passive) design and operation of distribution networks. These have included dynamic network reconfiguration to operate in interconnected (or meshed) as opposed to radial configurations. Meshed network configurations have contributed to: enhanced network capacity through improved controllability and resilience; improved power quality; reduction in losses and better security of supply.

Dynamic network reconfiguration requires the installation of additional equipment, such as switchgear, protection relays and telecommunication links, to enable the secure and efficient deployment. LCNF projects have developed and trialled new smart network devices to facilitate network interconnection and dynamic reconfiguration. Intelligent switching devices, that can be operated remotely from the network operator's control room, have been trialled to provide network monitoring (voltages, currents, power flow and harmonics) and advanced adaptive protection, coupled with network fault detection capability and automatic fault reclose functions.

Voltage management

Innovative voltage control and regulation technologies can allow more load and generation to connect to networks whilst remaining within statutory voltage limits. It also has a role in peak demand management, losses optimisation and conservation of energy.

Traditionally the distribution networks have been designed to operate passively with unidirectional power flows from the higher voltage transmission system to the lower voltage distribution system. This has led to the design and operation of distribution networks with limited voltage control and regulation capability. The introduction of low carbon technologies has resulted in complex network flow patterns and has challenged the real time management of network voltage within statutory limits. In particular, some DNOs have noted significant voltage rise on networks during periods of high distributed generation output and low local demand. Concrete information on the issues has been uncovered through Tier 1 and Tier 2 projects monitoring the network effects of, for example, rooftop photovoltaic (PV) solar panels. Network design policies have been adjusted based on this learning, allowing more generation to connect without reinforcement.

ENWL has trialled innovative voltage management techniques to provide new demand response options to distribution networks through its Customer Load Active System Services project. The techniques have explored the natural relationship between voltage and customer demand and have demonstrated how it can be used as a low cost, rapidly deployable solution that can provide a range of demand response capabilities and network voltage regulation services. Field trials have inferred the voltage / demand relationship from the normal increment and decrement of system voltage at primary substations across an annual period. A voltage / demand relationship matrix has been developed to describe mathematically the relationship for every half-hour in a year for each load group type trialled. These trials provided simplified guidance for practical application in updating network planning and operation standards.

Projects have investigated the use of demand response (initiated by voltage reduction) to manage the peak demand at a primary substation, through the lowering of the transformer taps. Field trials confirmed that the demand response via voltage reduction provided at the peak demand of a primary substation (normally in winter) can defer network reinforcement.

The Customer-Led Network Revolution project trialled other innovative voltage management techniques such as Enhanced Automatic Voltage Control (EAVC). Traditionally, voltage control in distribution networks uses the On-Load Tap Changers (OLTC) of the power transformers to move the tap position (via Automatic Voltage Control relays) so that the supply voltage on the secondary network is maintained at a specific setpoint. EAVC has the advantage of enabling the voltage setpoints to be controlled locally by a substation controller or remotely by an ANM system. Field trials tested the deployment of various EAVC schemes:

- EAVC of the OLTC at primary substations;
- EAVC of the OLTC at secondary substations;
- In-line voltage regulators on primary networks: can boost or buck the voltage along a feeder to compensate for any voltage drop due to demand or voltage rise as a result of generation;
- Switched capacitors banks in primary networks: compensate for reactive power on the circuit, which can reduce voltage drops, particularly for long spans of overhead line;
- Voltage regulators in low voltage networks: regulators can manage voltages on individual feeders.

Rural networks are often complex and difficult to reinforce due to long feeder lengths. These networks are often the ones that may be early adopters of low carbon technologies such as heat-pumps and renewable generation due to economic drivers from off-gas grid heating, or fewer planning restrictions. These long secondary network feeders tend to be voltage constrained rather than thermally constrained, and so the use of series voltage regulators, or in some circumstances reactive power compensation (e.g. switched capacitors), can create useful levels of an incremental capacity in a comparatively rapid and low-cost manner.

Projects, such as SPEN’s Accelerating Renewable Connections, have explored the application of voltage management techniques to provide voltage control in support of the Transmission System Operator. The operation of existing primary substation transformers in a staggered tap configuration (i.e. a pair of substation transformers operated at different tap positions) effectively absorbs reactive power from the upstream network (i.e. increases reactive demand) therefore reducing upstream network (i.e. grid) voltages and leaving customer voltages unchanged. Field trials have demonstrated that a reactive power absorption service can be provided to support voltage stabilisation on the transmission network. The field trials have closely monitored the health of primary transformers and tap changers to demonstrate that the voltage control techniques used had no material and detrimental impact on the health of those assets.

Projects have developed comprehensive customer surveys to quantify and understand the effect of applying voltage regulation techniques in distribution networks. Overall, field trials have demonstrated that customers have not been adversely affected by the small variations in voltage used by the different techniques.

The application of voltage management techniques through LCNF innovation activities have contributed to:

- Acceleration of the decarbonisation of the UK energy supply;
- Reduction in the DNO’s requirements for substation reinforcement by reducing system peaks;
- Providing rapid distribution network peak loading relief (of limited duration), bridging the operational time period needed until other forms of demand side response (e.g. via aggregators) or network reconfiguration actions come into effect;
- Boosting demand in distributed generation (DG) dominated distribution networks and hence balance the network flows thereby maximising the output of DG for a given network capacity.

Fault level management

Electricity distribution networks are designed and operated to provide safe, reliable and cost efficient distribution of electrical energy. On occasion, networks experience faults causing fault currents to flow in the network. These currents, which are significantly higher in magnitude than normal current (i.e. steady flow of electricity through the network), must be safely and quickly interrupted and removed from the network by protective equipment. The integration of new low carbon generation and demand technologies in distribution networks present a range of new challenges to network operators, including the potential increase of fault level currents. If the potential maximum fault current rises above the network fault level rating of the protective equipment, the flow of fault current may not be able to be interrupted and could result in catastrophic failure.

LCNF projects have developed and trialled advanced fault level management solutions that provide a range of innovative fault level mitigation techniques that can be adaptively controlled. These techniques avoid the need to prematurely replace capital intensive assets in the network (e.g. switchgear, transformers and cables), while also improving the utilisation of electricity network capacity. This facilitates the timely and cost-effective connection of customers' generation and demand and enhances security of supply. WPD’s FLEXDGRID project is exploring the deployment of several complementary methods to address the fault level management problem:

- Enhanced fault level assessment: this method has investigated the existing fault level calculation techniques and the connection assessment methodologies used to quantify the impact of demand or generation connections to the electricity network. The connections assessment process considers the impact of new connections on voltage, power flows and fault level under worse-case network operating conditions. The method has provided refined analysis techniques to understand the areas of the network that are likely to exhibit fault level issues. A Fault Level Index has been created, similar to the equipment Load and Health Indices, to characterise substations and determine where to deploy fault level monitoring and mitigation equipment. The learning captured from these enhanced assessments provide customers with more accurate and refined network connection offers.

- Real-time management of fault level: this method has deployed new real-time fault level monitoring techniques to measure the prospective fault level on a periodic basis. Real-time fault level measurement devices have been placed in the distribution network, to gather fault level data for various network running configurations and conditions and to determine the fault level. Real-time fault level management provides increased visibility and confidence in network operating conditions that could allow the safety margin to be reduced without compromising the safety of the network operator employees and the public. This fault level headroom gain translates to allowable additional capacity for customers' connections.

- Fault level mitigation technologies: this method has installed and trialled different technologies to limit fault level in distribution networks such as fault current limiters. The technologies have been installed in substations exhibiting fault level issues and where new connections were expected to cause an increase in fault currents. The method has delivered headroom gains as it has added fault level capacity by reducing fault currents.

Enhanced fault level assessment has delivered novel design tools with a direct impact on distribution network planning by identifying the most appropriate locations for fault level monitoring equipment. Novel fault level monitoring equipment has been installed within substations having a direct impact on distribution network planning and operation by identifying appropriate fault level mitigation technologies to deploy in different network environments. The introduction of mitigation technologies to manage fault level on a system-wide level is a novel operational method. The methods will defer or avoid significant capital investment and create a wider choice of connection options for customers who can accept a flexible connection to the network. These benefits will be provided to customers through advanced and modified generation connection agreements. Each method on its own will help customers to connect DG more flexibly. The methods used together will create greater customer choice and opportunities for connection.

There is other related activity, such as ENWL's Fault Level Active Response, which is currently planning the testing and trialling of near real-time fault level assessment and adaptive mitigation techniques to overcome the fault level challenges faced by network operators. The project is seeking to demonstrate that fault current can be managed at lower cost using existing assets and new commercial techniques. The project activities are deploying innovative intelligent software, namely the Fault Level Assessment Tool, to continually assess the fault level in distribution networks. Where this is found to be higher than a pre-set threshold, the tool will issue commands to enable a fault level mitigation technique that will operate in the event of a fault to manage the fault current safely. Three key techniques, designed to regulate fault level current in distribution networks, are currently being explored for real-world trial deployment: adaptive protection, fault current limiting service (i.e. commercial solution) and fault current limiting devices (known as IS-limiters). The new fault level mitigation techniques are only intended to operate in those rare occurrences when they are enabled and a fault occurs. Standard protection will operate for faults when the technique is disabled. This active response ability enables the extension of the useful life of protection equipment avoiding the need for costly reinforcement.

Dynamic ratings

The present industry best-practice for network planning and design uses the static thermal rating of assets (i.e. overhead lines, cables and transformers), based on representative equipment loadings and typical seasonal ambient conditions, to determine capacity. In real-time network operation, allowing more electricity to flow through an asset than it is designed to carry can cause excessive heat and can potentially result in asset damage and network outages. Consequently, the use of generic asset ratings that do not consider the actual thermal conditions experienced can lead to unnecessary triggering of network reinforcements and corrective measures to reduce load due to indications that thermal headroom is breached.

Real-time monitoring of loading and ambient conditions enables assets to be rated dynamically. The dynamic rating can be significantly higher than the static rating, either due to more favourable environmental factors (e.g. high winds) or reflecting that the asset takes time to heat up. This can release additional network capacity, potentially avoiding costly network reinforcement for relatively small levels of demand growth.

Several Tier 1 and Tier 2 projects including Flexible Approaches for Low Carbon Optimised Networks, Low Carbon Hub (both WPD) and Customer-Led Network Revolution (Northern Powergrid) have trialled Real-Time Thermal Ratings (RTTR) of overhead lines, cables and transformers as a smart grid solution to defer network reinforcement and manage increasing levels of demand and/or generation.

Some innovation activities have developed methodologies and algorithms for the quantification of the dynamic rating values and subsequently implemented them in the RTTR system. The algorithms have been tested and quality assured against the real-time monitored temperature and loading data. Significant data analyses were subsequently performed on the calculated and monitored data to determine the network capacity that could be unlocked by using the RTTR system.

These innovation trials have demonstrated that the calculated dynamic rating values can provide a relatively significant thermal rating uplift compared to the respective static seasonal thermal rating. Therefore the deployed RTTR systems have the real potential for unlocking significant network capacity in specific cases. However, due to the specific locational issues regarding the exposure of assets to variations in temperature and wind speed, RTTR solutions do not universally release additional capacity. Indeed, there can be cases where the rating of assets should be reduced due to prevailing ambient conditions.

Therefore, RTTR is being used in BAU, but they are not universally applied, rather they are considered as alternatives to conventional reinforcement on a case-by-case basis.

Network simulation and modelling

The ability to comprehensively understand and forecast network behaviour is becoming critically important as power flows increase in magnitude and variability. Also, as the range of, and complexity of, solutions increase, network designers and planners will require a new suite of tools in order to apply the most cost effective, technically viable solution. The LCNF projects have developed new tools and techniques to understand this challenge and produce deployable tools for use by network operators and customers.

UKPN's Flexible Plug and Play Low Carbon Networks project developed a novel desktop network planning tool, the Strategic Investment Model, to analyse the benefits of smart technologies and smart commercial arrangements that were trialled and demonstrated in the project. The model automates traditional network planning practices based on load flow analysis and provides the capability of optimising and coordinating a portfolio of smart and traditional investment decisions across multi-year time horizon.

In order to successfully integrate low carbon technologies into distribution networks, there are a number of challenges for the planning and design function within a DNO business. The planning approach must adapt to assess the likely volumes of these low carbon technologies and the effects they will have on electricity consumption over time. It is also necessary for planners to consider a range of novel solutions and approaches to mitigate these effects and to apply new design practices consistently. To date, a large amount of effort has been expended on understanding the novel approaches through field trials; but it is becoming increasingly important that this knowledge is transferred into the day to day network planning and design activities.

Thus, NPg's Customer-Led Network Revolution project has developed a novel desktop software tool: Network Planning and Design Decision Support (NPADDS). This is aimed at allowing network planners, designers and connections staff to assess the distribution network for thermal and voltage constraints and to evaluate the effectiveness of smart and conventional solutions at managing those constraints. NPADDS features five key functionalities:

- Network headroom: calculates network headroom using load flow;
- Load and low carbon technology forecasting: simulates load growth and LCT uptake scenarios, by allocating load increase and LCTs across consumers on a specific network;
- Network solutions: proposes potential solutions to a given network constraint.
- Cost Benefit Assessment: a range of solutions can be assessed against costs, benefits and technical merit;
- Thermal properties: analyses thermal performance of cables and transformers, based on the loading of individual pieces of equipment.
- Policy compliance: provides context specific guidance on network operator policies, design procedures and codes of practice.

To date, these outputs have not been transferred into BAU as the challenges for this (and similar tools in other DNOs) is the wide scale integration into DNO IT systems. Such a process is time consuming and costly. Other projects continue to investigate the benefits that can be realised through having more advanced modelling tools at their disposal.

For example, SSEPD's Solent Achieving Value from Efficiency project is seeking to develop two models. The first, a Customer and Community Model will identify how an individual customer, type of customer or community will respond to an energy efficiency measure. The second, a Network Model, will simulate operation and management of electricity distribution networks considering the energy efficiency interventions. The Customer/Community Model and the Network Model will be combined to develop an overarching Network Investment Decision Tool that allows network operators to assess and select the most cost efficient methodology for managing distribution network constraints with respect to both energy efficiency and traditional network reinforcement methods.

Electrical energy storage

The increased uptake of LCTs on distribution networks will result in increased peak network flows and therefore the requirement for additional capacity. Traditional network reinforcement is costly and can lead to overcapacity on the network (peak loading may only occur for a few half hours a year). This in turn translates to reduced network utilisation and hence poorer operational economics. Simultaneously, at system-wide level, the shift in generation mix towards renewable and nuclear will result in a supply side that is less flexible and more variable, creating challenges for both the real-time balancing of the system, and dealing with larger unforeseen variations in generation.

A number of innovation projects, including UKPN's Smarter Network Storage, Northern Powergrid's Customer-Led Network Revolution and WPD's SoLa Bristol, have explored the deployment of large scale (many MW) energy storage as an effective way of overcoming a wide range of constraints on distribution networks, thus avoiding the need for traditional reinforcement and increasing utilisation.

The projects have also recognised that deploying storage for a single network application is usually economically inefficient. Thus, the Smarter Network Storage project studied the deployment of large scale energy storage on distribution networks as a system-wide source of flexibility by providing reserve and response support to the balancing and stability of the transmission system. In this respect, it trialled innovative technical and commercial techniques to provide the means for storage to be used to solve distribution network constraints, whilst ensuring the value of the flexibility is maximised for the benefit of the wider system and customers. Specifically, the innovation activities undertaken within the projects focussed on:

- Deployment of large-scale distribution-connected energy storage;
- Implementation of a Smart Optimisation & Control system in order to manage and optimise the storage flexibility;
- Innovative commercial arrangements to support the shared use of energy storage in providing wider system benefits, including standby reserve and managing frequency; and
- Assessment and validation of the full value that storage can provide to DNOs and the wider system to support future business models for storage.

Project field trials have installed energy storage facilities at primary substations to demonstrate the capabilities and value of storage in the following areas:

- Peak shaving: reduction of the overall peak demand by providing additional energy to offset demand at peak times;
- Reactive power compensation: provision of reactive power from the power-conversion-system of the storage device to correct power factor, reduce losses and improve the real power capacity of the network circuits;
- Voltage support and stabilisation: through dynamic provision or absorption of energy, the voltage on the local network can be maintained within statutory limits more dynamically;
- Ancillary services: provision of reserve services via National Grid's short-term operating reserve (STOR) market; provision of static frequency response to maintain system stability in the event of unplanned outages or changes in demand/generation; and provision of dynamic frequency response to support real time deviations in system frequency.

Innovation projects have trialled novel commercial arrangements for energy storage in conjunction with control systems to maximise the value of the storage across the system. This included the interface between the energy storage device control system, the distribution network control room and the other electricity system participants that benefit from use of the flexibility provided by the storage.

Trials have demonstrated that network support provided by storage has helped accommodate load increases, avoiding the immediate need for reinforcement. The knowledge and learning from trials that use energy storage to support the wholesale electricity market and in offering multiple services simultaneously has been used to provide a robust assessment of the full potential value of storage based on real demonstrations, and how this can support the business models for future deployments of storage.

However, the historical treatment of energy storage as a subset of generation does pose some issues and create uncertainty regarding its ability to be used widely by DNOs. UKPN's Smarter Network Storage reports "The distinction between storage and generation needs to be acknowledged. Given the ripple effects of current default treatment as generation for ownership and operation options, this issue is a significant barrier to future deployment of storage."[11]

Other projects including WPD's SoLa Bristol, have trialled the deployment of energy storage devices in customers' premises to mitigate distribution network constraints at specific times of the day. The operation of the battery storage devices is shared virtually between the network operator and the customer to provide benefits to both parties. The trials have demonstrated that through batteries, the low voltage network has been operated more actively with additional capacity to manage peak load, control voltage rise and reduce system harmonics.

Demand side response

Innovation projects have deployed demand side response as a technical and commercial smart grid intervention to address distribution network constraints relating to limited network capacity and power quality issues (e.g. voltages outside of the statutory limits). Projects such as SPEN's Flexible Networks for a Low Carbon Future, ENWL's Customer Load Active System Services, NPg's Customer-Led Network Revolution and UKPN's Low Carbon London have trialled different demand side response techniques that enable the reduction of load by either

- Deferring or forgoing electricity consumption;
- Increasing generation to reduce import; and/or
- Increasing export of power to the distribution network.

These technical approaches have been proposed in conjunction with new commercial agreements. The agreements between the network operator and the customer allow the network operators to call upon flexibility in the customer's demand and/or generation to either increase or decrease power flows in the network, as required, to remove constraints from the network. Broadly, the contracts for the demand side response services have been characterised by a payment structure based on availability (i.e. being available to perform) and utilisation (i.e. being called to perform). The contracts have been established directly with Industrial and Commercial customers and via aggregators.

Distribution networks are currently designed with reasonable levels of redundancy to comply with security of supply standards. They are often interconnected by a normal open point which is only utilised in the event of a network fault or planned outage to re-supply customers from an alternative circuit. This planning and design philosophy means that the higher voltage circuits of the distribution network are typically operated at only 50–60% of their rated capacity in normal operation.

Projects such as ENWL's Capacity to Customers have applied proven techniques for network redesign (e.g. temporary meshing by closing normal open points) in conjunction with new customer commercial arrangements to release this inherent capacity and maximise the utilisation of the installed network capacity. Thus, to ensure that security of customer supply is maintained and that

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[11] UKPN (2015) Smarter Network Storage: Recommendations for regulatory and legal framework http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Smarter-Network-Storage-(SNS)/Project-Documents/Report+9.5+19Oct_v2.1_%28Final+Photos%29.pdf

supplies can be restored during fault outages, new post-fault demand response contracts, allowing network operators to reduce the consumption of contracted customers on the relevant circuits, have been developed and trialled. For new customers connecting to the network the new commercial arrangement offers the option to sign up to a managed contract in exchange for a reduced connection charge (i.e. equivalent of the saving of reinforcement costs). The contract allows the network operator to manage the customer's consumption at the time of a fault and hence enables the network operator to get all customers back online in as short a time as possible.

ENWL's Customer Load Active System Services has explored the application of new demand side response mechanisms to provide frequency management capability to the transmission system operator. The mechanisms have been designed to reduce demand at primary substations via voltage control within very short timescales. Innovation activities have trialled the following demand side response mechanisms for frequency response:

- Primary transformer: the disconnection of one of a paired arrangement of transformers at primary substations will result in the voltage supplying the substation load to instantaneously reduce triggering a demand reduction. The disconnection of a primary transformer has been achieved by automatic on-site detection of a low frequency signal.
- Tap Changer Operation: Change of secondary network supply voltage at a primary substation by raising or lowering the tap positions of the power transformers and consequently changing the level of demand.

The trials have confirmed both these mechanisms could be tailored to the Frequency Control by Demand Management (FCDM), Firm Frequency Response (FFR) and Fast Reserve (FR) commercial services

The provision of these frequency management solutions can contribute to a reduction in costs of the ancillary services market borne by all electricity customers as the need for spinning reserve are diminished.

Energy efficiency

Network operators are projecting increasing and more uncertain demands on the distribution networks, as the result of the electrification of heat and transport and the increased reliance on distributed generation. The participation of customers in schemes to reduce or time-shift demand will contribute to mitigating this substantial challenge and to achieve sustained energy savings. Energy efficiency measures can reduce customers' electricity bills and also support the distribution network by deferring or avoiding network reinforcement.

SSEPD's Solent Achieving Value from Efficiency (SAVE) project is currently designing and implementing customer field trials to establish to what extent energy efficiency measures can be considered as a cost effective, predictable and sustainable tool for managing peak demand as an alternative to network reinforcement. In particular, SAVE is evaluating the potential for network operators to investigate different types of energy efficiency opportunities that will incentivise customer behaviour change resulting in reduction of peak and overall demand on the electricity distribution network. Four energy efficiency interventions are being trialled to test their effectiveness in reducing and/or time-shifting electricity demand:

- LEDs: the provision of low energy LED light sources to reduce overall power consumption, especially at evening peaks;
- Enhanced engagement campaign: the provision of innovative information and media communications drawing on usage monitoring data (collected from the sample households during the baseline stage) and aimed at reducing overall consumption;
- DNO Time of Use (ToU) rebates: this intervention will combine the 'enhanced engagement campaign' above with network operator offered ToU incentives at different times of day to incentivise time-shifting of demand; and

- Community coaching: the provision of local community engagement activities through the embedding of a Community Energy Coach in two case study locations.

Another recently initiated LCNF project, UKPN's Vulnerable Customers and Energy Efficiency (VCEE) is currently working with fuel poor customers to understand their requirements (which have a significant overlap with those who are vulnerable). VCEE is exploring means of encouraging increased participation in energy efficiency through working collaboratively with key electricity suppliers and local community actors. The project activities are currently designing and implementing customer field trials to identify the magnitude of energy savings when participants have access to smart meters, in-home displays (IHDs), simple affordable energy saving devices and energy advice.

The trials will support these domestic customer groups in achieving the potential benefits of energy efficiency and help network operators manage the increasing and uncertain demands on the network. In addition, the trials will help network operators to develop the specific customer engagement measures that are required to ensure that fuel poor customers are effectively assisted, as smart technology, energy saving and shifting devices evolve.

Smart meters and time of use pricing

The mandated roll out of smart meters to the majority of domestic and business premises in the UK by 2020 will enable the introduction of Time of Use (ToU) pricing. The potential to reduce peak demand and shift load using ToU pricing brings prospective benefits for stakeholders across the value chain. However, most ToU pricing initiatives in GB have, to date, been led by energy suppliers, and based on potential wholesale cost savings rather than on the potential (local) network benefits. The use of ToU pricing schemes could potentially be used to defer the need to carry out reinforcement works on the distribution network. Customers on dynamic ToU tariffs might provide a response during a network outage. For example, if there is a capacity shortfall ahead of scheduled reinforcement works.

The LCNF projects described below designed, implemented and delivered smart meter customer trials in conjunction with ToU pricing to evaluate the benefits to both network operators and energy suppliers. The smart meter trials were mostly performed with domestic customers and studied the response of customers to static and dynamic ToU tariffs.

Northern Powergrid's Customer-Led Network Revolution used smart meters and static ToU tariffs to encourage customers to shift load away from periods of network stress (e.g. peak demand periods). Static ToU tariffs vary the electricity price by time of day during fixed time periods and price differentials. Domestic customers participating in the field trials were equipped with smart meters and In-Home Display (IHD) units providing a near real time signal of their current electricity load through a traffic light system and retrospective visualisations of electricity consumption. Additionally, customers were given access to a three band (day, evening and night) static ToU tariff characterised by higher electricity prices during the weekday peak period (e.g. 4pm-8pm) and lower prices in weekday off-peak periods and weekends. The tariff was designed to incentivise customers to shift electricity use from the peak demand periods into day periods, evenings or weekends.

UKPN's Low Carbon London used smart meters and dynamic ToU tariffs to send price information (e.g. high price signal) to customers, at short notice, to encourage customers to shift load away from periods of critical network events. Customers were informed of price events at the day-ahead stage through messages sent to the IHD units connected to the meter. The dynamic ToU tariff evaluated through the smart meter customer trials have broadly included two types of price event:

- Constraint management: a high ToU price has been used to encourage customers to shift load away from periods where network constraints are active. Constraint management events have included a high price surrounded by two low price periods to maximise the price differential that the customer is exposed to, aiming to simulate the high level of response that a network operator would seek during a high load period.

- Supply following: a combination of both high and low ToU prices are used to encourage customers to shift load away from periods where there is a shortfall in the supply of power to periods where there is surplus supply of power (e.g. periods of high wind generation). The events are intended to evaluate the response available from customers to support energy suppliers matching their contracts with generators and customer demand or to help the System Operator managing an operational constraint in the system.

These trials demonstrated that for network operators to realise network benefits through ToU tariffs, high price signals would need to be focused on periods of local network peak load. Such a signal would need to be controlled by network operators. Thus, two potential commercial models for ToU initiatives driven by network benefits have been considered:

i. The introduction of dynamic ToU Distribution Use of System (DUoS) charges. In constrained network areas network operators would focus variable DUoS charges on peak load hours to encourage load shifting. Under this option energy suppliers would need to be subject to a mandate to pass through these price signals to individual customers.

ii. Network operators to enter into commercial arrangements with energy suppliers for them to recruit customers onto a specific ToU tariff targeted at a particular network constraint. In this case customer uptake would be voluntary.

Whilst the application of ToU tariffs has generally been wholesale price-driven to date, the smart meter customer trials showed that there could be benefits available for network operators through the application of ToU tariffs for deferral of network reinforcement and mitigation of capacity shortfalls ahead of, or during, work to reinforce the network.

2.4 Conditions for connections

As a consequence of LCNF projects, DNOs are increasingly adopting processes to more flexibly manage connection requests; particularly those associated with renewable generation.

The need to enable generation connections to the network in a timely manner is a challenge that the industry as a whole recognised as being important in order to achieve overall carbon targets. DNOs have been able to offer improved information to potential generation connections and to accelerate the process by which these connections can be achieved, along with offering flexible connections at a reduced cost.

The use of active network management together with innovative commercial arrangements have allowed for considerable savings in this area and significant improvements to the BAU approaches of DNOs.

The 'conditions for connection' Output is related to the delivery of a fair, efficient and competitive service to all connections customers. Table 1 indicates that most of the LCNF projects have contributed, in some form, to this regulatory Output. Generally, the innovation projects have addressed the need for a more flexible, cost efficient and competitive approach to generation customer connections through the **development of new connection techniques and innovative contractual arrangements**.

During the 'project planning' and 'information' phases of the connection process, distributed generation developers tend to use the Long-Term Development Statements (LTDS), published by the DNOs. This allows the generation developers to identify: current and future development plans for the network; parts of the network where multiple developments for generation connection are under consideration; parts of the network with limited thermal headroom and plans to relieve network stressed areas. Nonetheless, the LTDS do not provide a reliable indication of the various potential combinations of generation which may eventually be connected, the order in which different generators will be connected, nor the timing for the requirement of substantial network reinforcement. This brings uncertainty to developers by leaving them in the unsatisfactory position of being unable to reliably predict network connection costs and therefore the commercial viability of their project.

LCNF projects, such as SPEN's Accelerating Renewable Connections, along with other non LCNF activities have encouraged DNOs to create stakeholder engagement forums to discuss generation connections issues in the distributed generation connection process. Significant learning has been produced on how improved dialogue between DNOs, developers and other parties such as local authorities and planners can help with the connections process. Feedback from the stakeholder engagement forum has helped improve the connections process.

Projects have **enhanced the information available to distributed generation developers**, beyond the statutory obligations of LTDS and Distributed Generation Connection Guides, **to allow them to make more informed choices**. Innovation activities have trialled the publication of up-to-date network information and data on a more regular basis.

- Specific sub-sets of the LTDS have been published providing granular data on connected, contracted and in-process applications for generation connections. The customer field trials have been used to determine how often the LTDS, or certain aspects of it, should be refreshed and published.
- Network heat maps have been published providing a 'rule of thumb' view of where cost effective connections will be possible based on distance from each substation and what can be accommodated through a diverse range of connection options (e.g. traditional connections

or smart interventions such as non-firm connections via improved network management techniques).

Projects have also trialled the introduction of an ‘enhanced connections process’ option whereby the network operator works with the generation developers prior to them submitting a formal connection application to help consider the potential options for a cost effective and timely connection. This process is intended to happen in addition to the present informal communication that exists as part of the information phase of the connection process. This creates an improved customer service by allowing customers to explore options for connections.

Through projects such as UKPN’s Flexible Plug and Play Low Carbon Networks, technical innovation in the form of ANM for decentralised monitoring, control and overall operational management of both network and distributed generation has been implemented. ANM demonstrated the ability of actively managing distributed generation export and distribution network configuration on a real-time basis, to enable a closer match of generation export and network capacity and to permit additional connections of distributed generation.

The current interactive connection application approach, applied to multiple generator applications that have an impact on the same part of the distribution network, considers each generator individually and therefore fails to recognise the possible benefits of considering groups of generators. The approach restricts network operators from taking a holistic approach to connecting distributed energy resources and potentially leads to a disjointed and sub-optimal network investment.

Real-world field trials have demonstrated the process for large scale deployment, implementation and management of ANM solutions including:

- Integration of smart devices to facilitate the management of distribution network constraints to accommodate higher levels of distributed generation;

- Integration of smart applications such as ANM to coordinate smart devices and generator active and reactive power to manage network constraints and therefore accommodate higher levels of distributed generation;

- Integration of an Information and Communications Technology (ICT) platform to facilitate the necessary information exchange and control capability across all smart devices and applications; and

- Development and implementation of smart commercial arrangements that define access to the network capacity available in real-time for more than one renewable generator.

Projects have **delivered commercial innovation by developing new commercial arrangements and connection agreements that enable distributed generators connected to the distribution network to be actively managed**, i.e. have their output regulated to meet distribution network constraints. The new commercial arrangements have delivered significant advancement on the existing connection charge assessment procedures by providing mechanisms that fairly apportion costs between generation developers. In particular, the contractual arrangements have addressed issues such as defining access to the network capacity available in real-time for more than one generator and estimating the anticipated energy volumes exported.

The penetration of higher volumes of distributed / embedded generation on the distribution network is starting to have an impact upon the transmission system to the effect that, within some DNO areas, relatively small generation projects are unable to connect ahead of major reinforcement works being completed on the transmission system. Furthermore, the existing distributed generation capacity currently exceeds the demand in some parts of the DNO licence areas, leading to Grid Supply Points (GSPs) within the area exporting power onto the transmission system.

Projects including SPEN's Accelerating Renewable Connections are currently exploring technical and commercial solutions to manage these constraints around the boundary with the transmission network. These include providing National Grid with visibility of the distributed generation connected (and contributing to energy export) from the GSP, and the operation of the ANM system managing generation connected below that GSP (i.e. within the distribution network). Thus, innovation activities will develop a link between the DNO and Transmission System Operator control rooms to share information and enable the ANM system to manage power flow constraints beyond the distribution network boundary in partnership with National Grid and the 'Connect and Manage' regime.

Several of the techniques described in this section have contributed to significant learning being adopted within BAU processes by the DNOs **to dramatically reduce both the time required to permit a connection of distributed generation to the network, and also the cost that would be borne by the generator** for reinforcement or enabling works to facilitate such a connection.

2.5 Environment

All projects in LCNF can be considered to have some positive environmental benefit given that they are enabling the transition to a lower carbon future.

A focus on the environmental benefit as the primary driver is rare as there is usually some other focus which has a positive effect on the environment as a consequence. However, through LCNF learning, DNOs are contributing to significant saving in carbon and also enabling the transition to decarbonised heat and transport.

For example, LCNF learning has enabled DNOs to better understand the implications of wide-scale uptake of electric vehicles and to trial technologies and approaches to be ready for that uptake. This is not yet in BAU, but is intended to be ready for the time at which this uptake reaches a critical mass.

Some projects are also considering the ability of networks to reduce losses through more active management, but these are still in progress and are not yet in BAU.

Low Carbon Network Funding was intended for DNOs to 'explore how networks can facilitate the take up of low carbon and energy saving initiatives' hence **all the projects on some level bear a positive environmental effect**. The projects involving Low Carbon Technologies, such as Electric Vehicles (EVs) and Heat Pumps, along with those that trial energy saving devices and initiatives, are given the greatest weighting in Table 1: LCNF Tier 2 projects and associated Outputs of the regulatory RIIO-ED1 framework. Renewable energy generation connections and deferred reinforcement also bring significant carbon emissions savings.

Allowing more low carbon technologies and renewable energy generation has a primary positive environmental effect. My Electric Avenue (MEA) was the largest LCNF Tier 2 project focused on trialling the impact of EVs on the electricity distribution network. Over 18 months 213 participants made journeys totalling 3,081,328 km in Nissan Leaf EVs representing a saving in direct emissions of around 105 tonnes of CO_2e as compared to the next best alternative, a new diesel vehicle. The **conventional means of enabling the load growth represented by low carbon technologies (reinforcement of the ageing network) is environmentally costly**. The civil work and material requirements for network reinforcements constitute significant carbon and other greenhouse gas emissions. My Electric Avenue found the penetration levels (amount of EVs on a network) at which network intervention is required and used this to assess the benefit of 'Esprit', a demand side management tool also tested in the trial, as compared to the conventional approach to network reinforcement. In the case of Low Voltage networks such as those assessed during the trial, reinforcement entails: the excavation of roads, laying new or additional cables, backfilling and reinstatement. By deferring or avoiding reinforcement through the implementation of Esprit MEA projects savings of between 11.4 and 19.4 tons CO_2e emissions by the end of 2030[12].

Customer Load Active System Services (Tier 2) findings **corroborate the environmental benefit of demand management** or response. ENWL state that the carbon benefit from the trialled combination of demand response and reactive power ancillary services could be as much as 116,000 tCO2e per annum[3]. The Tyndall Centre indicates that deployment of the Capacity to Customers (C_2C) Solution in conjunction with strategic traditional reinforcement on Electricity North West's HV network in the period 2015 - 2035 would give a net network wide reduction of 237-328 tCO_2e. This is based on saving 58,000 – 89,000 tCO_2e network wide from reduced deployment of assets and decreasing carbon associated with losses by 179,000 – 239,000 tCO_2e relative to traditional reinforcement techniques. Based on advancing connections by around six months, the C_2C Method could directly claim to facilitate 39,000 – 67,000 tCO_2e of emissions reductions in Electricity North West network area (depending on how the capacity is used)[13].

Besides demand side management there are various other solutions that infer an environmental benefit. From data gathered during the LV Templates project, WPD were able to calculate that a reduction in HV and LV system voltage will reduce CO_2 emissions by some 41000 tCO_2e each year, based on DECC 2011 data.

A number of the projects estimated the carbon savings associated with applying learning from a number of trialled solutions both technical and commercial:

- Customer-Led Network Revolution (CLNR): Northern Powergrid state that adopting the project learning is expected to yield between 10.8 and 32.5 Mt of CO_2 emissions savings between 2020 and 2050 for the low and high DECC LCT uptake scenarios. £0.32bn and £0.94bn carbon savings relating to the acceleration of the connections of LCTs[7].
- Low Carbon London (LCL): UKPN estimate that £7.5 - £8.5bn might accrue to the electricity system more broadly as a result of avoided carbon emissions and carbon penalties[14].

In addition to trialling various smart technologies, the Low Carbon London project explored ways of **enabling the electrification of heat and transport**. The closedown report says that if only one of the initiatives demonstrated is fully adopted across the country, a contribution of 5g/kWh towards reducing the carbon emissions from today's electricity system would be achieved, with the potential for far more.

Further projects, such as SSEPD's LEAN, are being explored to examine how **losses within networks can be reduced** by the more active management of network assets; such as switching off one of a pair transformers during times of low load, thereby avoiding the losses associated with that asset being energised.

It is important to recognise that the carbon saving figures are predictions based on assumptions. Further detail is available in each respective project's Closedown report.

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[12] EA Technology (2015) Successful Delivery Reward Criteria 9.8: An assessment of how much headroom an Esprit type solution would yield. (Online). Available: http://myelectricavenue.info/sites/default/files/My%20Electric%20Avenue%20%28I2EV%29%20SDRC%209.8%20Issue%201.4.pdf Last Accessed: 5 March 2016

[13] ENWL (2015) Capacity to Customers Project Closedown Report. (Online). Available: http://www.smarternetworks.org/Files/Capacity_to_Customers_150929103926.pdf Last Accessed: 10 March 2016

[14] UKPN (2015) Low Carbon London Project Closedown Report. (Online). Available: http://www.smarternetworks.org/Files/Low_Carbon_London_150701162635.pdf Last Accessed: 10 March 2016

2.6 Social obligations

DNOs have a requirement to consider their social obligations and to assist vulnerable customers. The vulnerability of a customer can be determined by their location and several projects have investigated approaches to improve the quality of supply received by remote island communities, with significant learning being gained in this area.

Vulnerable customers can also be defined by socio-economic status and one project has recently been initiated to specifically address such customers through engagement with social housing landlords.

Other ‘in-flight’ projects are looking at the way in which customers can save money through enhanced energy efficiency measures. Clearly, by reducing energy consumption, this can have a knock-on effect to avoid the need for expensive network upgrades.

In the main, this Output is not the main driver of LCNF projects, but nonetheless there is valuable learning that can be realised from such projects.

UKPN’s Tier 2 VCEE (Vulnerable Customers and Energy Efficiency) project addresses this RIIO Output most directly. It aims to trial technical solutions for the ‘hard-to-reach’ customers. At the time of writing the project is at the recruitment and installation stage. The Tier 1 project ‘Validation for Photovoltaic (PV) Connection Assessment Tool’ was subject to a three and a half month delay as a result of needing to gain trial participation agreement from more stakeholders than was originally anticipated but this learning was fed into VCEE. Landlords for tenanted properties were engaged as full project partners, from the beginning, with the help of a Customer Engagement Plan developed during the Tier 1 project. It should be highlighted that **a key benefit of the LCNF projects is the increased stakeholder engagement** driven by a need to bring on board participants willing to trial the technologies and feedback.

Beyond the socio-economic status, the vulnerability of a customer is also dependent on their location. The geography of the land makes transmitting electricity to and from certain areas more difficult and costly. A number of Tier 1 LCNF projects worked on delivering improvements to customers living in vulnerable parts of the network, in particular the islands off the North East and South West coasts of the UK – namely, Orkney and the Isles of Scilly. The DNOs with the relevant licence areas led these projects to **alleviate reliability issues** through employing a number of solutions such as Electrical Energy Storage (1MW Lead Acid battery in Orkney).

Electricity supplies to the Isles of Scilly consist of a single 33kV undersea cable from the mainland, supplemented by an island-based diesel generating station and generators on two outer islands with limited availability. WPD worked with the islanders through a LCNF project to help make the isles’ energy self-sufficient. The project established real time monitoring of substations, using a range of communications techniques. The project also developed advanced remote generation control to improve the reliability and availability of electricity supply.[15]

Other projects looking at energy efficiency measures to help reduce customer bills have previously been discussed and these projects also help deliver benefits and learning within the social obligations Output.

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[15] WPD (2013) Isles of Scilly. (Online). Available: http://www.westernpowerinnovation.co.uk/Projects/Isles-of-Scilly.aspx Last Accessed: 25 February 2016

3. Conclusions

The key findings of the analyses performed by EA Technology can be summarised as follows:

- LCNF projects have shown that a number of innovative technologies and approaches can provide benefits to customers. Examples of these technologies include those associated with active network management, demand side response and voltage management;

- A number of technologies have the potential to deliver further benefits, but certain economic or external barriers exist and therefore this potential cannot be realised immediately. For example, some demand management techniques can only deliver benefit when smart meters are fully deployed, or controlled electric vehicle charging technology will only realise its potential when uptake of electric vehicles reaches a certain threshold;

- A number of the technologies trialled within LCNF projects have already been transferred into BAU and are forming part of DNO activities in the current regulatory period. Examples of these include the use of flexible connections, the dynamic reconfiguration of the network to meet demand and restore outages, and demand side response techniques. A large body of the remaining learning from LCNF is in the process of making the transition from innovation into BAU;

- Learning from LCNF projects has contributed to many areas of DNO business activities, including all six of the key RIIO Outputs;

- A wide range of learning has been achieved through LCNF and this is informing ongoing strategy within DNOs regarding which projects to pursue next. The LCNF results provide a solid foundation upon which to build future innovation projects;

- Learning from projects regarding new customer technologies, such as electric vehicles, has assisted DNOs in preparing to meet the future challenges that these technologies will pose and hence to improve their state of readiness to meet the longer term needs of both customers and the network;

- The greatest benefits are observed in improving network performance and flexibility. Improvements in this area are likely to have direct consequential improvements such as the satisfaction of customers as a more reliable network, or shorter durations of interruptions.

Appendix I Framework for summarising learning of the Low Carbon Networks Fund projects

This section provides an overview of the framework developed to produce the summary of the key learning delivered to date by the innovation projects awarded under the LCN funding mechanism.

The LCNF stimulated the real-world trialling of new technologies and services, knowledge exchange across the electricity industry and a culture change among the DNOs so that innovation becomes a core part of their business. The LCNF has delivered extensive learning to the electricity industry through a wide range of projects involving the six GB DNO companies and various cross-industry partners and stakeholders. Under the regulatory RIIO-ED1 framework, DNOs are expected to deliver a series of well-defined Outputs in return for earning revenue from consumers. The framework focuses on mapping the key learning of the LCNF projects onto the six Output categories that network companies are expected to deliver throughout the RIIO-ED1 period. The Output categories reflect the broad role that energy network companies will play in delivering the objectives of the RIIO model and are defined as follows:

- **Customer satisfaction**: provide excellent customer service;
- **Safety**: minimise the safety risks associated with operating the network;
- **Reliability and availability**: maintain a reliable supply of electricity through a more resilient network;
- **Conditions for connection**: provide an excellent service for customers connecting to the network;
- **Environment**: reduce DNO’s own impact on the environment and facilitate lower carbon technology; and
- **Social obligations**: meet the needs of vulnerable customers.

Customer satisfaction

In the UK people expect a steady, reliable supply of electricity. If there are deviations from the norm customers like to know why. Certain customer segments want to engage in the development of a low carbon economy and more environmentally friendly lifestyles and the opportunity to take part in Innovation projects is welcomed.

Areas where customer satisfaction can be determined include:

- Customer service;
- Telephone response;
- Communicating with customers;
- Engaging with stakeholders;
- Resolution of complaints; and
- Increasing awareness of Guaranteed Standards of Performance;

Safety

The ‘safety’ Output is associated with minimising the safety risks to people involved with the distribution of electricity. DNO activities in this area include those relating to:

- Compliance with health and safety law;
- Reducing accidents;
- Substation security and theft of equipment;
- Educating the public on electricity safety matters;

Reliability and availability

The reliability and availability Output is broadly related to the delivery of improvements in the performance of the network so that electricity customers have fewer and shorter power cuts. This Output reflects the key learning achieved by the LCNF projects that developed a range of activities contributing to:

- the number and duration of network supply interruptions below a benchmark industry performance level in agreement with the “interruptions incentive scheme”;
- the delivery of specified minimum levels of performance according to the “guaranteed standards of performance scheme”;
- improve the reliability performance experienced by a small number of customers who endure a level of interruptions over and above a determined threshold specified by the “worst served customers scheme”;
- target specific network investments to specific risk reduction associated with the condition and loading of assets based on the “health and load indices scheme”; and
- the ability of the electricity distribution networks to continue to supply electricity to customers during disruptive events, such as severe storms or floods in agreement with the “network resilience”.

Conditions for connection

The ‘conditions for connection’ Output is related to the delivery of a fair, efficient and competitive service to all connections customers. Customers requiring a new connection to the distribution network may include demand connections (customers who use electricity), generation connections (customers who generate electricity and may need to export it into the network) and unmetered connections (customers with equipment that does not have its own meter such as street lighting). The LCNF projects have developed various activities that have contributed to:

- Providing a faster and more efficient connections service;
- Improving communication with customers;
- Enhancing the engagement with ‘major connection’ customers;
- Meeting connections Guaranteed Standards of Performance; and
- Facilitating competition in connections.

Environment

Low Carbon Network Funding was intended for DNOs to ‘explore how networks can facilitate the take up of low carbon and energy saving initiatives’ hence all the networks to some degree have a positive environmental effect. The projects involving Low Carbon Technologies, such as Electric Vehicles (EVs) and Heat Pumps are given the highest scores along with those that trial energy saving devices and initiatives. Renewable energy generation connections and deferred reinforcement also bring significant carbon emissions savings.

Social obligations

The ‘social obligations’ Output is about meeting the needs of the most vulnerable customers. Ofgem defines vulnerable customers as those who are a minority in numbers and:

- Significantly less able than a typical consumer to protect or represent his or her interests in the energy market; and/or
- Significantly more likely than a typical consumer to suffer detriment, or that detriment is likely to be more substantial

Appendix II Tier 1 to Tier 2 Project Mapping

Table 4 shows the mapping of Tier 1 projects which fed into various larger innovation projects. This is relatively easy to track within a DNO as the need and ability to carry out a large innovation project, such as LCNF Tier 2, has been identified following the findings of Tier 1 activities and it is often referred to in published documents. Table 4 shows this flow of learning within each DNO. As a consequence of the requirement for dissemination of project outputs, DNOs build on the foundations of numerous Tier 1 projects when devising larger Tier 2, or other innovation projects. This table indicates the 'direct' flow of learning within a DNO rather than attempting to capture all of the links that exist between such projects.

Table 4: LCNF Tier 1 projects mapped to Tier 2 projects

DNO	Tier 1	Follow-up projects
Electricity North West	The Bidoyng Smart Fuse	Smart Street
	Voltage Management of LV Busbars	
	Low Voltage Network Solutions	
	Low Voltage Integrated Automation (LoVIA)	
	LV Protection and Communications (LV PAC)	
	Combined On-Line Transformer Monitoring	FLARE
	Fault Sense	*ongoing*
Northern Powergrid	33kV SC Fault Current Limiter	*Potential NIA project*
Scottish Power Energy Networks	Real-Time Thermal Ratings	Flexible Networks for a Low Carbon Future
	Ashton Hayes Smart Village	
	Clyde Gateway	*Potential NIA project*
	Hydro Active Network Management	*information not currently available*
	Windfarm Cable Circuits	*NIA project*
	Smart Building Potential	*information not currently available*
Scottish & Southern Energy	1MW Shetland NaS Battery	Northern Isles New Energy Solutions
	Trial Evaluation of Domestic Demand Side Management (DDSM)	
	Orkney Energy Storage Park (Phase 1)	
	Trial of Orkney Energy Storage Park (Phase 2)	
	Benefits of Monitoring LV Networks	New Thames Valley Vision
	Honeywell I&C ADR - Demand Response	
	LV Network Modelling & Analysis	

DNO	Tier 1	Follow-up projects
	LV Network Storage	
	Impact of Electrolysers on the Network	*information not currently available*
	Digital Substation Platform	*NIA project*
UK Power Networks	Short Term Discharge Energy Storage	Smarter Network Storage
	Distribution Network Visibility	** see Appendix IV*
	Smart Urban Low Voltage Network	*information not currently available*
	Validation of PV Connection Assessment	** see Appendix IV*
	Power Transformer Real Time Thermal Rating	*NIA project*
Western Power Distribution	Interconnection of WPD and NGC SCADA	** see Appendix IV*
	Network Management on the Isles of Scilly	FALCON
	Voltage Control System Demonstration Project	*NIA project SVC demonstrator*
	Early Learning of LV Network Impacts from Estate PV Cluster	LV Network Templates
	Seasonal Generation Deployment	*n/a (project halted in summer 2013)*
	LV Current Sensor Tech Evaluation	LV Network Templates
	Implementation of AFLM Scheme	FlexDGrid
	Community Energy Action	Flexible Plug and Play
	Electric Boulevards	*information not currently available*
	PV Impact on Surburban Networks	** see Appendix IV*
	Hook Norton Low Carbon Community Smart Grid	** see Appendix IV*
	Energy Control for Household Optimisation (ECHO)	*ongoing*
	Voltage Control System Integration - D-SVC Phase 2	*ongoing*

Appendix III Tier 2 Project Overviews

The Tier 2 projects were the bulk of the funding representing investment of over £250million as opposed to the £30 million spent on the Tier 1 projects. The key outputs and benefits of the Tier 2 LCNF projects are provided below. All information is taken from project Closedown Reports and Submission Proformas.

It should be noted that all project business cases and benefits stated in the below are as reported by the DNO conducting the project and as part of this work these figures have not been validated or endorsed by either Ofgem or EA Technology.

The mapping of Tier 1 projects to the Ofgem RIIO-ED1 outputs is shown in Table 2. The Tier 1 projects acted as a precursor to Tier 2 projects hence they are not considered separately though some of their unique benefits are described in Section 2.

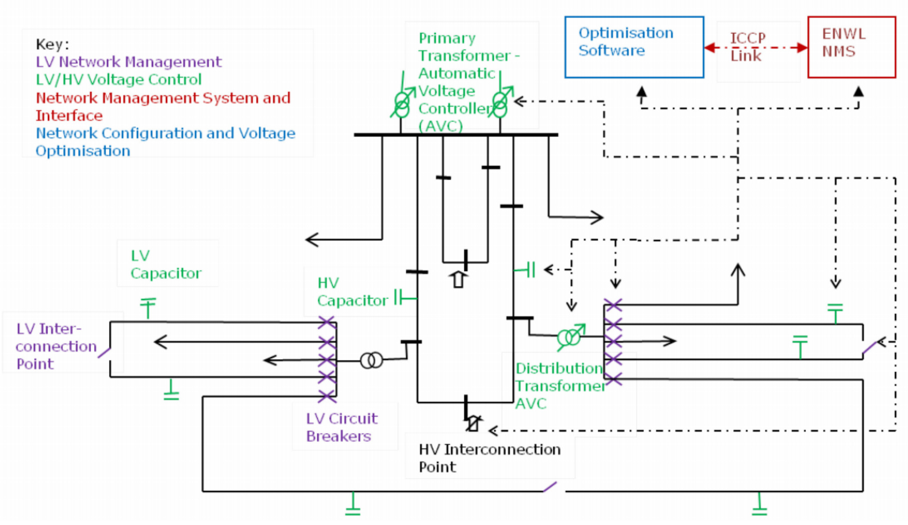
Table 5: Status of the Tier 2 LCNF projects.

DNO	Project Title	Start	End
Completed Tier 2 Projects			
WPD	LV network templates	Apr-11	Jul-13
UKPN	(LCL) Low Carbon London	Jan-11	Dec-14
NPg	(CLNR) Customer-Led Network Revolution	Jan-11	Dec-14
ENWL	(C2C) Capacity to Customers	Jan-12	Dec-14
SPEN	Flexible Networks for a Low Carbon Future	Jan-12	Dec-14
UKPN	(FPP) Flexible Plug and Play	Jan-12	Dec-14
WPD	BRISTOL	Dec-11	Jan-15
WPD	(LCH) Low Carbon Hub	Jan-11	May-15
ENWL	(CLASS) Customer Load Active System Services	Jan-13	Sep-15
WPD	(FALCON) Flexible Approaches for Low Carbon Optimised Networks	Nov-11	Nov-15
SSE	(My Electric Avenue) Innovation Squared: Electric Vehicles	Jan-13	Mar-16
Tier 2 Projects Underway (Appendix I)			
SSE	(TVV) New Thames Valley Vision.	Jan-12	Mar-17
WPD	FlexDGrid	Dec-12	Mar-17
UKPN	(SNS) Smarter Network Storage	Jan-13	Dec-16
SPEN	(ARC) Accelerating Renewable Connections	Jan-13	Dec-16
UKPN	(FUN-LV) Flexible Urban Network – LV	Jan-14	Dec-16
ENWL	(eta) Smart Street	Jan-14	Dec-17
UKPN	(VCEE) Vulnerable Customers and Energy Efficiency	Jan-14	Dec-17
SSE	(SAVE) Solent Achieving Value from Efficiency	Jan-14	Jun-18
New Tier 2 Projects			
UKPN	(KASM) Kent Area System Management	Jan-15	Dec-17
ENWL	(FLARE) Fault Level Active Response	Jan-15	Aug-18
SSE	(LEAN) Low Energy Automated Networks	Jan-15	Mar-19
WPD	(NE) Network Equilibrium	Mar-15	Jun-19

Disclaimer: the non-uniformity seen in the each of the below project summaries is due to the diversity in the material available for each project and the presentation of those available materials. For further information on any of the projects see the ENA portal at smarternetworks.org.

Electricity North West

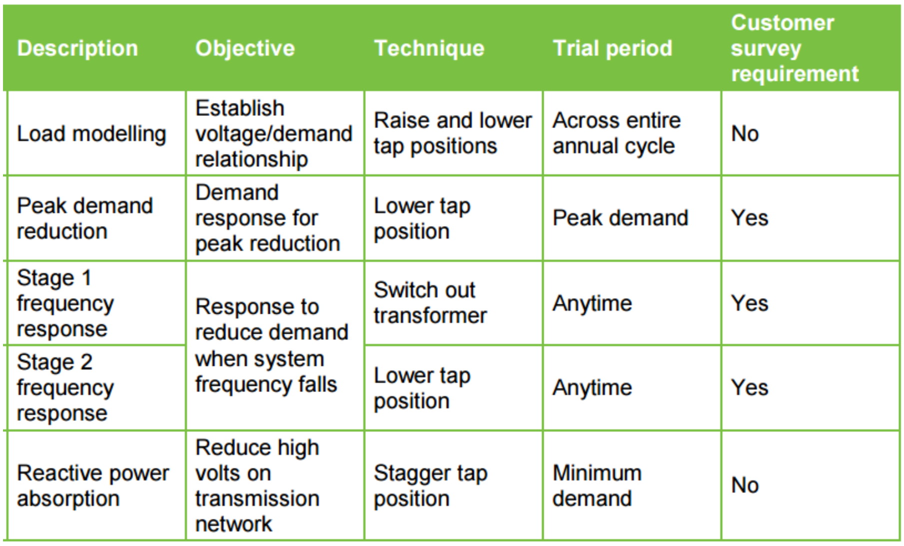
Table 6: Smart Street eta overview.

Project Title	Smart Street eta
Company	Lead: ENWL, Partners: Kelvatek, Siemens UK Ltd and Impact Research
Project Funding:	£11.476m – LCNF Tier 2 inc. partner contribution
Project Driver	Making effective use of interconnection combined with voltage control to facilitate increased use of LCTs and low carbon generation, and to reduce customers' energy consumption.
Project Objectives	To test the following hypotheses: • The 'eta' method will deliver a **reduction in customers' energy consumption** (Research Workstream); • Customers within the 'eta' trial area will not perceive any changes in their electricity supply (Customer Workstream); • The 'eta' method will have no adverse effects on customers' internal installation or appliances (Research Workstream); • The 'eta' method is **faster to apply than traditional reinforcement**, supports accelerated LCT connection and reduces network reinforcement costs (Research Workstream); • The 'eta' method facilitates the prioritisation of the range of solutions across differing LCT adoption scenarios based on a cost benefit analysis to accommodate customers' uptake of LCTs (Research Workstream); • The 'eta' method will deliver a **reduction in overall losses** through network configuration and voltage optimisation (Research Workstream); and • The 'eta' method facilitates real time control of a portfolio of LV network solutions, using retrofit technologies with application combined or in isolation (Technology Workstream).
Key Tech/Process Trialled	Integration of several technologies developed and separately tested under existing IFI or Tier 1 LCNF projects into a common operating regime, co-ordinated and managed through optimisation software. *Figure 2.2 eta Method intervention on stylised HV and LV networks* 

Project Title	Smart Street eta
Project Business Case (as reported by DNO)	The 'eta' method releases capacity up to four times faster and is 40% cheaper than traditional reinforcement techniques for LCT clusters. The eta **solution is transferable to 64% of the ENWL network and 72% of GB networks**; releasing capacity up to 2,985 MW and 39,630 MW for ENWL areas and GB respectively. This is less carbon intensive than traditional approaches delivering an **asset carbon saving of up to 93%.**
Timescales	January 2014 – December 2017
Current status	Underway – installation/commissioning phase
Outputs/ Implementation/ Impact (as reported by DNO)	The optimisation software delivers Conservation Voltage Reduction to improve the energy efficiency of customers' electrical appliances reducing energy up to 3.5% per annum, and lowering network losses by up to 2% per annum across HV and LV networks; delivering recurring financial savings for customers, without degradation to the quality of customers' supply. The key learning outcomes will be: • Installation Methodologies; • Network Management System Configuration; • Transforming LV radial networks; • Change proposals for design and operational standards; • Safe working practices; • HV and LV Voltage Control; • Network configuration and Voltage Optimisation; and • Customer engagement and feedback.

Table 7: Customer Load Active System Services (CLASS) overview.

Project Title	Customer Load Active System Services (CLASS)
Company	Lead: ENWL, Partners: Impact Research, Siemens UK Ltd, National Grid, Chiltern Power, The University of Manchester and the Tyndall Centre for Climate Change
Project Funding	£8.084m - LCNF Tier 2 inc. partner contribution
Project Driver	• Enable customer low carbon technology connections, whilst managing peak loads on the network and timing DNO's eventual interventions efficiently; • Provide a solution to network voltage control problems on the entire GB network; • Assist in reducing the requirement to constrain off low carbon generators for network balancing; and • Provide a low cost and effective system stability response facility.
Project Objectives	The objectives of the CLASS Project were to test the following hypothesis: • The CLASS method creates a demand response and reactive absorption capability through the application of innovative voltage regulation techniques; • Customers within the CLASS trial areas will not see/observe/notice an impact on their power quality when these innovative techniques are applied • The CLASS method will show that a small change in voltage can deliver a very meaningful demand response, thereby engaging all customers in demand response; • The CLASS method will defer network reinforcement and save carbon, by the application of demand decrement at the time of system peak; and

<table>
<tr><th>Project Title</th><th>Customer Load Active System Services (CLASS)</th></tr>
<tr><td></td><td>• The CLASS method uses existing assets with no detriment to their asset health.</td></tr>
<tr><td>Key tech/process trialled</td><td>

<table>
<tr><th>Description</th><th>Objective</th><th>Technique</th><th>Trial period</th><th>Customer survey requirement</th></tr>
<tr><td>Load modelling</td><td>Establish voltage/demand relationship</td><td>Raise and lower tap positions</td><td>Across entire annual cycle</td><td>No</td></tr>
<tr><td>Peak demand reduction</td><td>Demand response for peak reduction</td><td>Lower tap position</td><td>Peak demand</td><td>Yes</td></tr>
<tr><td>Stage 1 frequency response</td><td>Response to reduce demand when system frequency falls</td><td>Switch out transformer</td><td>Anytime</td><td>Yes</td></tr>
<tr><td>Stage 2 frequency response</td><td></td><td>Lower tap position</td><td>Anytime</td><td>Yes</td></tr>
<tr><td>Reactive power absorption</td><td>Reduce high volts on transmission network</td><td>Stagger tap position</td><td>Minimum demand</td><td>No</td></tr>
</table>
Figure 2: Summary of CLASS trials.</td></tr>
<tr><td>Project Business Case (as reported by DNO)</td><td>When the CLASS method is applied across all primary substations in the project, ENWL could gain up to 12.8MVA of network capacity, and **defer the reinforcement of five primary substations with an associated expenditure of £2.8m for up to three years**.
The CLASS Method can be **implemented** at **one primary substation 57 times faster** and **12 times cheaper than traditional reinforcement**.
It takes one week to retrofit into a primary substation at a cost of £44,000 compared with the typical average time to reinforce a primary substation of 57 weeks at a cost of £560,000.
These are the minimum benefits available by reducing the voltage by 1.5% (i.e. one tap position) at the primary substation. If the voltage is reduced by 5% ENWL could gain up to 250 MW of network capacity, and defer the reinforcement of 28 primary substations with an associated cost of £15.9m for up to three years. When applied at GB scale, it is possible to gain up to 3.1 GW of network capacity (the equivalent of 135 new primary substations), and defer £78m in reinforcement costs.</td></tr>
<tr><td>Timescales</td><td>January 2013 – September 2015</td></tr>
<tr><td>Current status</td><td>Complete</td></tr>
<tr><td>Outputs/ Implementation/ Impacts (as reported by DNO)</td><td>• The voltage/demand response is not linear. A 1% voltage change could result in an average MW demand response between 1.3% and 1.36%;
• During the trials, every primary substation in the trial area was subjected to a series of 3% and 5% voltage reduction tests for a period of time ranging from 30 minutes up to 180 minutes. During this period no voltage complaints were received and furthermore no voltage excursions outside of statutory limits were recorded;
• The ability to reduce network voltage at times of peak load provides the ability to defer asset replacement for a period of time. If a 5% network reduction was applied across ENWL’s network, this could potentially unlock 270 MW;
• If a 5% network reduction was applied across GB, based on a winter MD of 52 GW, the CLASS technique could unlock 3.3GW of demand;</td></tr>
</table>

Project Title	**Customer Load Active System Services (CLASS)**
	- Although it is clear that the CLASS Method will defer network reinforcement, it is very difficult to predict the exact time period due to load growth uncertainties. It is estimated that CLASS could defer an assessment replacement scheme by up to three years. - The CLASS technique can provide National Grid with a demand response for frequency reserve services. The results from the trials have shown that demand response can be achieved in less than 0.5 seconds; - The trials for reactive power absorption indicated a significant benefit. It is estimated that across the ENWL's network, a maximum of 167 MVAr could be absorbed during winter peak periods and 133 MVAr during the summer minimum. It is estimated that in GB a maximum of 1.84 GVAr could be absorbed during winter peak periods and 1.67 VAr during summer. These results indicate there is an opportunity to provide National Grid with reactive power services; and - The total **carbon impact benefit to National Grid** from the **combined demand response and reactive power ancillary services** could be as much as **116,000 tCO2e per annum.** Notably, there were no statistically significant variations in the proportion of customers who observed a change to their power quality in any of the customer segments consulted, demonstrating that CLASS was indiscernible to all types of customers. The level of overall satisfaction with service/supply quality amongst the survey population was either maintained or improved during the CLASS trials.

Table 8: Capacity to Customers overview.

Project Title	**Capacity to Customers (C_2C)**
Company	Lead: ENWL, Partners: IGE UK Ltd/Parsons Brinckerhoff Ltd, Flexitricity/ENerNoc/npower, NGET, University of Strathclyde/University of Manchester, Tyndall Centre for Climate Change and Association of Greater Manchester Authorities
Project Funding	£9.597m - LCNF Tier 2 inc. partner contribution
Project Driver	Unlocking capacity for generation and demand
Project Objectives	- Adaptive network control functionality: The trial will develop advanced network control functionality that will through productisation be available to all GB DNOs; - Demand response commercial templates: The trial will produce a series of model commercial contracts that can be used by all DNOs to extend the C2C method and its benefits to all DNO customers; - Customer segmentation template: The trial will produce a customer segmentation template, describing how a DNO's customer base can be segmented and hence better approached for the introduction of demand response contracts; - New connections process: The trial will produce a new connections process detailing those technical and commercial steps required to extend the benefits to future C2C customers; - Network data: Detailed analysis of the benefits of the C2C method on network losses and power quality in the form of a full set of network performance data; and - New design and planning standard: to inform the amendment or replacement of Engineering Recommendation P2/6.

Project Title	**Capacity to Customers (C_2C)**
Key tech/process trialled	• HV network automation – closing the Normal Open Point (NOP) between two adjacent HV circuits; and • PowerOn Fusion.
Project Business Case (as reported by DNO)	ENWL's analysis shows that if the technical and commercial elements of the C_2C solution were adopted across the ENWL's network, then it would **release 2.4 GW of existing capacity on the HV networks, without reinforcement.** This is around 35% of the existing firm HV network capacity or around 50% of simultaneous HV demand. Analysis of electrical energy scenarios to 2050 suggests the C_2C method could thus replace much of the traditional HV reinforcement activity in the period to 2035; however this is viewed as a conservative estimate and could indeed defer reinforcement in certain networks to 2050.
Timescales	January 2012 – December 2014
Current status	Complete
Outputs/ Implementation/ Impacts (as reported by DNO)	• ENWL's analysis shows that if the technical and commercial elements of the C_2C solution were adopted across the ENWL's network, then it would **release 3.1 GW of existing capacity on the HV networks**, without reinforcement. This is around 65% of the existing firm HV network capacity. Analysis of electrical energy scenarios to 2050 suggests the C_2C method could thus replace much of the traditional HV reinforcement activity in the period to 2035; however this is viewed as a conservative estimate and could indeed defer reinforcement in certain networks to 2050. • under high demand expectancy that the deployment of the C_2C Solution in conjunction with traditional reinforcement to form an economically optimised strategy has the potential to **reduce total future HV network reinforcement costs (i.e. both customer and DNO funded) by approximately £50m.** However, the avoidance of future expenditure under a lower demand requirement can be met with the C_2C Solution delivering £60m of benefits. Should the C_2C Solution be scaled up and rolled out across suitable GB networks, the customer savings are even more significant. • Based on advancing connections by around six months, the C_2C Method could directly claim to **facilitate 39-67 thousand tCO_2e of emissions reductions in Electricity North West network area** (depending on how the capacity is used). On the scale of Great Britain, this **carbon saving would be of the order of 0.5-0.9 million tCO_2e to 2035.** • The Tyndall Centre indicates that C_2C Solution deployment in conjunction with strategic traditional reinforcement on Electricity North West's HV network in the period 2015 - 2035 would give a **net network wide reduction of 237-328 tCO2e.** This is based on saving some 58-89 thousand tCO2e network wide from reduced deployment of assets, but decreasing carbon associated with losses by 179-239 thousand tCO2e relative to traditional reinforcement techniques. • For the ten new connections customers, the total customer contributions for a traditional solution would have been £7.84m versus the contributions required for the C2C Solution which totalled £0.37m, i.e. a saving of £7.47m for customers due to savings from the associated reinforcement. The customer types covered both demand and generation managed contracts and ranged in capacity from 500kVA to 10 500kVA. The following objectives were met or proven: • The C2C Method will release significant capacity to customers from existing infrastructure • The C2C Method will enable **improved utilisation of network assets** through greater diversity of customers on a closed network ring

Project Title	Capacity to Customers (C_2C)
	• The C2C Method will **reduce like-for-like power losses** initially but this benefit will gradually erode as newly released capacity is utilised • The C2C Method will improve power quality resulting from stronger electrical networks. • The C2C Method will **facilitate lower reinforcement costs** for customers for the connection of new loads and generation • The C2C Method will **facilitate a reduction in the carbon costs of network reinforcement** • The C2C Method will **effectively engage customers in a new form of demand and/ or generation side response** thereby stimulating the market and promoting the future use of commercial solutions • Interconnected C2C operation generally releases more demand capacity than radial C2C operation • Use of post-fault demand response in security of supply requirements.

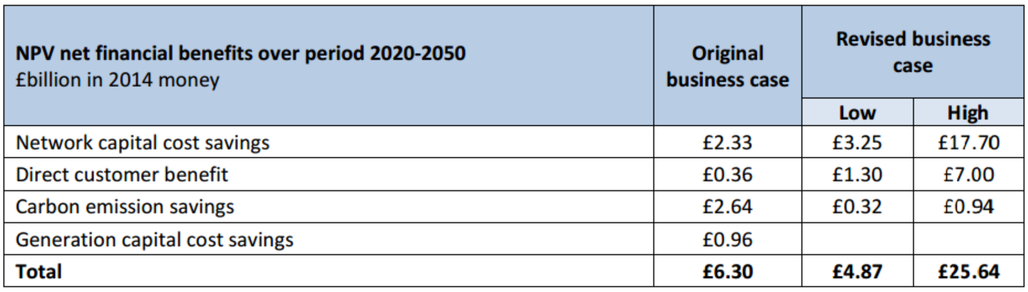
Table 9: Fault Level Active Response overview.

Project Title	Fault Level Active Response (FLARE)
Company	Lead: ENWL, Partners: ABB, Parsons Brinckerhoff, ENER-G, Impact Research and the Combined Heat and Power Association (CHPA)
Project Funding	£5.539m - LCNF Tier 2 inc. partner contribution
Project Driver	Active fault level management to help DNOs quickly connect customers' low carbon demand and generation at a lower cost than traditional reinforcement.
Project Objectives	• Trial the Fault Level Assessment Tool software; • Trial two technical and one commercial techniques which, when deployed on existing network infrastructure, will provide effective and efficient fault level control; • Deliver novel and highly transferable solutions that can be applied to the HV and EHV networks by any GB DNO; and • Demonstrate release of network capacity allowing quick and lower cost connection for customers' demand and generation, enabling DNOs to support the UK's decarbonisation strategy.
Key tech/process trialled	• Adaptive protection, also known as sequential tripping • Fault Current Limiting service utilising fault current limiters
Project Business Case (as reported by DNO)	• FLARE could deliver savings for DUoS customers of around £2.3 billion by 2050 and reduce costs for connections customers; and • FLARE could release 127,275 MVA of capacity for the connection of customers' new low carbon generation and demand.
Timescales	January 2015 – August 2018
Current status	Begun
Outputs/ Implementation/ Impacts (as reported by DNO)	• The FLARE Method releases the same capacity as traditional reinforcement but up to 18 times faster and at much lower cost – up to 80% cheaper – potentially saving GB £2.3 billion by 2050; and • It could also be used to enhance other fault level mitigation techniques such as those being trialled as part of FlexDGrid, a Second Tier LCN Fund project run by Western Power Distribution (WPD).

Northern Powergrid

Table 10: Customer Led Network Revolution overview.

<table>
<tr><th>Project Title</th><th>Customer-Led Network Revolution</th></tr>
<tr><td>Company</td><td>Lead: NPg, Partners: British Gas, Durham University and EA Technology</td></tr>
<tr><td>Project Funding</td><td>£31m - LCNF Tier 2 inc. partner contribution</td></tr>
<tr><td>Project Drivers:</td><td>• Test flexibility in the way customers generate and use electricity;
• Reduce customers’ energy costs and carbon footprint;
• Reduce network costs associated with mass uptake of LCTs; and
• Accelerate delivery of LCTs.</td></tr>
<tr><td>Project Objectives</td><td>• Maintain current planned level of network performance potentially at a lower cost than with traditional methods;
• Predict future loading patterns;
• Research novel network and commercial tools and techniques; and
• Develop new commercial arrangements.

In addition to the above, the project had the following learning outcomes:
• To understand current, emerging and possible future customer (load and generation) characteristics.
• To what extent are customers flexible in their load and generation, and what is the cost of this flexibility?
• To what extent is the network flexible and what is the cost of this flexibility?
• What is the optimum solution to resolve network constraints driven by the transition to a low carbon economy?
• What are the most effective means to deliver optimal solutions between customer, supplier and distributor?</td></tr>
<tr><td>Key Tech/Process Trialled</td><td>Electrical Energy Storage (EES)
Enhanced Automatic Voltage Control (EAVC)
Real Time Thermal Rating (RTTR)
Demand Side Management (DSM)</td></tr>
<tr><td>Project Business Case (as reported by DNO)</td><td>Adopting project learning nationally, £5-26 billion net financial benefit between 2020 and 2050 and 10.8-32.5 Mt CO_2 emissions savings corresponding to low and high uptake scenarios from DECC.

<table>
<tr><th rowspan="2">NPV net financial benefits over period 2020-2050
£billion in 2014 money</th><th rowspan="2">Original business case</th><th colspan="2">Revised business case</th></tr>
<tr><th>Low</th><th>High</th></tr>
<tr><td>Network capital cost savings</td><td>£2.33</td><td>£3.25</td><td>£17.70</td></tr>
<tr><td>Direct customer benefit</td><td>£0.36</td><td>£1.30</td><td>£7.00</td></tr>
<tr><td>Carbon emission savings</td><td>£2.64</td><td>£0.32</td><td>£0.94</td></tr>
<tr><td>Generation capital cost savings</td><td>£0.96</td><td></td><td></td></tr>
<tr><td>Total</td><td>£6.30</td><td>£4.87</td><td>£25.64</td></tr>
</table></td></tr>
<tr><td>Timescales</td><td>January 2011 - December 2014</td></tr>
<tr><td>Current status</td><td>Complete</td></tr>
<tr><td>Outputs/ Implementation/ Impact (as reported by DNO)</td><td>Adopting project learning nationally, £5-26 billion net financial benefit between 2020 and 2050 and 10.8-32.5 Mt CO_2 emissions savings corresponding to low and high uptake scenarios from DECC.</td></tr>
</table>

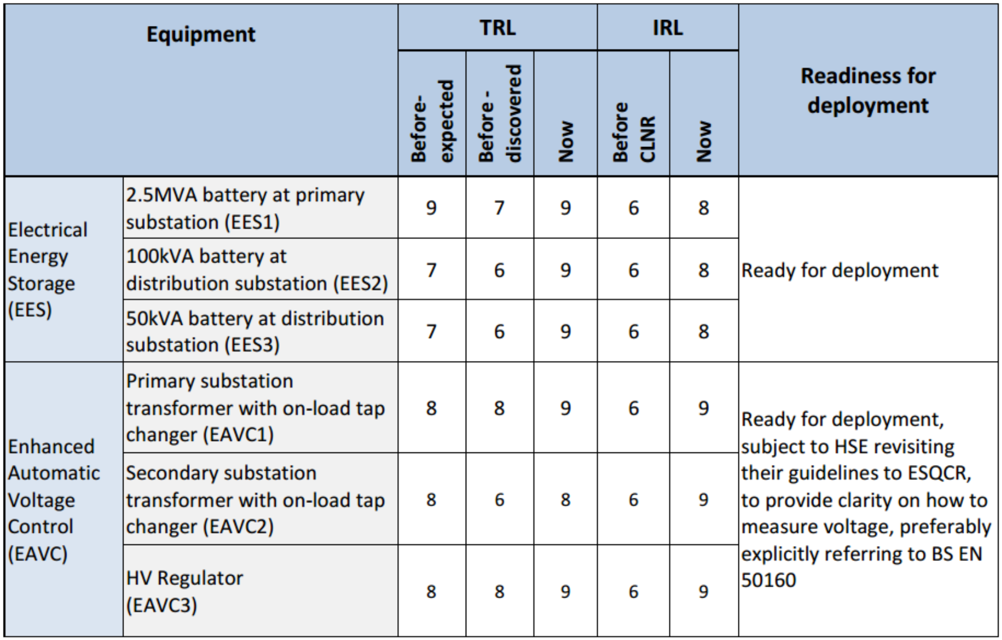
Project Title	Customer-Led Network Revolution

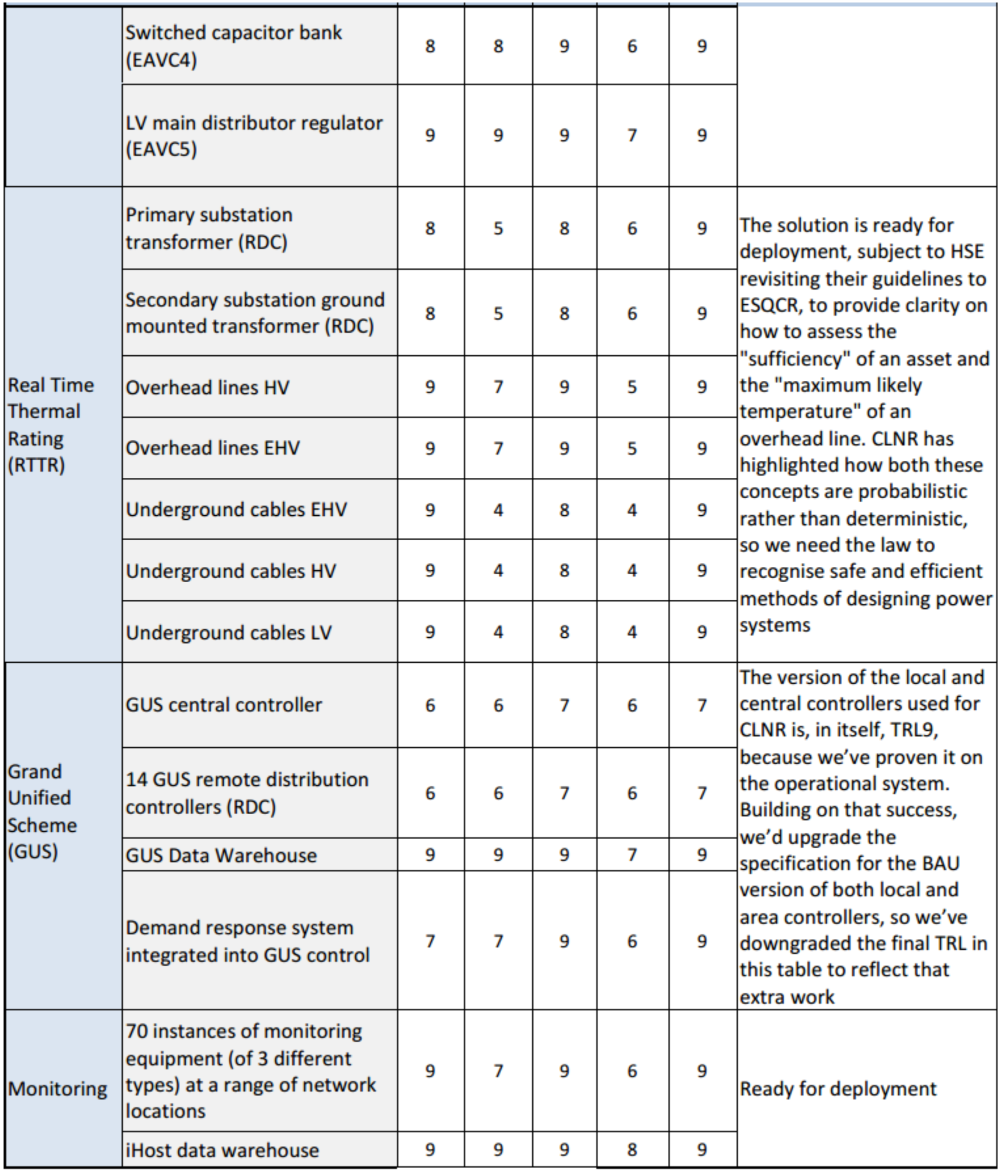
- Time of Use (ToU) Tariffs – changes to billing arrangements to be implemented April and November 2015;
- DSM as an alternative to network solutions for major substations expected to approach capacity through to 2023;
- Rolling out bespoke rating assessments for all assets and customer groups;
- Using RTTR, example of **additional unused capacity 74%** - used for connection of wind turbines because of synergies that higher wind speed creates between higher generation and increased overhead line ratings. Requires commercial arrangements – flexibility, quicker to implement. Not otherwise deployed before 2023 because of high cost of technology, unless design of the asset or location is particularly conducive;
- Deploying EAVC, 'by applying smarter solutions to the unbundling of looped-service cable NPg estimated a **cost saving benefit in 2015-2023 of £27m'** EAVC is one of such solutions that will address voltage issues from clustering of LCTs. It constitutes:
    - Revising voltage control policy.
    - Specifying new automatic voltage control relay to enable enhanced load-drop compensation at every primary substation.
    - Roll out of enhanced load-drop (generation-rise) compensation to target voltage setting of automatic voltage control relays to most substations above 20kV from 2015 to 2023;
- Rolling out secondary distribution transformers with On Load Tap Changers as a BAU solution for PV clusters likely to have voltage issues;
- HV voltage regulators as a BAU solution for HV feeders to customer groups whose load characteristics differ significantly from those around them;
- Remote terminal units with smarter characteristics to manage the use of DSM to off-load primary substations under N-1 fault conditions during constrained periods;
- Coordinated area control rolled out as BAU (faster and cheaper solution to connect DG to congested parts of the distribution system).

Equipment		**BAU cost £ Per unit**
Electrical Energy Storage (EES)	2.5MVA battery at primary substation (EES1)	£4,150,000
	100kVA battery at distribution substation (EES2)	£490,000
	50kVA battery at distribution substation (EES3)	£410,000
Enhanced Automatic Voltage Control (EAVC)	Enhanced voltage control at primary substations (EAVC1)	£45,000
	Secondary substation transformer with on-load tap changer (EAVC2)	£100,000
	HV Regulator (EAVC3)	£52,000
	Switched capacitor bank (EAVC4)[6]	£2,000,000
	LV main distributor regulator (EAVC5)	£93,000
Real-Time Thermal Rating (RTTR)	Primary substation transformer (RDC[7])	£20,000
	Secondary substation ground mounted transformer (RDC)	£15,500
	Overhead lines HV	£12,300
	Overhead lines EHV	£16,600
	Underground cables EHV	£55,000
	Underground cables HV	£55,000
	Underground cables LV	£26,000

The Technology Readiness Level of each of the new technologies has improved by on average 2 on a scale of 1-9. The Implementation Readiness Level for each of those technologies has also improved by about 3. Further information is available in the following tables, TRL refers to Technology Readiness Level and IRL refers to Implementation Readiness Level.

Project Title	**Customer-Led Network Revolution**

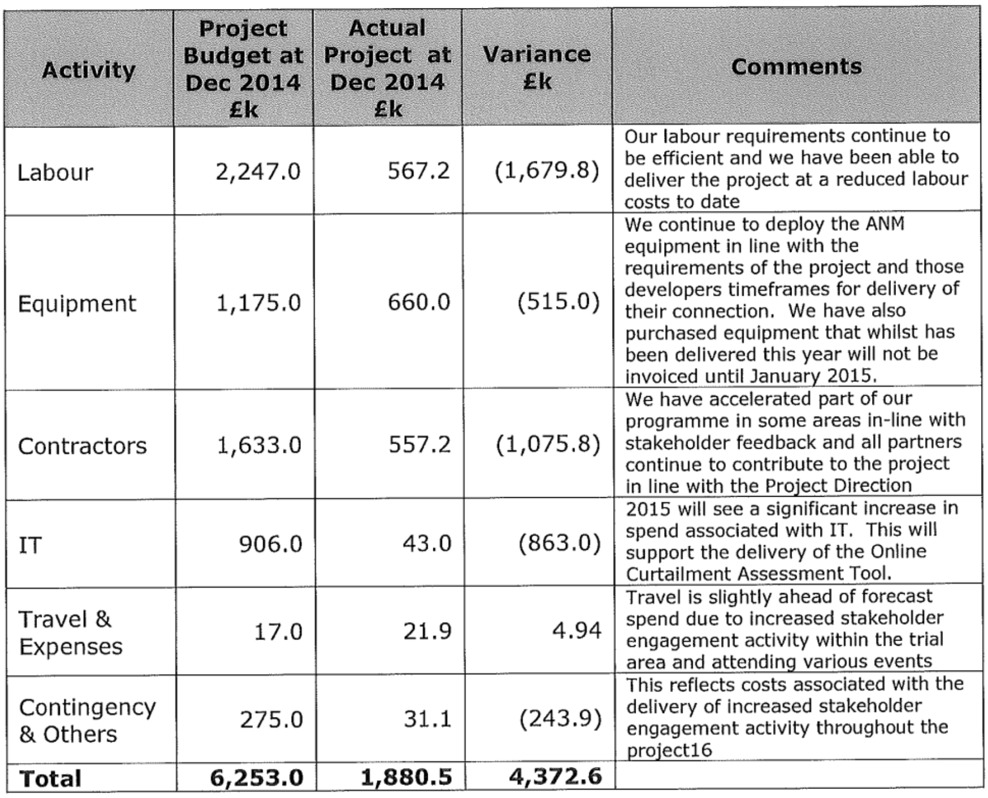




Equipment		**TRL**			**IRL**		**Readiness for deployment**
		Before-expected	**Before - discovered**	**Now**	**Before CLNR**	**Now**	
Electrical Energy Storage (EES)	2.5MVA battery at primary substation (EES1)	9	7	9	6	8	Ready for deployment
	100kVA battery at distribution substation (EES2)	7	6	9	6	8	
	50kVA battery at distribution substation (EES3)	7	6	9	6	8	
Enhanced Automatic Voltage Control (EAVC)	Primary substation transformer with on-load tap changer (EAVC1)	8	8	9	6	9	Ready for deployment, subject to HSE revisiting their guidelines to ESQCR, to provide clarity on how to measure voltage, preferably explicitly referring to BS EN 50160
	Secondary substation transformer with on-load tap changer (EAVC2)	8	6	8	6	9	
	HV Regulator (EAVC3)	8	8	9	6	9	
	Switched capacitor bank (EAVC4)	8	8	9	6	9	
	LV main distributor regulator (EAVC5)	9	9	9	7	9	
Real Time Thermal Rating (RTTR)	Primary substation transformer (RDC)	8	5	8	6	9	The solution is ready for deployment, subject to HSE revisiting their guidelines to ESQCR, to provide clarity on how to assess the "sufficiency" of an asset and the "maximum likely temperature" of an overhead line. CLNR has highlighted how both these concepts are probabilistic rather than deterministic, so we need the law to recognise safe and efficient methods of designing power systems
	Secondary substation ground mounted transformer (RDC)	8	5	8	6	9	
	Overhead lines HV	9	7	9	5	9	
	Overhead lines EHV	9	7	9	5	9	
	Underground cables EHV	9	4	8	4	9	
	Underground cables HV	9	4	8	4	9	
	Underground cables LV	9	4	8	4	9	
Grand Unified Scheme (GUS)	GUS central controller	6	6	7	6	7	The version of the local and central controllers used for CLNR is, in itself, TRL9, because we've proven it on the operational system. Building on that success, we'd upgrade the specification for the BAU version of both local and area controllers, so we've downgraded the final TRL in this table to reflect that extra work
	14 GUS remote distribution controllers (RDC)	6	6	7	6	7	
	GUS Data Warehouse	9	9	9	7	9	
	Demand response system integrated into GUS control	7	7	9	6	9	
Monitoring	70 instances of monitoring equipment (of 3 different types) at a range of network locations	9	7	9	6	9	Ready for deployment
	iHost data warehouse	9	9	9	8	9	

Scottish Power Energy Networks

Table 11: Accelerating Renewable Connections overview.

<table>
<tr><th>Project Title</th><th>Accelerating Renewable Connections (ARC)</th></tr>
<tr><td>Company</td><td>Lead: SPEN, Partners: Community Energy Scotland, Smarter Grid Solutions and the University of Strathclyde.</td></tr>
<tr><td>Project Funding</td><td>£7.742m - LCNF Tier 2 inc. partner contribution</td></tr>
<tr><td>Project Driver</td><td>Facilitate increased penetration of renewable generation gaining access to the distribution network in a timely manner.</td></tr>
<tr><td>Project Objectives</td><td>• Improve access to connect generation to the network;
• Accelerate the time to connect generation;
• Enable connections to be facilitated around constraints; and
• Create an enduring process and learning that can be rolled out across the UK.</td></tr>
<tr><td>Key Tech/Process trialled</td><td>• ANM
• Commercial arrangements</td></tr>
<tr><td>Project Business Case (as reported by DNO)</td><td>The total project cost stands at c.£8.9 M, and analysis shows that the future cost of deploying the overall enablers such as the ANM and telecoms platform would reduce to somewhere in the region of £3-4 M, which would be funded by the DNO in the future as part of the operation of the network.
Through the analysis of the case studies, savings of between 18-75% are likely to be achievable for future connections along with savings in the time it takes generators to connect.

<table>
<tr><th>Activity</th><th>Project Budget at Dec 2014 £k</th><th>Actual Project at Dec 2014 £k</th><th>Variance £k</th><th>Comments</th></tr>
<tr><td>Labour</td><td>2,247.0</td><td>567.2</td><td>(1,679.8)</td><td>Our labour requirements continue to be efficient and we have been able to deliver the project at a reduced labour costs to date</td></tr>
<tr><td>Equipment</td><td>1,175.0</td><td>660.0</td><td>(515.0)</td><td>We continue to deploy the ANM equipment in line with the requirements of the project and those developers timeframes for delivery of their connection. We have also purchased equipment that whilst has been delivered this year will not be invoiced until January 2015.</td></tr>
<tr><td>Contractors</td><td>1,633.0</td><td>557.2</td><td>(1,075.8)</td><td>We have accelerated part of our programme in some areas in-line with stakeholder feedback and all partners continue to contribute to the project in line with the Project Direction</td></tr>
<tr><td>IT</td><td>906.0</td><td>43.0</td><td>(863.0)</td><td>2015 will see a significant increase in spend associated with IT. This will support the delivery of the Online Curtailment Assessment Tool.</td></tr>
<tr><td>Travel & Expenses</td><td>17.0</td><td>21.9</td><td>4.94</td><td>Travel is slightly ahead of forecast spend due to increased stakeholder engagement activity within the trial area and attending various events</td></tr>
<tr><td>Contingency & Others</td><td>275.0</td><td>31.1</td><td>(243.9)</td><td>This reflects costs associated with the delivery of increased stakeholder engagement activity throughout the project16</td></tr>
<tr><td>**Total**</td><td>**6,253.0**</td><td>**1,880.5**</td><td>**4,372.6**</td><td></td></tr>
</table>
The above table is from an ARC 6 monthly report published in December 2014.</td></tr>
</table>

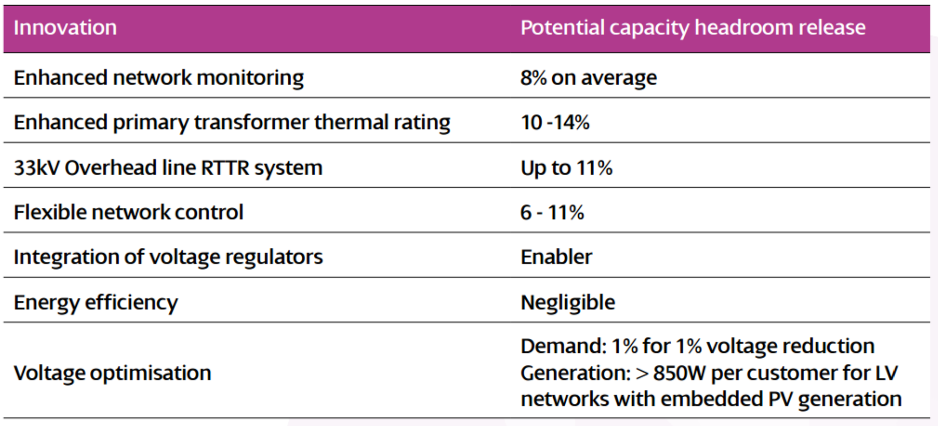
Project Title	Accelerating Renewable Connections (ARC)
Timescales	January 2013 – December 2016
Current status	Underway
Outputs/ Implementation/ Impacts (as reported by DNO)	The ARC project team have enabled the connection of: • An additional generation unit (1.6 MW Wind Farm) by the end of Q1 of 2015 that would otherwise, under National Grid Electricity Transmission's existing contractual and connection policy arrangements, have been delayed in connecting until 2021 at the earliest; and • An 80kW PV array on 11kV network connected on a non-firm Actively Managed basis delivered at a fraction of the original cost estimate. According to SPEN's December 2014 Progress Report ANM was being accelerated through to BAU 18 months ahead of schedule.

Table 12: Flexible Networks for a Low Carbon Future overview.

Project Title	Flexible Networks for a Low Carbon Future
Project Title:	Lead: SPEN, Partners: University of Strathclyde, TNEI, Nortech and the BRE
Project Funding:	£6.362m - LCNF Tier 2 inc. partner contribution
Project Driver	Increasing network capacity to allow higher levels of low carbon technology to be accommodated without adversely affecting quality of supply.
Project Objectives	• Develop an enhanced network monitoring methodology and based on this network data, develop and integrate improved DNO planning and operations tools and practices that are optimised for future low carbon networks and use of the innovative techniques being trialled; • Trial novel technology measures for improved performance of the network such as dynamic thermal ratings of assets, voltage optimisation, and flexible network control; • Identify the measures by which material improvements in the cost-effectiveness of accommodation of future energy needs can best be demonstrated; • Develop an investment and future roll-out plan where appropriate cost-benefit exists; and • Disseminate learning to key stakeholders such as customers and other DNOs to ensure sustainable user adoption, through future technical and regulatory policy changes for example.

<table>
<tr><th>Project Title</th><th>Flexible Networks for a Low Carbon Future</th></tr>
<tr><td>Key tech/process trialled</td><td>Enhanced monitoring and analysis to precisely determine existing performance, and the deployment of novel technology for improved network operation, including flexible control and dynamic rating.
Innovative techniques trialled for demand constrained networks comprise;
• Improved network analysis techniques;
• Enhanced thermal ratings for primary transformers;
• Real time thermal ratings for 33kV overhead lines;
• Flexible network control enhanced with voltage regulators;
• Customer energy efficiency; and
• Voltage optimisation.
Innovative techniques that can also be applied to generation constrained networks comprise;
• Improved network analysis techniques;
• Real time thermal ratings for 33kV overhead lines; and
• Voltage optimisation.</td></tr>
<tr><td>Project Business Case (as reported by DNO)</td><td>
<table>
<tr><th>Site</th><th>Lowest cost traditional method</th><th>Year to complete traditional reinforcement</th><th>Future method cost</th><th>Additional capacity</th></tr>
<tr><td>St Andrews</td><td>£6,200k</td><td>3</td><td>£646k</td><td>4.2MVA</td></tr>
<tr><td>Whitchurch</td><td>£3,100k</td><td>2</td><td>£612k</td><td>3.8MVA</td></tr>
<tr><td>Ruabon</td><td>£1,200k</td><td>1-2</td><td>£337k</td><td>514W per customer</td></tr>
</table>
<i>Cost comparison between traditional and innovative solutions for network capacity expansion.</i>
</td></tr>
<tr><td>Timescales</td><td>January 2012 – December 2014</td></tr>
<tr><td>Current status</td><td>Complete</td></tr>
<tr><td>Outputs/ Implementation/ Impact (as reported by DNO)</td><td>• A 20% increase in network capacity through a number of innovative measures.
• Learning outcomes from Flexible Networks indicate that net benefits may be greater than the initially reported saving of £8.1m against traditional network solutions.
• A reduction in reinforcement costs of between 70% and 90% was achieved for the three trial sites.
• The total project cost was £5.2M. Updated analysis indicates that the future method cost for these same three sites will be approximately £1.6M in total. Compared to a base case cost of £10.5M, this provides a net benefit of £8.9M.
• Whilst energy efficiency measures were not applied at St Andrews or Ruabon as part of the future method, adequate capacity gain was achieved</td></tr>
</table>

Project Title	**Flexible Networks for a Low Carbon Future**
	through other measures.



Innovation	Potential capacity headroom release
Enhanced network monitoring	8% on average
Enhanced primary transformer thermal rating	10 -14%
33kV Overhead line RTTR system	Up to 11%
Flexible network control	6 - 11%
Integration of voltage regulators	Enabler
Energy efficiency	Negligible
Voltage optimisation	Demand: 1% for 1% voltage reduction Generation: > 850W per customer for LV networks with embedded PV generation

Capacity headroom release for Flexible Networks methods trialled.

Scottish and Southern Energy

Table 13: Low Energy Automated Networks overview.

Project Title	**Low Energy Automated Networks**
Company	Southern Electric Power Distribution plc (SEPD)
Project Funding	£3.068m - LCNF Tier 2
Project Driver	Ofgem reports that approximately 6% of the electrical energy generated in the UK is lost within the distribution network each year, worth approximately £1 billion. Loss reduction in the networks will provide corresponding decreases in customer's energy bills. Conventional losses comprise of fixed (transformer energisation) and variable (copper losses). With an increasing number of LCTs coming onto the network, the gap between the network maximum and minimum loads will increase. This will lead to greater losses than is currently experienced in LV network and HV/LV transformers. SEPD are proactively seeking to reduce losses and therefore costs incurred by customers; the LEAN project aims to deploy and demonstrate methods to achieve this.
Project Objectives	• To deploy and demonstrate innovative methods of reducing electrical losses within the 33kV/11kV distribution network; and • To demonstrate new methods that can be applied to existing assets to reduce losses in the shorter term.

Project Title	**Low Energy Automated Networks**
Key tech/process trialled	The principal method for the LEAN project involves the use of a Transformer Auto Stop Start (TASS) mechanism. SEPD will deploy a second method, Alternative Network Topology (ANT), where appropriate. The TASS system is a technical solution, which will be applied to selected 33kV/11kV primary substations that have dual transformers. SEPD will deploy the TASS system to switch one in a pair of transformers off when load is low enough to reduce fixed losses. ANT is a technical method that will implement network meshing of selected 11kV network circuits dependent on network demand. ANT simply "matches" a substation selected for TASS (where one of a pair of transformers may be switched off and one will remain energised) and interconnects it to another substation nearby via the 11kV network.
Project Business Case (as reported by DNO)	The project's loss savings estimations are based on the same methodology used in the recent RIIO-ED1 submission. In this process, the value of lost energy was identified as £48.42 per MWh. If the typical figure of 90 MWh per annum is assumed, then the energy saved each year has an approximate annual value of £4,500 and, based on an unchanged load factor, the discounted present value over 45 years would be approximately £126,000 per site. This project will investigate the opportunity to de-energise transformers by a variety of means including manual operation, remote control via existing switchgear and automatic control using high-performance switchgear. The estimated method cost is described below: Option 1: De-energise transformers via remote control of existing switchgear with additional 11kV network automation if appropriate. Option 2: De-energise transformers using remote control including advanced local control equipment to ameliorate any switching surges, or inrush currents. Option 3: De-energise transformers using remote control with high-performance switchgear to reduce inrush currents repeatedly.
Timescales	January 2015 - March 2019
Current status	Begun
Outputs/ Implementation/ Impact (as reported by DNO)	• Continue current, successful asset replacement programme to deploy lower loss equipment, and with optimal configuration of the network. • Continue with programme of implementing a range of technologies designed to reduce losses as part of normal business processes on the lower voltage networks (11kV and below). • Use innovation to increase the range of technologies available for standard implementation. • Improve understanding of the energy use of customers and work with customers to reduce their overall energy use, especially at peak times, taking advantage of smart metering as part of this process. • Use new sources of data to create better models that allow analysis and losses tracking, and target loss reduction. • Work with Electricity Supply Licensees to detect and prevent fraudulent energy use.

Table 14: Solent Achieving Value from Efficiency overview.

Project Title	**Solent Achieving Value from Efficiency (SAVE)**
Company	Lead: SEPD, Partners: University of Southampton, DNV KEMA and Wireless Maingate
Project Funding:	£10.338m - LCNF Tier 2
Project Driver	This project seeks to synchronise energy efficiency with the network problem hence avoiding or deferring the need to invest in traditional solutions. A major part of the DECC Carbon Plan focuses on making UK homes greener and less energy intensive. The SAVE project will also help to evaluate the role DNOs can play in this process.
Project Objectives	• Create hypotheses of anticipated effect of energy efficiency measures (via commercial, technical and engagement methods); • Monitor effect of energy efficiency measures on consumption across range of customers; • Analyse the effect and attempt to improve in a second iteration • Evaluate cost efficiency of each measure; • Produce customer model revealing customer receptiveness to measures; • Produce network model revealing modelled network impact from measures; • Produce a network investment tool for DNOs; and • Produce recommendations for regulatory and incentives model that DNOs may adopt via RIIO.
Key tech/process trialled	The project intends to use technical and commercial measures as well as proactive customer engagement to promote energy efficiency (a change in consumption levels and patterns). The technical means of facilitating energy efficiency will involve utilising LED lighting in one trial, and the provision of meter sensors and smart plugs in another. The trial utilising sensors and smart plugs will provide graphical views of total property and individual appliance demand, and this data will be used to inform the campaigns as part of the proactive customer engagement approach (effectively meaning the trial utilises both technical means and proactive engagement). Commercial means of promoting energy efficiency will encourage customers through a target-related reward that is provided directly by the DNO. This will test the sensitivity of customers to incentives and the scale required. As a result the project will design a blueprint for an energy efficiency incentive measure that Ofgem may consider implementing as a future phase of RIIO, by making recommendations on the type and level of incentive that would be necessary.
Project Business Case (as reported by DNO)	• The potential to reduce capital investment requirements for network operators consistent with the objectives of RIIO EDI that will be beneficial to customers; • It will inform how stakeholder and customer engagement can support SSEPD's future business plans, notably in creating win-win, collaborative bottom-line solutions and allowing for more effective planned investment to develop local capacity; • Facilitate the connection of more low carbon technologies, such as EVs and heat pumps, and subsequently develop a cost effective network model for use by SSEPD and the other GB DNOs;

Project Title	**Solent Achieving Value from Efficiency (SAVE)**
	• Working closer with stakeholders and communities will serve to explore and develop potential commercial and development solutions to sustain bottom line benefits to DNOs and other stakeholders; and • The most challenging part of replacing distribution assets is at the low voltage level. The replacement value for the renewal of these assets, in SEPD and SHEPD's (Scottish Hydro Electric Power Distribution) license areas would be in the region of £3 billion. Therefore SEPD believes there is an urgent need to consider such measures as the SAVE project proposes and failure to take action now would result in major disruption and costs to the DNOs, stakeholders and customers
Timescales	January 2014 - June 2018
Current status	Begun
Outputs/ Implementation/ Impact (as reported by DNO)	Following the consultation from Ofgem dated 7th December 2012 entitled 'Low Carbon Networks Fund- Electricity Demand', SEPD became interested in potentially trialling such demand reduction. At present this is untested and therefore cannot be used in BAU. Through these trials, SEPD hopes to quantify the most cost effective approach to having a measurable change in the operation of the distribution system and develop means of controlling the demand reduction in order to be able to rely on the demand reduction and defer or avoid network reinforcement.

Table 15: My Electric Avenue overview.

Project Title	**I^{2}EV (My Electric Avenue)**
Company	Lead: SEPD (sponsored), EA Technology (lead); Partners: Nissan, Fleetdrive Electric, De Montfort University, Northern Powergrid, Charge Your Car, Automotive Comms
Project Funding	£9.08m – £4.5m funded from LCNF Tier 2
Project Driver	Commercial innovation: third party delivery of an innovation project Technical innovation: • Decarbonising the transport sector; • Assess and mitigate the impact of clustering of EVs on electricity networks (mainly LV)
Project Objectives	• To test the delivery of an innovation project by a third party, and to develop a commercial blueprint for future roll out of innovation projects • Learn customer driving and EV charging habits; • Trial Smart equipment to mitigate the impact of EV charging on the network; and • Explore the network benefits of such technology.
Key Tech/Process Trialled	• Commercial blueprint • ‘Esprit’ a DSM technology which curtails EV charging at peak demand.
Project Business Case (as reported by DNO)	Based on Transform model simulations, with the DECC scenario for High Uptake of EVs, 32% of GB networks would need intervention and using Esprit could save £2 billion on the cost of network reinforcement by the end of 2050.
Timescales	January 2013 - December 2015
Current status	Completed

Project Title	**I^{2}EV (My Electric Avenue)**
Outputs/ Implementation/ Impact (as reported by DNO)	• Across Great Britain 32% (312,000) of low voltage feeders will require intervention when 40%-70% of customers have EVs based on 3.5kW (16A) charging; • **Esprit** is a solution that **could save GB DNOs £2.2 billion by 2050** as compared to traditional reinforcement methods; • Esprit mitigates all thermal problems on the network accommodating up to an extra 46% of customers and can also raise voltage headroom by 10%; • Curtailing EV charging had no significant effect on customer satisfaction; • 41% of customers strongly agreed with the sentiment that they would continue to lease and 6% said the same to buying an EV after the trial; • Over 18 months 213 participants made journeys totalling 3,081,328 km in their Nissan Leaf EVs representing a saving in direct emissions of around 105 tonnes of CO_2e as compared to the next best alternative, a new diesel vehicle; • By deferring or avoiding reinforcement the implementation of Esprit is projected to save between 11.4 and 19.4 tons CO_2e emissions by the end of 2030. By 2050 the carbon emissions savings are expected to be between 814 and 1,390 tons CO_2e; • 'Top 10 Tips' series of flyers disseminate the project findings on the following topics: Customer Engagement, Customer Recruitment, Novel Commercial Arrangements, Procuring Partners, Trial Installations, Data Monitoring, Database Management, Managing EV Uptake (http://myelectricavenue.info/top-10-tips).

Table 16: New Thames Valley Vision overview.

Project Title	**New Thames Valley Vision (NTVV)**
Company	Lead: SEPD. Partners: University of Reading, GE Honeywell, EA Technology, KEMA (now DNV-GL) and Bracknell Forest Council
Project Funding	£29.9m – LCNF Tier 2
Project Driver	Enabling the transition to a low carbon economy, while maintaining security and quality of supply to customers and without any unnecessary capital investment and repair costs.

Project Title	**New Thames Valley Vision (NTVV)**
Project Objectives	• Understand the different customer types connected to the distribution network, and their effect on network demand; • Understand how the behaviour of different customer types allows informed network investment decisions to be made; • Demonstrate mitigation strategies, both technical and commercial, in a live environment, to understand: ○ The extent to which DSR can contribute to network flexibility, and identifying which customers are most likely to be early and effective adopters of DSR; ○ Where and how power electronics (with and without energy storage) can be used to manage power factor, thermal constraints and voltage to facilitate the connection of renewables on the LV network; • Link network reinforcement to a better understanding of SSE's electricity consumers; • Undertaking dissemination and scaling activity to ensure validity and relevance to the GB, with learning and understanding provided at two levels: ○ Provide front line training courses for the industry to embed real practical knowledge and skills; and ○ Keeping the public informed so the intentions and benefits of the smart grid are clear and opinions informed.
Key tech/process trialled	The project will demonstrate that common mathematical and statistical techniques used in other areas, such as consumer retail, can be applied to electricity consumers and fed into network planning processes. Such analysis will help to: • Target investment and the strategic placement of 'distributed LV solutions'; • Facilitate scenario planning; • Minimise errors in network design; and • Reduce risk to connected customers. This sophisticated analysis will be complemented by credible alternatives to conventional network reinforcement.
Project Business Case (as reported by DNO)	Using the methodology developed and scaling it for two SSEPD licences yields net benefits of over £600m from 2020 - 2050: • Southern Electric Distribution Ltd - £482m (based on the difference between £936m of novel deployment costs to £1,400m of conventional reinforcement); and • Scottish Hydro Electric Distribution Ltd - £143m (based on the difference between £302m of novel deployment costs to £440m of conventional reinforcement). Further to this SSE anticipates that NTVV will yield more immediate benefits including: • Accelerated low carbon technology connection for customer; • Avoidance of supply failure resulting from unanticipated demand peaks; • Reduction of network losses as a result of power factor correction; • Informed business plans going into RIIO-ED1 with the ability to model scenarios; • Customer groups with an improved understanding of how to self-mitigate network issues through the way in which they select and implement low carbon solutions; • Evaluation of resource and skill requirements;

Project Title	**New Thames Valley Vision (NTVV)**
	• Training and learning dissemination; • Enhanced data to inform DPCR5 output measures; • A range of specific innovative alternatives to reinforcement; • A no-customer minutes lost (CML) impact implementation strategy; and • Enduring productive relationships with stakeholder.
Timescales	January 2012 – March 2017
Current status	Begun
Outputs/ Implementation/ Impact (as reported by DNO)	The Learning Objectives (LO) are as follows: 1. An understanding of what SSEPD needs to know about customer behaviour in order to optimise network investment. 2. Anticipation of how SSEPD can improve modelling to enhance network operational, planning and investment management systems. 3. Understanding to what extent modelling can reduce the need for monitoring and enhance the information provided by monitoring. 4. Understanding of how might a DNO implement technologies to support the transition to a Low Carbon Economy? 5. Understanding which commercial models attract which customers and how will they be delivered?

UK Power Networks

Table 17: Flexible Plug and Play overview.

Project Title	**Flexible Plug and Play (FPP)**
Company	Lead: UKPN, Partners: Cable & Wireless Worldwide, Silver Spring Networks, Smarter Grid Solutions, Alstom Grid, Converteam, Fundamentals, S&C Electric, GL Garrad Hassan, Imperial College London, University of Cambridge and the IET.
Project Funding	£9.7m - LCNF Tier 2 inc. partner funding
Project Driver	Connecting distributed generation to the distribution network
Project Objectives	Develop a Strategic Investment Model which will allow DNOs to quantify, for different demand and generation scenarios, the integrated value and benefits of different smart technologies, smart commercial arrangements and smart applications. This model will also determine from both an economic and carbon perspective whether it is better to reinforce the network or use smart alternatives.
Key tech/process trialled	ANM/telecommunications – technical parameters DNOs need to consider when designing and operating such systems. Identifying critical constraint points in the network and actively managing them with ANM and smart devices. First DNO to explore the use of RF mesh technology for ANM applications. Commercial Arrangements – alternative methods of allocating curtailment, pro-rata and Last-In-First-Off, performance and practicality. Connection offers and connection agreements which form legal contract between customer and DNO and new T&Cs.

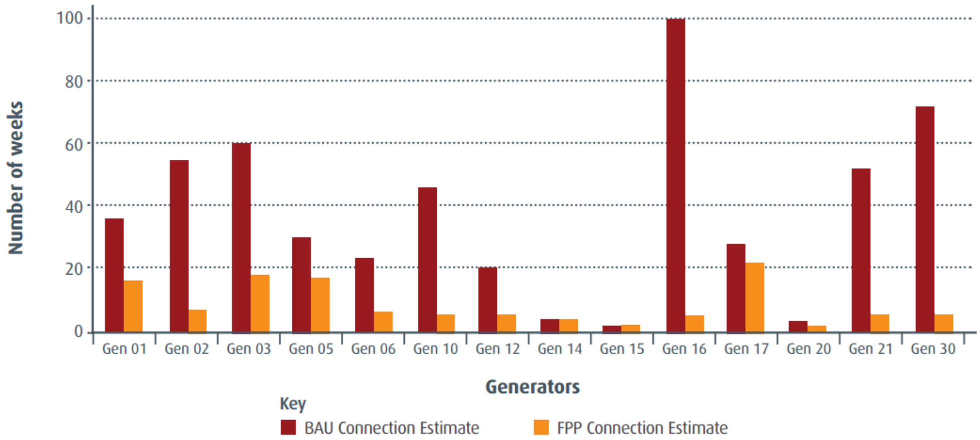
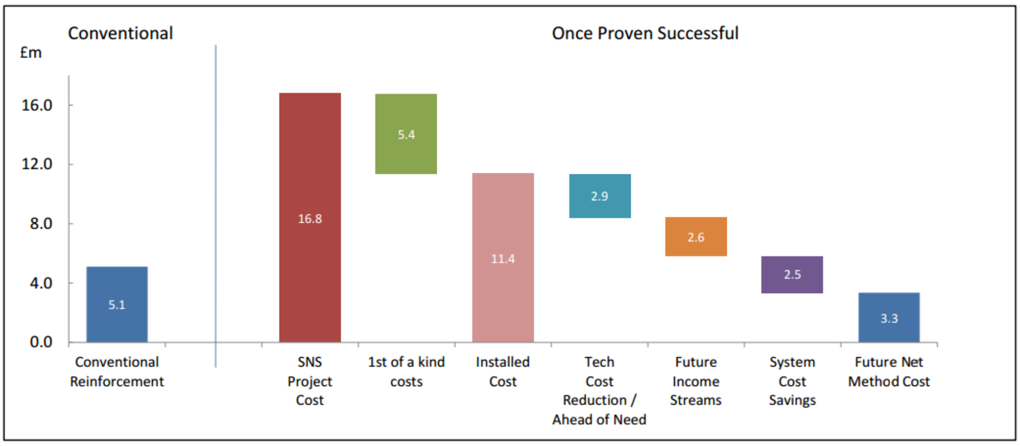
Project Title	**Flexible Plug and Play (FPP)**
	Smart device – EAVC systems, dynamic line rating systems, optical sensors, a quadrature-booster and associated control system, novel protection systems. – support the delivery of the flexible connections by reducing the levels of generation curtailment whilst maintaining network security.
Project Business Case (as reported by DNO)	The technical innovation focuses on the development of an open standards platform to enable end-to-end communication between distributed smart network technologies and generation. FPP allows for decentralised monitoring, control and overall operational management of both network and generation by active network management applications. This concept and technical architecture has not been tested in a production environment in the UK before and will be a leap forward in the evolution of the DG-enabled network. Commercial innovation will be delivered in the form of investment modelling and new commercial contracts to provide flexibility and customer choice to generation customers. FPP will address the need for a more responsible, cost efficient and flexible approach to generation customer connections.
Timescales	January 2012 - December 2014
Current status	Completed
Outputs/ Implementation/ Impact (as reported by DNO)	The **flexible connections quotations** issued to DG customers in the trial area since March 2013 have proven to be a cheaper alternative than the business-as-usual alternative, **saving a minimum of 45% compared to the traditional business-as-usual offer**, with **over half of the flexible connection offers providing a saving over 90%**. Across all of the projects the **average saving is of approximately 87%, which equates to a reduction of approximately £6.5m per project**. Taking into consideration all the ANM and communication equipment costs and curtailment, over a 20 year period, all but two of the flexible connection offers were still more financially viable than the business-as-usual offers with an average saving of ~65% or £5.4m per project. This further reinforces that flexible connections do not only provide a short-term benefit, but **even after 20 years of curtailment they provide a long-term viable alternative**. The **average connection time saving is approximately 29 weeks.**  *Time to connect a generation customer, comparing BAU with FPP offers.* UKPN will integrate Flexible Plug and Play connection offers (as per UKPN's Low Carbon Network Fund Project) into BAU by Q2 2015.

Table 18: Smarter Network Storage overview.

Project Title	**Smarter Network Storage (SNS)**
Company	Lead: UKPN. Partners: AMT-SYBEX, Durham University, Imperial College London, KiWiPower, National Grid, Pöyry Management Consulting, Smartest Energy and Swanbarton.
Project Funding	£15.292m – LCNF Tier 2
Project Driver	• Remove the barriers of energy storage adoption across distribution networks; • Better understand the strengths and limitations of large scale deployments; • Improve the predictability of business models for maximising the value of energy storage; and • Improve the regulatory frameworks to ease long-term integration and flexibility.
Project Objectives	• Demonstrate how 6MW / 10MWh of lithium-ion storage can be deployed on the distribution network to support security of supply; • Trial the multi-purpose application of storage for a range of different system benefits to help maximise value, e.g. investment deferral and ancillary services; and • Develop a new optimisation and control system and trial the commercial arrangements for shared use of energy storage.
Key tech/process trialled	• Demonstrate how 6MW/10MWh of lithium-ion storage can be deployed on the distribution network to support security of supply; • Trial the multi-purpose application of storage for a range of different system benefits to help maximise value e.g. investment deferral and ancillary services; and • Develop a new optimisation and control system and trial the commercial arrangements for shared use of energy storage.
Project Business Case (as reported by DNO)	The present value of net benefits of this additional flexible capacity at a national level are then calculated at around £0.7bn, resulting from savings in distribution and transmission investment, value from supporting system balancing, displacement of peaking generation capacity and reduced costs of curtailment of low carbon generation. These benefits assume that the storage is leveraged across only a limited number of applications simultaneously for short periods, although in practice it is expected storage capacity could be much more flexible  *NPV breakdown of reinforcement route incorporating SNS.*
Timescales	January 2013 – December 2016

Project Title	Smarter Network Storage (SNS)
Current status	Underway
Outputs/ Implementation/ Impact (as reported by DNO)	Overall this project should help to inform the means in which storage can be incorporated more cost effectively into future business plans of DNOs. The specific findings from the June 2015, 6 monthly report are: • The provision of TRIAD avoidance service is likely to form an important part of the portfolio of services for a commercial operator, which in some scenarios could cause conflicts with services to a DNO; • EMC compatibility testing and factory acceptance should be thoroughly carried out using representative layouts, connections and scales of equipment as close as possible to the 'as-installed' system; • Earthing systems appropriate for high frequency currents should be specified for future installations of building housed storage to avoid unwanted circulating currents; • Consideration needs to be given to appropriate validation test methods for frequency response behaviour; • Control systems that have no synchronisation in the architecture at the system level may cause small fluctuations in power output, if they choose to optimise power delivery amongst inverters; and • Relatively simple parts of the overall solution can become single points of failure that could have a significant effect on network support operations or commercial services. Redundancy and resilience should be considered at all sub-system and IT levels. Learning reports are available for the following deliverables: **SDRC 9.1** - practical issues and consideration in the design and planning of large-scale distribution-connected storage. **SDRC 9.2** - overall design of the Smart Optimisation & Control System incorporating a description of the business processes to be implemented across participants to facilitate the SNS solution. **SDRC 9.3** - contract templates for commercial arrangements that can also be tailored for other forms of flexibility and leveraged system wide by DNOs. **SDRC 9.4** - commissioning and operation of energy storage device.

Table 19: Low Carbon London overview.

Project Title	Low Carbon London (LCL)
Company	Lead: UKPN, Partners: EDF Energy Networks, Siemens, Imperial College, Logica, Smarter Grid Solutions, Npower, EnerNOC, Flexitricity, Greater London Authority/London Development Agency, Transport for London and National Grid
Project Funding	£34.5m – LCNF Tier 2 inc. partner contributions
Project Driver	Support London's objective to become a leading Low Carbon Capital and promoting a low carbon economy. Assess the impact of various Low Carbon Technologies on London's electricity distribution network.
Project Objectives	• Using smart meters and substation sensors to facilitate smart grids; • Enabling and integrating Distributed Generation; and • Enabling the electrification of heat and transport.

Project Title	**Low Carbon London (LCL)**
Key tech/process trialled	• Trialling a dynamic time-of-use tariff; • Wind-twinning trials with both residential and I&C customers; • Active smart management of EV charging to effect peak load shedding but with no perceptible degradation to the EV owner's charging experience; and • Pioneering work on distribution system state estimation using the project's instrumentation and measurement framework.
Project Business Case (as reported by DNO)	Benefits of "Smart" **Benefit/Cost** — **Value (£)** Direct benefits — £1.5m DNO benefits (residential & commercial DSR) — £0.12 bn DNO benefits — £0.9-1.9 bn System carbon benefits — £8.6 bn Gross benefits — £8.6 bn Costs — £2.3 bn Net benefit — £7.3-8.3 bn Project learning directly informed £43.5m in UKPNs ED1 savings, meaning it pays for itself 2.5 times within the ED1 period.
Timescales	January 2011 – December 2014
Current status	Complete
Outputs/ Implementation/ Impacts (as reported by DNO)	• Creation of what is considered to be the largest contiguous smart meter dataset ever assembled in GB – 16,300 consumers with a full year (2013) of half-hourly readings, coupled with detailed demographic profiling; • The largest household energy use and appliance survey for over 30 years; and • Implementation of project learning directly into UK Power Networks ED1 business plan with I&C DSR. • By recognising that reinforcement could be deferred in 10 LPN substations out of the 88 with potential additional capacity under ANM, the CBA concludes that the NPV of gross network benefits could be £2.6m for a passive approach that connects more DG and uses more monitoring, or £8.7m for an active approach that uses ANM. • Case study analysis suggests that £25/customer of benefits might be available through deferring reinforcement using dToU price signals at some substations, before the full costs of implementing such a tariff are taken into account • The experience and findings from LCL have allowed UK Power Networks to adopt DSR as a business as usual activity. This has culminated in **savings within the 2015 RIIO-ED1** business plan submission of £12m across the LPN licence and a **total of £43.5m** across all three of UK Power Networks' licensees during the period. • Financially the project met its in-project benefits case, delivering **£1.5m of network reinforcement savings through the successful application of I&C DSR** at Ebury Bridge substation.

Project Title	**Low Carbon London (LCL)**
	• Finally, LCL completed all its objectives under budget, enabling a further £4.8m to be returned to LPN customers • Carbon emissions from today's electricity system are around 450g/kWh. If only one of the initiatives demonstrated in Low Carbon London was fully adopted across the country, an additional contribution of 5g/kWh towards this reduction would be achieved, with the potential for far more. • The project estimates that the GB will gain in the order of £9.5bn of gross **benefits, of** which **£1.0-2.0bn** might be expected to accrue **to DNOs** from their **making use of flexible demand** and the remaining **£7.5 - £8.5bn might accrue to the electricity system more broadly as a result of avoided carbon emissions and carbon penalties**. The estimated cost of accessing these benefits has reduced from £3.5bn to £2.3bn.

Table 20: Flexible Urban Networks overview.

Project Title	**Flexible Urban Networks (FUN-LV)**
Company	Lead: UKPN, Partners: GE Digital Energy, IC Consultants Ltd, PPA Energy and CGI UK Ltd
Project Funding	£8.86m – LCNF Tier 2 inc. partner contributions
Project Driver	Government policy / low carbon targets driving the connection of LCTs in areas of network constraint
Project Objectives	• **Optimise capacity on the low voltage network closest to customers** to accommodate the forecasted growth in electric vehicle charging, heat pumps and microgeneration on existing connections by making the network more flexible and resilient through capacity sharing between substations; • **Improve connection offers (time & cost) in urban areas** by knowing where best to connect, and by managing voltage, power flows and fault current through the use of power electronics; and • **Advance the future network architecture debate for the sector** through the evaluation and dissemination of financial learning, benefits and architecture of the power electronics applications on different network architectures and by providing network configuration control in combination with remote switching.
Key tech/process trialled	Three types of power electronic device (PED) connected to 36 trial sites in London and Brighton, across radial and interconnected networks. The trials will explore the following: • Suitability of PEDs to release capacity and defer network reinforcement; • PED control algorithms required for autonomous control; • Connection of PEDs to network control systems; and • Modelling of PEDs in planning tools to demonstrate power flow Enhanced Network Assets (LV automation and soft open points) Communications, System Integration and Data Management
Project Business Case (as reported by DNO)	There are important non-financial, and presently unquantified benefits expected from FUN-LV. For some benefits (and costs) it will only be possible to meaningfully quantify these during the course of the project. Work stream 4 is dedicated to conducting a cost benefit analysis of FUN-LV.

Project Title	**Flexible Urban Networks (FUN-LV)**
	The overall business case for carrying out the project remains strong. At a GB scale, the benefits have fallen slightly from £112.8m to £90.2m but are significant. This will be validated further during the workstream 4 cost benefit analysis activities.
Timescales	January 2014 – December 2016
Current status	Underway
Outputs/ Implementation (as reported by DNO)	• Network Awareness and Process Improvements • Cost Benefit Analysis of using PEDs against traditional network reinforcement methods.

Table 21: Kent Area System Management overview.

Project Title	**Kent Area System Management (KASM)**
Company	UKPN with National Grid, Navigant Consulting (Europe) Ltd. Bigwood Systems Inc.
Project Funding	£3.90m – LCNF Tier 2 inc. external funding
Project Driver	Enabling renewable energy connections Building a stronger and smarter grid
Project Objectives	Operate the network closer to its limit and hence as an alternative to traditional reinforcement; Reduce constraints placed on generators during maintenance and other planned outages; Improve operational processes to reduce time-constraints on outage planners and reduce the overall risk on the network.
Key tech/process trialled	Innovative application of a software tool, real-time contingency analysis, in a DNO control room. Transmission system operators currently use a variant of this tool to actively manage the reliability of complex transmission networks. The method brings together a number of technical and commercial components: 1. The development of the business processes and functional requirements to enable enhanced sharing of real-time operational data between DNOs and TNOs; 2. The implementation of a sophisticated suite of software tools that enables analysis of power flows for the current (intact) and post-fault (N-1, N-X) network states in operational timeframes and automatically quantifies operating shortfalls; and 3. The development of sophisticated near term unit-specific and bus-specific load and generation forecasting capabilities to enable accurate modelling of corrective and preventative control actions.

Project Title	**Kent Area System Management (KASM)**
Project Business Case (as reported by DNO)	Estimated **net benefit of £0.6 million in present (2014) terms** over the business as usual approach according to quantification of: • the projected costs of the base case, or business as usual; • the projected costs of the KASM method; • the benefits which are unlocked through its deployment; • the net benefit.
Timescales	January 2015 – December 2017
Current status	Underway
Outputs/ Implementation/ Impact (as reported by DNO)	1. Development of the strategy for inter-control room communication protocol for the purposes of KASM 2. Completion of the system integration of Contingency Analysis (CA) software into UK Power Networks systems, excluding a real-time link to National Grid 3. Completion of installation of forecasting modules that will link the DNO control room with other data sources 4. Demonstration of use of real-time contingency analysis in the control room 5. Completion of trials and implementation of reliability management, outage management and network capacity management 6. Development of business design to incorporate contingency analysis as business-as-usual Deferral of traditional reinforcement. Higher utilisation of wind and solar capacity. Maintaining existing outage planning labour. Analysis conducted on the number of export constrained GSPs in the GB today and under alternate supply and demand scenarios identifies that there are between 5 - 8 credible sites per year that could benefit from the deployment of the KASM method. Using a conservative estimate of 3 sites per year for ten years starting in 2018, the estimated net benefit of a wider rollout across the GB is in excess of £65m in present value (2014) over the lifetime of the investment. This level of benefit is achieved through a full rollout of contingency analysis and enhanced outage planning and management processes across all GB DNOs, and by achieving the performance improvements as assumed in the analysis presented above. The nature of the proposed solutions means that incremental or partial benefits can still be achieved with a more limited rollout. Linear extrapolation of the benefits estimated for the East Kent region, results in an estimated carbon emissions savings of approximately 275,000 tonnes of CO_2. This equates to an associated financial savings of an additional £7.6 million in present value (2014) terms.

Table 22: Vulnerable Customers and Energy Efficiency overview.

Project Title	**VCEE - Vulnerable Customers and Energy Efficiency**
Company	UKPN with British Gas, CAG Consultants, University College London (Energy Institute), Tower Hamlets Homes, Poplar HARCA, Bromley-by-Bow Community Centre and the Institute for Sustainability, National Energy Action, British Red Cross (Critical Friend) and Consumer Futures (Critical Friend).
Project Funding	£5.49m LCNF Tier 2 inc. external funding
Project Driver	The government's Low Carbon Transition Plan necessarily has an impact on customers' energy bills. Those with the potential to be hardest hit include the 4.5 million fuel poor in the UK (2011, DECC), of which a significant number are also vulnerable in some way. Separately, the Distribution Network Operators (DNOs) are forecasting increasing and more uncertain demands on their networks as the result of the electrification of heat and transport and the increased reliance on micro-generation and distributed generation (DG). The more customers that participate in providing time-shifting or Demand Side Response (DSR) and the more customers that can achieve sustained energy savings, the more it will help to mitigate this substantial challenge.
Project Objectives	How to identify and use existing trusted social resources to effectively engage fuel poor customers in the adoption and use of smart metering technologies; The amount of energy savings (in energy and monetary terms) arising from a set of intervention measures tailored to the specific resources and needs of the trial area community; The amount of energy shifting arising from a package of intervention measures tailored to the specific resources and needs of the trial area community The impact on network reinforcement from reduction or shift in energy consumption Improved demand profiling for these customers What engagement material and communications channels were effective in reinforcing and supporting their behaviour.
Key tech/process trialled	Demand reduction and demand shifting, by providing 550 households in 2 groups with a smart meter, simple energy saving and energy shifting devices, energy advice and Time-of-Use tariffs. The trials will research the effectiveness of techniques and capture learning on the: • Level of response from fuel poor to smart meter data & price signals • Energy cost savings achieved from customer interaction and network benefits • Improved demand profiling for these customers • What engagement material & channels were effective in supporting their behaviour.

Project Business Case (as reported by DNO)	£413k to £825k saving over 45 year asset life for 2.5MVA to 5MVA 10 year reinforcement deferral. £1.05m to £2.1m saving over 45 year asset life for 2.5MVA to 5MVA indefinite reinforcement deferral (no reinforcement over life of asset). £180k saving from a 52.4GWh reduction in energy distributed. £38 to £61 bill saving potential for households when participating in energy efficiency.
Timescales	January 2014 - December 2017
Current status	Underway
Outputs/ Implementation/ Impact (as reported by DNO)	The project hopes to understand: • the extent to which this residential customer group is able and willing to engage in energy efficiency and an 'off peak' tariff; • the benefits that they can realise from their change of behaviour in household energy management; • the challenges and best approaches to engaging with these groups of customers to achieve these aims; • consequently how their move and reduction in demand away from network peak periods may benefit the electricity network by deferring or avoiding network reinforcement.

Table 23: Fault Level Active Response overview.

Project Title	Fault Level Active Response (FLARE)
Company	UKPN with ABB, Parsons Brinckerhoff, Energ-G, Impact Research, Combined Heat and Power Association, Schneider Electric, United Utilities and The University of Manchester School of Electrical & Electronic Engineering, Tyndall Manchester Centre for Climate Change, Greater Manchester Combined Authority
Project Funding	£5.49m LCNF Tier 2 inc. external funding
Project Driver	To help distribution network operators to quickly connect customers' low carbon demand and generation and at a lower cost than traditional reinforcement.
Project Objectives	1. To trial the Fault Level Assessment Tool software; 2. To trial two technical and one commercial techniques which, when deployed on existing network infrastructure, will provide effective and efficient fault level control; 3. To deliver novel and highly transferable solutions that can be applied to the HV and EHV networks by any GB DNO; 4. To demonstrate release of network capacity allowing quick and lower cost connection for customers' demand and generation, enabling DNOs to support the UK's decarbonisation strategy.

Project Title	Fault Level Active Response (FLARE)
Key tech/process trialled	1. Adaptive Protection – also known as sequential tripping. This technique re-sequences the operation of CBs and is retrofitted into existing substation equipment. 2. Fault Current Limiting service (FCL service) – Industrial, commercial and generation customers can operate their equipment so they can offer fault level management services to DNOs using new technology trialled under FLARE. This commercial solution will enable customers to earn rewards and will benefit all distribution customers through reduced reinforcement. 3. IS-limiters – an existing technology used on private networks in the UK and extensively on public networks in Europe, USA and Australia as a fault current mitigation technique. This will be the first installation of an IS-limiter on a GB DNO network. A 2004 report written by Parsons Brinckerhoff Development of a safety case for the use of current limiting devices... 4 suggested that installation of IS-limiters would lead to difficulties in complying with a number of Electricity Safety, Quality and Continuity Regulations (ESQCR) and Electricity at Work regulations. PB Power is the technical support Partner for this Project. Together we aim to demonstrate how these devices can be deployed safely and legally and unlock the benefits this technology can provide for customers.
Project Business Case (as reported by DNO)	The FLARE Method releases the same capacity as traditional reinforcement but up to 18 times faster and at much lower cost – up to 80% cheaper – potentially saving GB £2.3 billion by 2050.
Timescales	January 2015 – October 2018
Current status	Begun
Outputs/ Implementation/ Impact (as reported by DNO)	The FLARE Method will reduce overall costs of the distribution network, avoid fault level reinforcement and enable much quicker connection of low carbon demand and generation. FLARE could deliver savings for DUoS customers of around £2.3 billion by 2050 and reduce costs for connections customers. It could also be used to enhance other fault level mitigation techniques such as those being trialled as part of FlexDGrid, a Second Tier LCN Fund project run by Western Power Distribution (WPD). FLARE could release 127 275MVA of capacity for the connection of customers' new low carbon generation and demand.

Western Power Distribution

Table 24: LV Network Templates overview.

Project Title	LV Network Templates
Company	WPD with RWE Npower, University of Bath
Project Funding	£9.02m– LCNF Tier 2
Project Driver	To complicate matters, the LV network is also the part of the network about which we have the least information about, or knowledge of the 'headroom' available to accommodate a low carbon future. We do not accurately understand the impact of low-carbon initiatives on the LV network, and have little insight into the supply performance of the LV network against the European power quality standard EN50160. Therefore, we do not have a clear

Project Title	**LV Network Templates**
	picture of how best to design or manage the network to meet these challenges. Nor can we tell National Grid (NG) how much UK LV microgeneration is running – having knowledge of this microgeneration will optimise the UK's spinning reserve.
Project Objectives	The project will give WPD a view of the power flows and voltages of the LV network in South Wales, together with visibility of impacts arising from Welsh Assembly Government (WAG) low-carbon initiatives covering some 3,000 homes, and including 1,000 PVs installations
Key tech/process trialled	Development of LV templates that can with an 82.2% level of accuracy estimate the load and voltage flows at a given LV substation without the need for costly monitoring.
Timescales	April 2011 – July 2013
Outputs/ Implementation/ Impact (as reported by DNO)	The reduction in HV in target voltage will **reduce maximum demand by 15.7MW.** The reduction in HV and LV system voltage will **reduce Customer bills by a calculated £9.4M each year**, based on DECCs current valuation of domestic and I&C rates. - The reduction in HV and LV system voltage will **reduce CO_2 emissions by some 41,000 Tonnes each year**, based on DECC 2011 data. DECC provisional 2012 data would give a figure 10% higher than this. The transmission entry capacity of major generators for the same period was 81.742 giving a margin of 24,252MW, and thus a saving of 618MW would (coincidentally) also represent **an increase of 2.5% in current capacity margin**, though that figure would increase with impending station closures. - At that rate, the value to domestic customers alone of such a reduction in energy would be some £315M per annum based on DECCs current valuation of marginal domestic and I&C rates. - Taking that voltage reduction applied at primary substation level would also apply to HV connect customers, the annual carbon reduction figure of an annual **1.98 Million Tonnes of CO_2** is conservative for the current generation mix.

Table 25: Sola Bristol overview.

Project Title	**SoLa Bristol**
Company	WPD with Siemens, University of Bath (with RWE npower) and Bristol City Council. Moixa Energy
Project Funding	£2.48m – LCNF Tier 2 inc. external funding
Project Driver	Reduce need for network reinforcement Facilitate connection of low carbon devices at reduced cost
Project Objectives	The project will test the following Hypotheses: - Should new Low Carbon Technologies (LCTs) increase distribution network peaks and cause thermal overloads, then battery storage, demand response and DC networks could be an efficient solution,

Project Title	**SoLa Bristol**
	conventional network reinforcement for short thermal overloads may not the most efficient use of customers money • If DC networks in properties could be used to reduce network harmonics, phase distortion and improve voltage control then their use may be vital in the connection of LCTs. Because the safe, efficient operation of distribution networks is reliant on the power quality and voltage being within statutory limits • If DNOs and customers could share battery storage on DC networks with a variable tariff, then the mutual benefits may make battery storage financially viable, as battery storage could be a shared asset or sold to customers as a service
Key tech/process trialled	Home energy storage with demand response New variable tariffs DC networks
Project Business Case (as reported by DNO)	By 2030 the total carbon savings associated with BRISTOL is expected to be 1,452.3 thousand tonnes of CO_2 corresponding with a saving of £36.8m from deferred network reinforcement.
Timescales	December 2011 – January 2015
Outputs/ Implementation/ Impact (as reported by DNO)	Benefits for domestic customer came from the demand reduction brought by PV and demand shift brought by battery storage, both of which were triggered by Time-of-Use tariff. The **average bill saving of the 11 houses on the trial were £52.10 in the seven months of the trial**, a saving of almost 25% on their original bills. With the penetration levels of battery and PV being relatively low in the trial network the corresponding network investment deferral was found to be less than £300. However when the penetration and network utilisation increases, the network investment deferral is increased to thousands of pounds. Battery and DC circuit helped keep the lights on during power outage even when on prepayment key meter.

Table 26: Network Equilibrium overview.

Project Title	**Network Equilibrium**
Company	Lead: WPD, Partners: National Grid, SPEN, Newcastle University and Parsons Brinckerhoff
Project Funding:	£13m - LCNF Tier 2 inc. partner contribution
Project Driver	Development of smart grids and ensuring network stability

Project Title	**Network Equilibrium**
Project Objectives	• **Increase the granularity of voltage and power flow assessments,** exploring potential amendments to ENA Engineering Recommendations and statutory voltage limits, in 33kV and 11kV networks, to unlock capacity for increased levels of low carbon technologies, such as DG; • Demonstrate how **better planning for outage conditions** can keep more customers (generation and demand) connected to the network when, for example, faults occur. This is particularly important as networks become more complex, with intermittent generation and less predictable demand profiles, and there is an increased dependence on communication and control systems; • **Develop policies, guidelines and tools,** which will be ready for adoption by other GB DNOs, to optimise voltage profiles across multiple circuits and wide areas of the network; • **Improve the resilience of electricity networks** through flexible power link (FPL) technologies, which can control 33kV voltage profiles and allow power to be transferred between two, previously distinct, distribution systems; and • **Increase the firm capacity of substations,** which means that the security of supply to distribution customers can be improved during outage conditions, leading to a reduction in customer interruptions (CIs) and customer minutes lost (CMLs).
Key tech/process trialled	• Advanced planning tool • System voltage optimisation • Flexible power link
Project Business Case (as reported by DNO)	By 2050, WPD conservatively estimates that Network Equilibrium will release 11.3 GW of capacity for LCTs across GB, with a cost saving of £1.5 bn when compared to the most efficient traditional solutions, such as network reinforcement, presently in use.
Timescales	March 2015 - June 2019
Current status	Begun
Outputs/ Implementation/ Impact (as reported by DNO)	The expected benefits are: • The **Carbon Benefit** (expressed in terms of DG capacity released); • There will be **lower Distribution Use of System (DUoS) charges for distribution customers**, due to lowering the socialised part of DG connections. This will result in lower bills for electricity consumers, when Equilibrium's solution is installed instead of conventional (network reinforcement) solutions; • The additional resilience of the electricity network and **increased security of supply to distribution customers** can be measured through reductions in customer interruptions (CIs) and customer minutes lost (CMLs); • The **avoidance / deferral of network reinforcement** (particularly the new build of overhead line infrastructure) will result in benefits to the GB Environment, such as in Areas of Outstanding Natural Beauty and financial benefits for the National Grid and other transmission system operators. • GB DNOs will benefit from: the amendment and/or creation of new standards for voltage control and power flow management within electricity networks; design specifications, procurement specifications and other policy documents through the associated resource savings; • Existing DG customers will benefit from reduced downtime, due to electricity network outages;

Project Title	Network Equilibrium
	• Future **DG customers** will receive improved connection offers, they will be able to **connect to the network more quickly and more cost-effectively** than by conventional solutions; and • The Equilibrium Solution will be equally as applicable to existing and/or future demand customers, particularly those looking to integrate LCTs into electricity networks, creating a fair system.

Table 27: Flexible Approaches for Low Carbon Optimised Networks overview.

Project Title	Flexible Approaches for Low Carbon Optimised Networks (FALCON)
Company	Lead: Western Power Distribution (East Midlands), Partners: Cranfield University, Aston University, The Open University, Alstom, GE Digital Energy, CISCO, Thamesway Energy and Logica
Project Funding	£15.1m - LCNF Tier 2 inc. partner contribution
Project Driver	Traditional electricity network design standards and system operating techniques use tried and tested engineering assumptions, used to preserve the integrity of the local grid. Two such core assumptions are: • A system annual load growth of around 1%; and • A reliance on diversity of consumption (i.e. netting of high individual consumption peaks - e.g. kettle/shower usage - with low usage by other customers at the same time). It is feared that new LCTs, such as DG, heat pumps and EVs will challenge these two core assumptions. At present, DNO's have no means to evaluate the alternative ways of addressing constraints on the 11kV network, with no industry standard way of comparing the appropriateness of standard reinforcement versus the viability of local DSM for example. Whilst most ongoing LCNF projects are investigating the impact of low carbon technologies on the low and primary voltage networks, more work is required to investigate the impact on the 11kV network, the backbone of the local grid.
Project Objectives	• Enable the uptake of low carbon technologies • Determine the viability of delivering faster and cheaper 11kV connections and reduced DUoS charge increases for all • Generate learning applicable to all DNOs, shared through established LCNF dissemination channels
Key tech/process trialled	The Falcon project trialled intervention methods to increase utilisation of both existing and new 11kV networks, to meet the potentially rapid, uncertain changes in customer demand. It assessed the applicability of each intervention Method a clear understanding of the current capacity of the 11kV network needed to be determined, as traditional 11kV network design had not required monitoring. No such understanding existed; this was developed as part of the Project. WPD focused this Trial on areas of the network with known constraint issues. **Method 0** - This method created a network investment model for quantifying and predicting available capacity on the 11kV network. The model was populated with data from existing industry sources, and verified through data obtained through the WPD Tier 2 South Wales project. The model supports constraint prediction using forecast take-ups of low carbon technologies.

Project Title	**Flexible Approaches for Low Carbon Optimised Networks (FALCON)**
	The six Intervention Methods trialled are listed below: **Method 1** - (technical) Dynamic calculation and utilisation of 11kV asset ratings to free up unused capacity previously constrained by design ratings; further enhancing the techniques used in the WPD Lincolnshire Low Carbon Hub project. **Method 2** - (technical) Automatic load transfer between 11kV feeders within primary substations to increase available capacity on the 11kV network. This built on algorithms currently used to manage interruptions and quickly restore customer supply. **Method 3** - (technical) Implementation and operation of a meshed (interconnected) 11kV network in suburban and rural areas in order to maximise capacity. **Method 4** - (technical) Deployment of new battery technologies using innovative chemistry with increased portability, capacity and scalability which will alleviate 11kV constraints. These units were located in distribution substations. **Method 5** - (commercial) Control of distributed generation to increase capacity on the 11kV network using innovative commercial arrangements. **Method 6** - (commercial) Control of customer demand to increase capacity on the 11kV network through the use of innovative commercial arrangements, such as a centralised auctioneer.
Project Business Case (as reported by DNO)	In addition to a **net financial benefit of £1.2m from the four year project**, based on mid-range penetration levels of LCTs and area comprising of 0.19% of UK customers, WPD estimated that a **national rollout** of FALCON could realise a **£660m financial benefit over 20 years** and will **save over 680 ktonnes of CO_2e by 2050** (accounting for an additional £36m of benefits).
Timescales	November 2011 – November 2015
Current status	Complete
Outputs/ Implementation/ Impact (as reported by DNO)	Benefits within the lifecycle of the project are hard to quantify due to the area used in the trials and therefore it is stated that no benefits occur within the lifecycle of the project. The £1.2m savings figure (above) is based on estimates derived from an Imperial College & ENA paper (Benefits of Advanced Smart Metering for Demand Response based Control of Distribution Networks, Summary Report V2.012) on national network investment needed in the 2020-2030 period in order to cope with increased demand from and load input to the HV network. – Net financial savings were calculated as the difference in investment between "business as usual" investment (BAU) and smart grid investment to cope with this modelled growth in demand. This was the calculation of choice for the techniques and trials in this project. – The paper derived models of electricity demand growth and profile changes on the UK HV and LV networks. Primarily responsible for these changes are the increase in electric vehicle and heat pump use, as well as underlying assumptions about increases in energy efficiency for buildings. –WPD's estimates for £1.2m saving on infrastructure were based on using a BAU investment in HV grids less the 13 calculated investment needed using these smart grid technologies nationally during the same period (including modelling their roll out, effectiveness, penetration and actual savings). This

Project Title	**Flexible Approaches for Low Carbon Optimised Networks (FALCON)**
	is then normalised to the size of the trial area by the number of customers in the area as a percentage of national number of customers. Various technology penetrations were modelled between 2020 and 2030, assuming a starting point of 5% by 2020. We selected their mid-range 50% penetration level of electric vehicles (EVs) and electric heat pumps (HPs) by 2030. – To derive projected figures for the project using these national figures, WPD have estimated the percentage of the UK covered by the project area (55,000 customers as opposed to 28.7m across UK) to be 0.19%. – To refine this figure further, WPD have estimated the % projected uptake of the techniques; WPD are investigating across the country, their effectiveness and their cost saving to an overall figure of ~36%. This, along with an estimated 50% roll out across reinforcement projects, is then applied to give national costs of infrastructure investment under smart grid trials Dynamic Asset Rating of 11kV overhead lines (OHL), 33/11kV transformers, 11kV/400V transformers and 33kV and 11kV cables sections were undertaken. For all the asset types (OHL, cables, and transformers) periods of time were found where the real-time dynamic ratings were above the applicable static rating, and there were periods when the dynamic ratings were below static ratings. Recommendations based on this technique are: • Widespread application of 11kV OHL DAR is not recommended due to high variability, difficult to rely on in real-time, and complexity of widespread application • Widespread application of Distribution transformer DAR is not recommended due to the likely requirement for bespoke transformer modelling

Table 28: Low Carbon Hub overview.

Project Title:	**Low Carbon Hub (LCH)**
Company:	WPD
Project Funding:	£3.527m – LCNF Tier 2
Project Driver	Conventional design solutions to the resulting changes in fault level, voltage control and capacity are often substantial cost. This can mean that in areas which have abundant renewable energy resources the connection of DG is uneconomical. Lincolnshire is one such area. It has a rich wind resource which may be underutilised for distributed generation due in part to electricity distribution network connection costs.

Project Title:	**Low Carbon Hub (LCH)**
Project Objectives	• Dissemination to the other GB DNO’s and IDNOs of design recommendations for connecting optical fibre and wireless links to new and existing wood pole overhead power lines; • Dissemination of a new set of commercial agreements jointly created between generators and the DNO; • Completion and demonstration of the dynamic voltage control capability implemented within GE POWERON (Network control system widely used by UK DNOs); • Completion of the nominated 10.5km of OHLs that have already been included in the DPCR5 submission to the new LCH standard; • Installation and commissioning of the Flexible Alternating Current Transmission system (FACTS) device; and • Operation of the 33kV active network ring connecting Alford, Trusthorpe, Chapel St Leonards and Skegness. Creating a network suitable for demonstrating the high penetration of DG.
Key tech/process trialled	The LCH has six project components and these will be trialled together as outlined below: **Network enhancements** – Sections of existing overhead lines will be upgraded within the demonstration area with higher rated conductors to increase the network’s capacity to connect DG. This work is in addition to investment already funded through the DPCR5 settlement. **New commercial agreements** – Innovative agreements will be negotiated with DG customers to optimise their output and mitigate network issues (e.g. to deliver reactive power service) using real time network measurements. Potential limitations of the current regulatory framework will be identified. **Dynamic voltage control** – Building on the principles of an existing IFI project, the 33kV target voltage will be actively varied. This will be done dynamically based on real time measurements of demand and generation. Dynamic voltage control should increase network utilisation whilst maintaining the system voltage within the statutory limits. **33kV active network ring** – The active ring allows increased control of the 33kV system and network reconfiguration based on real time power flows. Construction of the ring will involve the installation of an additional circuit breaker, a new interconnector and smart grid protection and control. **Flexible AC Transmission System (FACT) Device** – A Flexible AC Transmission system device will enable WPD to control both network voltage and system harmonics of the active ring. This equipment is not normally deployed on Distribution networks for this purpose. Shunt compensation will be used to generate or absorb reactive power. These highly technical solutions will be designed to increase the amount of DG that can be connected. **Dynamic system ratings** – The Skegness Registered Power Zone delivered lines. This component will further develop the solution and test new techniques to calculate the network capacity and operating limits based on real time asset data.
Project Business Case	**Ring Method** - The costs associated with the ring method are high, and the capacity released is relatively modest. As a result of the ring method, an additional 10MVA. Alternative Connection has accepted due to the reduction in constraints.

Project Title:	**Low Carbon Hub (LCH)**
	Network enhancements – The additional costs have been estimated as £8,000 per km, whilst capacity released is approximately 12MVA of additional headroom. The method has also reduced voltage rise by 24%. **Dynamic Line Ratings** – This is less appropriate at 33kV due to the increased risk of sheltering. This is a significant barrier to DLR being used at 33kV to unlock additional generation capacity so the effective business case for this approach is very poor **Dynamic Voltage Control** - Dynamic Voltage Control did not demonstrate a cost benefit during this project. However it shouldn't be written off as an approach because there is much potential for it in the future. **FACT Device** - The D-STATCOM has proven to be very effective at controlling network voltage and reducing losses by balancing reactive power flows. The device could also be used to manage reactive power flows between the distribution network and transmission networks.
Timescales	January 2011 – May 2015
Current status	Complete

Outputs/ Implementation/
Impact (as reported by DNO)
	• As of February 2015 34 Alternative Connections (a new commercial agreement) offers had been made in East Lincolnshire and have **facilitated 48.75MVA of additional generation connections.**
	• As part of the internal implementation, ANM policies and Standard Techniques have been written for offering alternative connections as a BAU process, WPD's 200+ planners have been trained how to offer alternative connection offers, and we have changed its core database to facilitate the alternative connections.
	• The Ring Method arrangement increases power flow route diversity, with the associated **benefits to system availability and losses reduction.** The project showed that an existing radial network could be modified, rather than rebuilt, to enhance capacity. It is now understood that the use of 33kV switchboards at a number of sites would have been an economically advantageous alternative to an Air Insulated Switchgear (AIS) or hybrid AIS solution since it offers a reduced network risk during an offline build, a quicker construction phase, and a simpler network to operate. The learning from the project also showed that, having suitable current and voltage transformers in the right locations is often a limitation to smarter solutions which often require a greater number of measurement points.
	• The Network Enhancements (reconductoring a circuit with a larger conductor) have **increased the summer capacity of the circuits from 16MVA to 41MVA** and it has been modelled to **reduce voltage rise by 24%** compared to the existing circuit during maximum reverse power flows. At the end of the project the estimated TRL is 9.
	• Dynamic Line Ratings - The method has showed that using wind farm electrical data can cost effectively calculate an enhanced theoretical rating of the OHL based on using the calculated wind speed data.
	• Dynamic Voltage Control has shown there are substantial opportunities to optimise target voltage settings. VVT is a lower cost, quicker and simpler solution to installing new VTs and associated equipment into an existing primary substation for steady state measurements. The cost of retrofitting VVT into an existing standard SuperTAPP® n+ scheme has been estimated at £4k, whilst the associated cost of installing a fixed outdoor VT is approximately £40k, although this is site dependent.
	• Development of a UK technical recommendations for:
	  • Installing optical fibre on existing and new wood pole OHL;
	  • Installing microwave or radio links for networks.

Project Title:	**Low Carbon Hub (LCH)**
	• Development and dissemination of a future financial model detailing how future Low Carbon Hub could be created in other suitable network locations without LCN Funding. • Development of the FACTS device to control voltage changes, determining if the voltage can be controlled by installing and operating the FACTs device. • Development of a stronger relationship with distributed generators.

Table 29: FlexDGrid overview.

Project Title	**FlexDGrid – Advanced Fault Level Management in Birmingham**
Company	WPD with Parsons Brinckerhooff, University of Warwick, S&C Electric, Outram Research Limited and Birmingham City Council, Cofely, University of Southampton, University of Manchester.
Project Funding	£15.2m LCNF Tier 2 inc. external funding
Project Driver	Timely and cost-effective integration of customers' generation and demand within urban HV electricity networks.
Project Objectives	To develop and Trial an Advanced Fault Level Management Solution to improve the utilisation of DNO 11kV (HV) electricity networks while facilitating the cost-effective and early integration of customers' generation and demand connections.
Key tech/process trialled	(Alpha) Enhanced Fault Level Assessment; (Beta) Real-time Management of Fault Level; (Gamma) Fault Level Mitigation Technologies.
Project Business Case (as reported by DNO)	The FLEXGRID Solution can deliver £1bn savings across GB through the avoidance of network reinforcement and safeguarding of electricity network assets. This could facilitate 6 GW of generation connections and offset 5.05 $MtCO_2$ / year.
Timescales	December 2012 - March 2017
Current status	Underway
Outputs/ Implementation/ Impact (as reported by DNO)	Customers wishing to connect distributed generation will benefit from lower costs of connection and shorter times to connect. Customers who wish to install DG will gain from earlier access to DG benefits with direct long term cost benefits and increased security of supply. All customers will benefit from an improved quality of supply. This project will also increase the network’s capacity to be run in parallel which will reduce customer minutes lost (CMLs) and customer interruptions (CIs). All customers will benefit from lower than predicted DUoS charges as a result of the use of lower cost alternatives to conventional reinforcement and a reduction in distribution losses due to the ability to install generation closer to load. Customers in city centre areas may also benefit from reduced heating bills through the introduction of CHP district heating schemes which are facilitated by this solution; this would assist the Government in addressing fuel poverty.

Appendix IV Tier 1 Project Overviews

Of the LCNF Tier 1 projects only those that represented significant independent learning are considered below. Six projects could not be considered as, at the time of writing they were not complete or had no closedown reports available; while over half of the Tier 1 projects can be regarded as foundations for further innovation projects, such as LCNF Tier 2 projects. The benefits of these projects were therefore not considered separately so as to avoid duplication. Further information on the mapping of projects illustrating how innovation projects have helped inform later projects (and hence indicate the 'flow' of learning can be found in Table 4, Appendix II.

It should be noted that all project business cases and benefits stated in the below are as reported by the DNO conducting the project and as part of this work these figures have not been validated or endorsed by either Ofgem or EA Technology.

Table 30: Tier 1 ENWL Smart Fuse overview.

Project Title	The Bidoyng Smart Fuse
Company	ENWL
Project Funding	£442,000 – LCNF Tier 1
Project Driver	Reducing the impact of transient faults on customers.
Project Objectives	The primary aim of this project is to test the feasibility of installing a sufficient number of Smart Fuses to reduce the impact of Transient Faults on our network, if the Smart Fuse proves a reliable solution the project will provide enough data to develop a business case for the installation of a substantial number of units. The objective is to demonstrate the advantages of being able to automatically restore supplies to LV connected customers and to gather data about the performance such a device will deliver to the network. It is envisaged that other smart grid opportunities will arise once data has been gathered and evaluated.
Key tech/process trialled	200 smart Fuses installed, 94 for load profiling and 106 for fault management.
Timescales	January 2012 – December 2014
Outputs/ Implementation/ Impact (as reported by DNO)	• Formed the basis of ENWLs internal policy and code of practice documentation and installation instructions and procedures. • The Smart Fuse now provides a means to manage low voltage transient faults by eliminating 80% of fuse operations once faulty feeders are identified. • The Smart Fuse has provided over 2GB of high resolution data that has been used to analyse the performance of selected low voltage underground feeders. • Electricity North West's current average short duration interruption is approximately 60 minutes therefore when a Smart Fuse restores supplies in under the IIS target of 3 minutes it effectively eliminates 'Customer Interruptions' (based on an average number of customers connected to low voltage feeders) and 60 minutes of 'Customer Minutes Lost' penalties, it is estimated that an average penalty of £500 is avoided with every Smart Fuse low voltage feeder supply restoration. In addition to the financial benefits from an enhanced performance under the IIS incentive, the benefits of being able to better manage transient faults whilst keeping customers connected cannot be underestimated.

Table 31: Tier 1 SPEN Temperature Monitoring overview.

<table>
<tr><th>Project Title</th><th>Temperature Monitoring Wind Farm Cable Circuits</th></tr>
<tr><td>Company</td><td>SPEN</td></tr>
<tr><td>Project Funding</td><td>£710,500 – LCNF Tier 1</td></tr>
<tr><td>Project Driver</td><td>Enable further network capacity being available without the need for network reinforcement to allow increasing number of DG connections.</td></tr>
<tr><td>Project Objectives</td><td>Determine dynamic cable ratings for three cable circuits and assess the impact the renewable generation from the three wind farms will have on these circuits.</td></tr>
<tr><td>Key tech/process trialled</td><td>Temperature monitoring of cables;
Determination of dynamic cable ratings associated with wind generation output; and
Determination of available head room capacity.</td></tr>
<tr><td>Project Business Case (as reported by DNO)</td><td>Needs further work to quantify, but potential for increased headroom and increased capacity of connection of, in particular, wind farms.
<table>
<tr><th>Expenditure Area</th><th>Value (£)</th></tr>
<tr><td>IT</td><td>£31,623</td></tr>
<tr><td>Labour</td><td>£161,263</td></tr>
<tr><td>Optical fibre installation</td><td>£321,315</td></tr>
<tr><td>Distributed Temperature Sensing (DTS) and Dynamic Cable Rating (DCR) equipment</td><td>£181,000</td></tr>
<tr><td>TOTAL</td><td>£695,200</td></tr>
</table></td></tr>
<tr><td>Timescales</td><td>October 2012 – March 2015</td></tr>
<tr><td>Outputs/
Implementation/
Impact</td><td><p>The installation of the optical fibre cable and micro-ducts in the centre of the trefoil cable arrangement was an effective approach for measuring the surrounding temperature of the cable, as this location can provide the closest temperature to the cable core, whilst the risk of damage to the micro-duct and optical fibre cable is relatively low.</p><p>The data analysis of loading of wind farms circuits showed that the actual heat dissipation levels in these cable circuits was likely to be higher than the heat dissipation levels assumed for a continuous cable loading. In other words, considering dynamic ratings, rather than continuous rating, seemed more relevant for sizing the wind farm cable circuits.</p><p>There is a new project under the NIA funding mechanism to prepare DTS and DCR systems for full business adoption. The new project has been registered as “Enhanced real-time cable temperature monitoring” (NIA SPEN0003). The following developments have been considered in the new project:</p>
Data analysis of a 12-month period;
Requirements for integration of DTS and DCR systems into an ANM system architecture; and
Policy documents and technical specifications for future DTS and DCR systems for BAU application.</td></tr>
</table>

Table 32: Tier 1SPEN Implementation of RTTR overview.

Project Title	**Implementation of Real-Time Thermal Ratings**
Company	SPEN with University of Durham, Areva, Imass and Parsons Brinckerhoff
Project Funding:	£450,000
Project Driver	Enable more flexibility in new generation
Project Objectives	• Release network capacity for 132kV wind generation; and • Gain business confidence to offer ANM solutions for prospective generation customers, as part of a RTTR system.
Key tech/process trialled	RTTR including installation of meteorological stations
Project Business Case (as reported by DNO)	It was found that the average uplifts ranged from 1.24 to 1.55 times the static summer rating. The potential average additional annual energy yield ranged from 10% to 44% for the circuits considered. These results are highly encouraging and demonstrate the potential merit of RTTR system deployments. The practical exploitable headroom and energy yields values are lower than the theoretical values. This is because the RTTR system deployed in the LCNF project takes into account constraints such as cable ratings and protection equipment ratings. For business acceptance, safety margins were introduced and estimates on the side of caution were refined, in comparison to the R&D project. IT expenditure included communications infrastructure, security, and delivery of the RTTR algorithm by GE. Materials include the weather stations. IT: £77,952 Materials: £1,306 TOTAL: £79,258
Timescales	July 2010 – June 2013

Project Title	Implementation of Real-Time Thermal Ratings
Outputs/ Implementation/ Impact	A Business Adoption Strategy was developed as part of the RTTR system trial and is soon to be implemented by SP Energy Networks. Key learning points in deploying RTTR systems: • The importance of incorporating graceful degradation algorithms within the monitoring and control system to deal with equipment failure, communications interruptions and erroneous data; • Balance of centralised versus distributed intelligence and using distributed intelligence to report back information (not just data); and • Use of multiple vendors for equipment supplies. Recommendations for other projects: • The reliability of communications systems should not be taken for granted and should not be assumed to be 100%, particularly with GPRS systems; • Inclusion of end-to-end system diagnostics so that sources of error (equipment outages, communications outages and data outages) can be identified and pinpointed immediately, triggering remedial actions within suitable timescales; and • Budgeting for whole project lifecycle (TotEx: CapEx, OpEx, decommissioning) and incorporation of ‘spare’ equipment in budgets. SPEN make the following recommendations on how the outcome of the project can be exploited: • For the facilitation of wind farm connections; • Network reinforcement avoidance / deferral; • Data could be used for research purposes; and • RTTR systems can be combined with ANM to capture the benefits of rating uplifts.

Table 33: Tier 1UKPN Distribution Network Visibility overview.

Project Title	Distribution Network Visibility
Company	UKPN
Project Funding	£2,890,000 – LCNF Tier 1
Project Driver	The main aim of the project was to demonstrate the benefits of the smart collection, utilisation and visualisation of distribution network data.
Project Objectives	The main objective of the project will be to demonstrate the business benefits of the smart collection, utilisation and visualisation of existing data (i.e. analogues available from RTUs). The project will establish optimum levels of distribution network monitoring and frequency of sampling for specific scenarios and applications. It will also trial various optical sensors that could potentially be used to provide detailed monitoring of sites with no RTUs.
Key tech/process trialled	• A production web-based application was successfully developed to implement a suite of visualisations and analysis tools for network data. • **Load Flow Tools:** Two commercially available load flow tools (GE DPF and CGI DPlan)

Project Title	Distribution Network Visibility
Timescales	January 2012 – December 2015
Outputs/ Implementation/ Impact (as reported by the DNO)	**Visualisation application:** This application has now been adopted business as usual by UK Power Networks as part of our corporate IT landscape and is being used by various business units. **Data Integration:** Data from six separate databases has been integrated into the visualisation application to ensure users are provided with useful information to support business decisions and deliver benefits. **An IT White Paper has been written** to assist other DNOs, particularly their IT departments, in replicating the results of the project. **Remote Terminal Unit (RTU) upgrade:** 9,885 Secondary RTUs on the London network were upgraded to allow retrieval of a further 11 analogue network measurements in addition to the existing four previously available. **Advanced RTUs features:** These were only partly assessed due to concerns principally relating to compromising the operational SCADA or communication systems, which resulted in only 27 independent RTUs being upgraded and a limited number of network events captured. Areas where benefits are expected to be delivered through network data analysis and visibility have been identified, and functionalities required to deliver them developed. Examples include: - **Deferring and avoiding network reinforcement:** Relying on assumptions when analysing load allocation on networks necessarily involves the use of safety margins to account for unknown and unexpected loading conditions. Having accurate information regarding the loading of assets allows them to be utilised more efficiently, while at the same time ensuring they are not unknowingly overloaded. - **Reducing frequency and duration of customer interruptions:** Having greater visibility of network conditions allows DNOs to identify areas of the network that may be experiencing abnormal loading. Failures could be prevented, avoiding customer interruptions. It will also mean that when interruptions do occur, responses can be faster, better targeted and remedial action can be more effective. - **Avoiding and limiting damage to assets:** Detailed network loading analysis can ensure that assets are being utilised within safe limits in terms of load, duty and other parameters such as harmonics, ensuring they are not being subjected to damage. Simulation of planned operations using historic data will also help to avoid damage related to these operations and the conditions the network experience as a result of these operations. - **Improved customer service:** In addition to reducing interruptions, DNOs are able to take proactive approaches to voltage issues and be able to provide customers with better information regarding outages. More accurate and timely connection proposals can also be made.

Table 34: Tier 1UKPN PV Connection Assessment Tool overview.

Project Title	Validation of PV Connection Assessment Tool
Company	UKPN
Project Funding	£367,000 – LCNF Tier 1

Project Title	Validation of PV Connection Assessment Tool
Project Driver	UK Power Networks hence initiated this project to ensure that its PV connection assessment tools, procedures, and design assumptions are fair to customers, minimise the risk of adverse impacts on the network, and incorporate the best practices, knowledge, and solutions available in GB.
Project Objectives	• Validate UK Power Networks' guidelines for assessing PV connection requests and develop a formal policy. • Develop a better understanding of the impact (including weather-related behaviour) that PV clusters have on the LV network by monitoring 20 secondary substations and 10 PV connection points. • Understand how information available to PV installers could be used by DNOs. • Gain a better understanding of the solutions available to address network constraints.
Key tech/process trialled	• Validate UK Power Networks' guidelines for assessing PV connection requests and develop a formal policy. • Develop a better understanding of the impact that PV clusters have on the LV network • Understand how information available to PV installers could be used by DNOs. • Gain a better understanding of the solutions available to address network constraints.
Timescales	January 2012 – November 2014
Outputs/ Implementation/ Impact (as reported by the DNO)	A validated and pragmatic connection assessment approach, comprising a formal design procedure and an improved tool, that UK Power Networks will adopt into business as usual and share with other GB DNOs during 2015: • The formal design procedure includes recommended design assumptions, based on real-life data. • The improved tool calculates voltage rise in three steps: the first step provides a worst-case result using minimal inputs, and if required, subsequent steps provide more-accurate results, using more-detailed inputs. A rich dataset, available for GB DNOs and academic institutions to use, comprising: • Measurements from 20 distribution substations and 10 customers' PV installations; • 25,775 days of valid data, spanning 16 months; • Over 171 million individual observations; and • Nearly three months of high-resolution (one-minute) measurements over summer 2014. A review of voltage control solutions that could be trialled or adopted in GB, including recommendations of which solutions best suit likely constraint scenarios. When planning to install equipment inside customers' homes, DNOs should expect 70% of homes to be unsuitable, and increase recruitment quotas accordingly. UK Power Networks will adopt a new engineering design procedure and improved voltage rise assessment tool into BAU during 2015.

Table 35: Tier 1 WPD Hook Norton Low Carbon Community Smart Grid overview.

Project Title	**Hook Norton Low Carbon Community Smart Grid**
Company	WPD
Project Funding	£350,000 – LCNF Tier 1
Project Driver	One of the key challenges faced by communities, such as Hook Norton is lack of visibility of energy usage at a personal and community level. Through the Smart Hooky project this has been achieved through a combination of substation and consumer energy monitoring.
Project Objectives	• To develop and explore customer engagement and incentive programmes. This aspect will include a small scale domestic demand response trial. • To develop community data measurement and display capabilities (e.g. to ascertain the total electricity consumption of the village by installing measurement devices at various locations. Subsequently, to provide this and other relevant information back to the local community via a web portal/customer interface (which if successful, could then be used for other villages)) • To deploy Power Line Communications (PLC) technology at scale within the low voltage (LV) network, illustrating its potential capabilities for enabling smart grid end point measurement and data aggregation. • To test an 'off the shelf' asset monitoring solutions for HV/LV pole-mounted and ground-mounted substations. The quality of the product will be assessed, alongside the installation methods. • To test and demonstrate a miniature smart grid telecommunications network (with multiple technologies) that will enable both local and remote network visibility • To explore the changes that could be made to a network control system for enabling simple forms of Low Voltage (LV) network monitoring and management
Key tech/process trialled	• To develop community data measurement and display capabilities (e.g. to ascertain the total electricity consumption of the village by installing measurement devices at various locations. Subsequently, to provide this and other relevant information back to the local community via a web portal/customer interface). • To deploy Power Line Communications (PLC) technology at scale within the low voltage (LV) network, illustrating its potential capabilities for enabling smart grid end point measurement and data aggregation. • To test an 'off the shelf' asset monitoring solution for HV/LV pole-mounted and ground-mounted substations. • To test and demonstrate a miniature smart grid telecommunications network (with multiple technologies) that will enable both local and remote network visibility. • To explore the changes that could be made to a network control system for enabling simple forms of Low Voltage (LV) network monitoring and management.
Timescales	Ends October 2013
Outputs/ Implementation/	• Substation monitoring has been installed in 11 substations with 46 load monitoring nodes installed in customer premises.

Project Title	Hook Norton Low Carbon Community Smart Grid
Impact (as reported by the DNO)	• Radio communications have been established between the substations and the WPD communications network allowing data to be backhauled into the control system. • Data has been exported from the WPD Enmac system via a FTP link to the National Energy Foundation every 15 minutes where it is in turn published on the customer portal. • Power line carrier communications have been successfully used between customer nodes, and distribution substations. We have been able to demonstrate that PLC communication can work on UK LV networks with an average success rate of 70-75%. The backhaul communications solution used for this scheme was also a success with reliability in excess of 95%. • From a customer engagement perspective, a wide range of recruitment techniques were trialled, although overall customer participation in the trial was lower than expected.

Table 36: Tier 1 WPD Suburban PV Impact overview.

Project Title	Suburban PV Impact
Company	WPD
Project Funding	£100,000 – LCNF Tier 1
Project Driver	Understand the effects of PV on distribution networks
Project Objectives	The project will monitor the profile of eight selected substations or individual feeders in areas where PV panels have already been installed or are expected to be installed. Exploring: • How to measure and capture voltage, current, harmonic, real and reactive power data on a range of distribution assets in suburban areas. • How to install equipment safely with minimal or no interruption of supply • How often the network characteristics need to be monitored (for example 1min, 5min, 15min) • How we can interrogate the large amounts of data generated to highlight significant network issues created by the installation of PV panels • What the effect is of installing large numbers of PV panels on the LV network
Key tech/process trialled	• How to measure and capture voltage, current, harmonic, real and reactive power data on a range of distribution assets in suburban areas. • How to install equipment safely with minimal or no interruption of supply • How often the network characteristics need to be monitored • What the effect is of installing large numbers of PV panels on the LV network
Timescales	Ends November 2013
Outputs/ Implementation/ Impact (as reported by the DNO)	• The magnitude of power flows from the HV network, through the distribution transformer into the LV network is significantly reduced during periods of high solar irradiance due to the export from the installed micro generation.

Project Title	**Suburban PV Impact**
	• The data shows that even during the longest summer days the installed solar PV had a relatively modest effect at reducing the traditional network peak demands at breakfast (7:00am – 8:30 am) and during the evening (6pm – 8pm) • The absence of reverse power flows for the duration of the trial means the voltage profile is still largely dominated by the tap changers on primary transformers and not by voltage rise from the embedded solar PV. • The installed PV generation operates at unity power factor, the connected domestic loads operating at a lagging power factor. At periods where the PV generation supports the majority of the network demand, the power factor was shown to be as low as 0.185. • The analysis of current and voltage waveforms shows the voltage remains relatively sinusoidal at all times. The sinusoidal current waveform is highly distorted due to harmonics. • WPD’s existing design policies and software tools have been amended to allow the connection of a further 20% solar PV on multiple LV properties, this is due to the measured diversity and lower than expected kW outputs. Exceeding a further 20% PV would lead to reverse power flows and could lead to unacceptable voltage rise.

Table 37: Tier 1 NPg 33kV Superconducting Fault Current Limiter overview.

Project Title	**33kV Superconducting Fault Current Limiter**
Company	NPg
Project Funding	£2,880,000 – LCNF Tier 1
Project Driver	To facilitate the connection of distributed generation (DG) from renewable sources at the distribution level, the network needs to be capable of withstanding the consequential increase in fault level associated with such connections.
Project Objectives	This project trialled a specific piece of new equipment that has a direct impact on the operation and management of the distribution system. The first phase was to identify suitable locations for the installation and undertake a feasibility and systems readiness study to analyse the network, outlining the optimum application and specification, and confirm the business and carbon cases. The second phase was to design, build, install and commission a three-phase 33kV superconducting fault current limiter (SFCL) on the Northern Powergrid distribution network.
Key tech/process trialled	33kV Superconducting Fault Current Limiter placed at the boundary of the transmission and distribution networks at a substation jointly owned by National Grid and Northern Powergrid.
Timescales	01/2010 - 06/2013
Outputs/ Implementation/ Impact (as reported by DNO)	‘With the experience from this activity, and a previous trial at 11kV, there is now sufficient confidence to specify fault current limiters as a standard network solution at 11kV for deployment during ED1. It is recommended that

Project Title	33kV Superconducting Fault Current Limiter
	appropriate standards and policies are now generated to facilitate this within Northern Powergrid. These are planned for review and update during 2015.'[16] However the 33kV SFCL was not found to be capable of meeting the required performance specification at the time.

Table 38: Tier 1 SPEN Clyde Gateway overview.

Project Title	Clyde Gateway
Company	SPEN
Project Funding	£525,000 – LCNF Tier 1
Project Driver	The application of the latest technologies on various smart grid components, on a relatively small network, was expected to: • Assist with the development of efficient and effective solutions; • Provide learning outcomes not only on the smart aspects of the grid infrastructure but on design standards, network voltages and utilisation of assets; and • Inform industry and the supply chain on smart grid challenges and solutions.
Project Objectives	The project aimed to demonstrate the integration of a number of smart grid components within an established infrastructure and aimed to facilitate the development of solutions in a number of areas including power quality, HV/LV automation, auto-sectionalising and load-transfer.
Key tech/process trialled	Five Methods were identified for trialling in this project: 1. Voltage Optimisation. 2. Asset Management. 3. Reduction of Losses. 4. Integration of Distributed Generation. 5. Reduction of Outages
Timescales	01/2012 - 03/2014
Outputs/ Implementation/ Impact (as reported by DNO)	1. Conceptual design of the HV/LV automation system; 2. Production of a functional design specification for the HV/LV automation system and identification of its components; 3. Specification and identification of a trial site; 4. Development of the detailed system architecture (including the electrical infrastructure, HV/LV automation components and ICT infrastructure); 5. Detailed design of the HV/LV automation system in the trial site (specifying equipment types and quantities); 6. Procurement, installation and commissioning of the electrical infrastructure (this was part funded by DECC's Smart Grid Capital Grant Programme);

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[16] NPg (2015) 33kV SFCL Closedown Report (Online). Available: https://www.ofgem.gov.uk/sites/default/files/docs/2015/03/33kv_sfcl_final_closedown_report_ver_1_0_final.pdf Last Accessed: 3 April 2016

Table 39: Tier 1 SPEN Temperature Monitoring Windfarm Cable Circuits overview.

Project Title	Temperature Monitoring Windfarm Cable Circuits
Company	SPEN
Project Funding	£525,000 – LCNF Tier 1
Project Driver	To help inform future cable rating calculations which could negate or postpone the requirement for upgrading/reinforcing the Distribution system.
Project Objectives	To determine dynamic cable ratings for three cable circuits (3 - 33kV) and assess the impact the renewable generation from the three windfarms will have on these circuits. From this analysis the prospect of further network capacity being available will be determined.
Key tech/process trialled	Technology for monitoring cable temperatures. System architecture, communication system and thermal models.
Timescales	10/2012 - 03/2015
Outputs/ Implementation/ Impact (as reported by DNO)	The outcomes of the project are outlined as follows: 1. **Implementation** of the DTS system for the Calder Water, West Browncastle, Dungavel and Ardoch & Over Enoch 33kV circuits. 2. **Monitoring** of half-hourly temperature variations of every metre of the optical fibre cables installed along the cable circuits through a user-friendly interface, DC-View, customised specifically for this project. 3. Development of transient thermal **models** for each of the cable circuits, which are used for estimating the core temperature of each circuit based on the corresponding optical fibre temperature. 4. **Calculations** of maximum core temperatures and thermal pinch point locations along the cable circuits. 5. **Validation** of temperatures measured by the DTS system by deploying the independent temperature sensors (Tinytags). 6. Gathering and **analysis** of the DTS data in conjunction with cable circuit loading data to provide learning on cable temperature profiles and causes of the thermal pinch points. • The Dynamic Cable Ratings (DCR) of all the 33kV cables, except Dungavel, are determined and the DCR values of cable circuits are available through the DCR and DC-View dashboards, which have been specifically designed and customised for this project. The real-time outputs of the windfarms are also transmitted from SPEN's PowerNet network to the DCR workstation. Dungavel circuit is scheduled to be energised in third quarter of 2015, once this circuit energised the DCR values will be also available for this circuit. • The comparison between maximum recorded fibre temperatures representing the surrounding temperature of the cable with the maximum permissible operating for cable core temperature (78˚C for 33kV XLPE) suggests that there may be additional network capacity available, which could be utilised if the windfarm developers decide to increase their outputs. This is subject to further assessment for at least a 12-month period after Dungevel windfarm is commissioned in third quarter of 2015.

Table 40: Tier 1 SSEPD Digital Substation Platform overview.

Project Title	**Digital Substation Platform**
Company	SSEPD
Project Funding	£360,000 – LCNF Tier 1
Project Driver	A reduction in the cost of hardware and software resource requirements for a typical primary substation installation. The aim of the project is to prove that software developed for a standalone platform can be re-coded for another platform, and maintain its integrity and functionality, without causing any adverse effects on the new host platform.
Project Objectives	1. Demonstration of data integration and interfacing between the two platforms (ANM and protection systems); 2. Simulated control of a generator to allow the management of voltage on the network; 3. Protection of primary assets using Locamation's suite of protection algorithms; 4. Definition of a methodology for deeper integration in Phase 2
Key tech/process trialled	Development and testing of data communications between Locamation (protection systems) platform and the ANM system
Timescales	01/2015 - 03/2015
Outputs/ Implementation/ Impact (as reported by DNO)	1. Demonstration of the protection of High Voltage network assets using SASensor's suite of protection algorithms; 2. Simulated control of a generator to allow for the management of voltage on the network; 3. Demonstration of data integration and interfacing between the two platforms. This project was not intended to produce a system that could be passed into BAU. The project is a proof of concept, looking at whether or not it is feasible to combine two different network management functions into one set of hardware. The extra work needed to produce an installable system is: 1) Carry out full functionality testing on a live network (PNDC Test Network) 2) Decide on the protection functionality that is required in a live substation environment. 3) Install the system in a primary substation and use it to monitor the existing protection system, checking to see that the new system produces the same actions as an existing system does. 4) Assess the results of the monitoring in an operational environment, and then decide on suitability for BAU.

Table 41: Tier 1 WPD Voltage Control System Demonstration Project overview.

Project Title	**Voltage Control System Demonstration Project**
Company	WPD
Project Funding	£525,000 – LCNF Tier 1

Project Title	Voltage Control System Demonstration Project
Project Driver	This project aimed to address the issue of fluctuations seen in long distribution lines in a rural area with Distributed Generation (DG) in the form of wind turbines.
Project Objectives	The objective was to determine the effectiveness of D-SVCs (Static VAr Compensator for Distribution Networks) as a system to control voltage on 11kV rural networks.
Key tech/process trialled	The intention was to trial a single installation of Hitachi's D-SVC on the 11kV network. Once the impact of a single device was established then a second phase would investigate the impact of multiple devices. The first phase's initial deployment has produced a number of outcomes that mean Phase 2 will be better investigated through a wider project scope. The output from Phase 1 has highlighted important learning from operating a single device. In light of this learning, Phase 1 was suspended and the new scope for Phase 2 will be extended and run as a new project.
Timescales	03/2014 - 03/2015
Outputs/ Implementation/ Impact (as reported by DNO)	This project established that the D-SVC could help control the voltage on the 11kV rural network by marginally reducing the absolute voltage and significantly helping to smooth the voltage profile. The project also highlighted the need of closer integration between the Hitachi systems and WPD's control systems along with the need to consider an innovative, reliable and high band width communication solution. The integration of the D-SVC with DNO's systems was more complex than envisioned. The D-SVC was originally designed to be almost entirely stand alone. In addition to this, the absolute effect of the D-SVC on the HV voltage was less than expected. It was thought this was predominantly due to the use of a standard transformer and the output of the D-SVC not being optimal for the size of the windfarm. The D-SVC did demonstrate a good ability to smooth the voltage profile. It was possible to assess the wider impact of reactive power on the system too. Additionally, the suitability of the eMS sub.net monitors for monitoring various parameters was explored. This highlighted inconsistencies of harmonic measurements from the sub.net alongside other 'Class A' devices.

Table 42: Tier 1 WPD Interconnection of WPD and NGC SCADA Systems overview.

Project Title	Interconnection of WPD and NGC SCADA Systems
Company	WPD
Project Funding	£79,000 – LCNF Tier 1
Project Driver	Establish a real time link between the SCADA systems operated by NGC and WPD using the ICCP protocol such that data on either system can be viewed on the other in real time
Project Objectives	· Establish the link · Establish access to the data and methods of viewing the data · Establish the security measures required to ensure the security of the link to both of the systems against Cyber attack
Key tech/process trialled	The IT infrastructure required to achieve the above objectives.

Project Title	Interconnection of WPD and NGC SCADA Systems
Timescales	12/2011 - 12/2012
Outputs/ Implementation/ Impact (as reported by DNO)	This trial has been a success with data from the WPD POWERON system being visible with the XA/21 control system at NGC. It is therefore envisaged that the link will be used to allow further real-time data to be collated and transferred, potentially from multiple sources. For WPD to make this live, addition configuration would be required in POWERON to transfer the aggregation and trace process from a test function to a live application. Additional configuration works would also be required to create the aggregation points, allowing the process to collate data prior to transfer through the ICCP link. For NGC to take this forward with additional links, further configuration works will be required on a specific case by case basis. This will include the development of a separate Front End Processer (FEP) for each link to ensure security can be maintained. At initiation of this trail, the ICCP link functionality was at TRL 7. As further work is required to assess the use of the link with multiple connections, it is considered that the TRL is unchanged.

Glossary

ANM	Active Network Management
BAU	Business as Usual
DG	Distributed Generation
DNO	Distribution Network Operator
DSM	Demand Side Management, whereby consumer demand for energy is modified through various methods.
DSO	Distribution System Operator
DSR	Demand Side Response, whereby actions are taken by customers in response to a signal and therefore the customer demand is altered.
DTR	Dynamic Thermal Rating
DUoS	Distribution Use of System, charges levied by the UK's DNOs that go towards the operation, maintenance and development of the UK's electricity distribution networks.
EAVC	Enhanced Automatic Voltage Control, a set of solutions perform in a similar way to traditional Automatic Voltage Controllers but with the key differential that the voltage setpoints can be adjusted remotely through a communications channel by an Active Network Management system.
EES	Electrical Energy Storage
ENWL	Electricity North West Limited
ESQCR	Electricity Safety, Quality and Continuity Regulations
EV	Electric Vehicles
Fault Level	A parameter calculated based on the maximum prospective current that will flow in event of a fault.
FCDM	Frequency Control by Demand Management
FCL	Fault Current Limiter
FLM	Fault Level Monitoring
FFR	Firm Frequency Response, the firm provision of Dynamic or non-Dynamic responses to changes in frequency.
FR	Fast Response, provides the rapid and reliable delivery of active power through an increased output from generation or a reduction in consumption from demand sources, following receipt of an electronic despatch instruction from National Grid.
GSP	Grid Supply Point
GUS	Grand Unified Scheme, a specific example of Active Network Management system.
HV	High Voltage (above 1kV)

IDNO	Independent Distribution Network Operator
IEC	International Electrotechnical Commission, the international standards and conformity assessment body for all fields of electrotechnology.
I&C	Industrial & Commercial
IFI	Innovation Funding Incentive
IP	Internet Protocol, a set of rules governing the format of data sent over the Internet or other network.
IRL	Implementation Readiness Level
LCNF	Low Carbon Network Fund, the innovation funding allocated by Ofgem in the DPSRC price review period.
LCT	Low Carbon Technology, includes the likes of Electric Vehicles and Heat Pumps.
LEDs	Light Emitting Diodes, a low energy use lighting technology.
LTDS	Long Term Development Statement,
LV	Low Voltage (below 1kV)
NaS	Sodium Sulphur, a type of battery technology
NIA	Network Innovation Allowance, a set allowance each RIIO network licensee receives as part of their price control allowance.
NIC	Network Innovation Competition, an annual opportunity for electricity network companies to compete for funding for the development and demonstration of new technologies, operating and commercial arrangements.
NMS	Network Management System
NPg	Northern Powergrid
Ofgem	Office of Gas and Electricity Markets
OLTC	On-Load Tap Changer, a mechanism that allows the alteration of a transformers stepping voltage without interrupting the supply.
Reactive Power	Not all power used by electrical equipment is ‘productive’; but instead, depending on the type of electrical load, different amounts of power can be required without directly driving any ‘outputs’. This unproductive power is known as reactive power.
RIIO-ED1	(Revenue = Incentives + Innovation + Outputs Electricity Distribution 1), current Ofgem electricity distribution price review period 2015-2023.
RTTR	Real Time Thermal Rating
Smart Fuse	A single shot auto-recloser designed to remove intermittent faults from the Low Voltage network.
SPEN	Scottish Power Energy Networks

SSEPD	Scottish and Southern Energy Power Distribution
ToU	Time of Use, a tariff type
TRL	Technology Readiness Level
UKPN	UK Power Networks
WPD	Western Power Distribution

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Our customers include electricity generation, transmission and distribution companies, together with major power plant operators in the private and public sectors.

- Our products, services, management systems and knowledge enable customers to:
- Prevent outages
- Assess the condition of assets
- Understand why assets fail
- Optimise network operations
- Make smarter investment decisions
- Build smarter grids
- Achieve the latest standards
- Develop their power skills

Safer, Stronger,
Smarter Networks

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