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EA TECHNOLOGY – REVIEW OF GB INNOVATION STRATEGIES AND PROJECTS

RP6 Network Investment Plan

REPORT

NIEN Review of Innovation Strategies and Projects

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Executive summary

EA Technology has prepared this report to help NIE Networks in their preparation for their RP6 business plan submission. NIE Networks expressed a need to better understand the extent of innovation projects carried out by Great British Distribution Network Operators (DNOs) and particularly under Ofgem funding.

GB DNO Innovation Funding

In Distribution Price Control Review 5 (DPCR5), which ran from 2010 – 2015, Ofgem introduced a £500m new fund, the Low Carbon Networks Fund, to stimulate a culture change, innovation and trialling of new technologies. Of the £500m fund, £320m was allocated to a small number of flagship Tier 2 projects, of which £215m was awarded. For the smaller scale Tier 1 projects, £29m was awarded from a £79m fund. A further £100m was available to DNOs through discretionary awards to both Tier 2 projects, which successfully delivered against a set of pre-agreed criteria, and to those Tier 1 and Tier 2 projects that brought particularly valuable learning to the industry.

In addition to the Low Carbon Networks Fund, there was continuation of the Innovation Funding Incentive; introduced in 2005 to encourage the DNOs to conduct R&D. The Innovation Funding Incentive allowed each DNO to recover 80% of its eligible project expenditure up to a figure of 0.5% of yearly revenues. This amounted to ~£20m per year at the start of DPCR5, rising to £29m in line with DNO revenue increases, by the end of the price control period. On average, around 50% of this funding was claimed each year.

Looking beyond DPCR5 to RIIO-ED1 (2015-2023), the total funding allowance is split between the electricity Network Innovation Competition (available for electricity transmission and distribution networks) and the Network Innovation Allowance. The Network Innovation Competition annual allowance is £81.9m/annum. In the first year, £68.4m was requested by the bidding transmission and distribution companies and £44.9m was awarded overall, with £18.3m of this being awarded to GB DNOs.

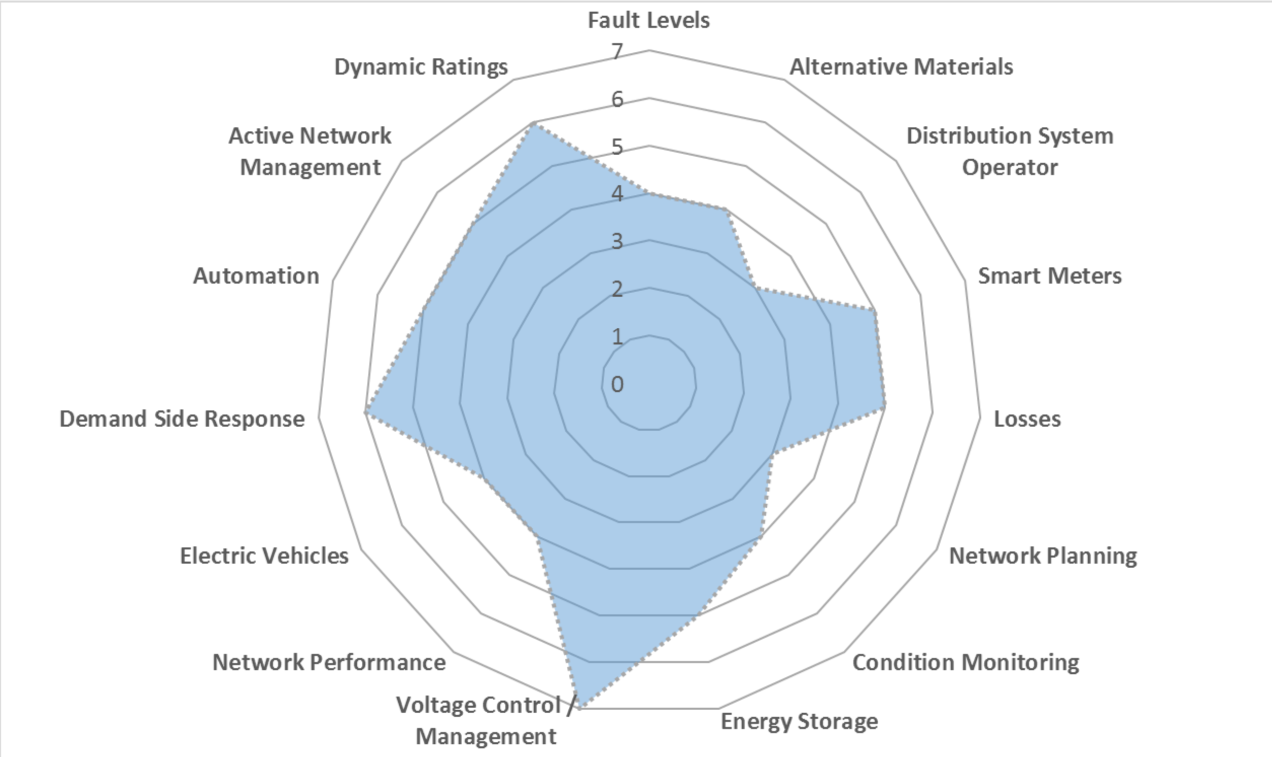
The Network Innovation Allowance provides limited funding to RIIO network licensees to fund smaller technical, commercial, or operational projects and the preparation of submissions to the NIC funding scheme. It can be seen from the table below that the combined NIA funding, available to GB DNOs, is £26.3m for the 2015/16 financial year. The NIA allowance is set on a sliding scale from 0.5% - 1% of DNO revenue by Ofgem as part of the RIIO-ED1 negotiation. Companies receive more funding by demonstrating a well thought through Innovation Strategy, with clear links to delivering customer benefit at time of the price review settlement. GB DNOs have stressed that their annual revenues, and therefore the Network Innovation Allowance, will be fixed in real terms throughout RIIO-ED1. The floor level of funding (0.5% of revenue) would amount to approximately £0.91m per annum if applied to NIE Networks.

Available NIA funding to GB DNOs for the 2015/16 financial year.

DNO Group	% of Annual Revenue	Indicative real-term annual funding available from 2015/16 – 2022/23
ENWL	0.7	£3.0 M
NPG	0.6	£4.0 M
SPEN	0.5	£3.3 M
SSEPD	0.5	£3.6 M
UKPN	0.5	£6.1 M
WPD	0.5	£6.3 M
Total	-	**£26.3 M**

GB DNO Innovation Strategies

The review provides an overview of the Innovation Strategies that form part of the GB DNOs' Business Plans from April 2015 to 2023, the RIIO-ED1 period. The figure below shows an overview of the GB DNO Innovation plans indicating how many DNOs are actively pursuing each of the innovation areas. It can be seen that voltage control/management, DSR and dynamic ratings feature heavily in the GB DNO innovation strategies for the RIIO-ED1 period.



DNO Innovation plans for the RIIO-ED1 period.

Innovation Areas Applicable to NIE Networks

NIE Networks has recently commissioned EA Technology to develop a Northern Ireland specific version of the Transform Model. This work has enabled NIE Networks to gain a deeper understanding of the likely challenges posed by the integration of low carbon technologies, and how these challenges can be mitigated.

As part of the outputs from the Transform Model, there is a list of solutions that are recommended to be deployed to most efficiently integrate the low carbon technologies at low cost, while retaining network integrity. These solutions are selected to resolve the constraints experienced by the distribution network in Northern Ireland and, as such, are thought to be directly relevant to the types of feeders that are prevalent within it.

The innovative solutions that are selected most often by the model (as of May 2016) are as follows:

- Permanent meshing of urban networks at LV;
- Real time thermal rating for overhead lines at HV;
- Active network management at HV;
- Temporary meshing (use of soft open points) at HV;
- Generator providing network support (e.g. by operating in PV mode) at HV;
- Permanent meshing of networks at EHV;
- Active network management at EHV;
- Permanent meshing of suburban networks at LV; and
- Generator providing network support (e.g. by operating in PV mode) at HV.

It is clear from the above list that the voltage level most frequently targeted for the deployment of innovative solutions is HV (11kV and 6.6kV). The outputs of the Transform Model analysis indicated that HV was the voltage level requiring the greatest level of investment as the adoption of low carbon technologies increases. It therefore seems sensible to focus any targeted innovation projects at this area. It is also noteworthy that the solutions that are selected over the shorter timeframe (i.e. in the latter part of the next regulatory period) are the real time theremal rating and active network management solutions. Therefore, it would seem logical that these should be some of the focus areas for innovation activity.

In order to deploy the above solutions, a number of ‘enabling technologies’ will be required. These are devices that do not contribute to releasing network capacity or resolving constraints themselves, but are vital pieces of the overall system to allow the smart solutions to work effectively. Therefore any targeted innovation approach will also require the capability to fully deploy, integrate and manage additional devices on the network. The enabling technologies that are deployed to allow the above solutions to operate effectively are as follows:

- HV circuit monitoring;
- EHV circuit monitoring;
- Dynamic network protection at HV;
- Advanced control systems at HV;
- Ring Main Units fitted with actuators;
- Last mile communications to/from devices;
- Weather monitoring;
- Advanced control systems at EHV;
- LV circuit monitoring; and
- Advanced control systems at LV.

Depending on which of the above solutions are selected for deployment in targeted pilots and latterly business as usual, a number of these enabling technologies are also required. Therefore any innovation program needs to incorporate all of these elements to ensure its success. Similarly, more actively managing networks and running them in different operating configurations will require the network protection to be able to cope with these different conditions. In some cases it is the deployment of these enabling technologies that can pose as great a challenge as the deployment of the solution.

Recommendations for NIE Networks

The following innovative techniques and approaches are recommended as being worthy of further investigation by NIE Networks as they are likely to deliver greatest value to customers.

Real Time Thermal Ratings

Real Time Thermal Ratings (RTTR), when applied to HV overhead lines, was the top ranked solution selected by the Transform Model for the Northern Ireland network. It has been trialled successfully in a number of innovation projects by several DNOs (NPG, WPD, and SPEN). For HV overhead lines NPG's assessment puts the technology at a readiness level of 9 and an implementation readiness level of 9. This suggests that there are no substantial barriers to the adoption of the technology into business as usual.

There is a synergy between the use of RTTR and enabling increased capacity of some distributed renewable generation. In higher winds, when more power is generated by wind farms, the overhead lines can carry more power because of additional cooling. NPG's Customer-Led Network Revolution (CLNR) found additional unused capacity of up to 74%. SPEN's Tier 1 projects found an average uplift ranging from 1.24 to 1.55 times the static summer rating with potential average additional annual energy yield ranging from 10% to 44% protection equipment ratings were taken into account and, for business acceptance, safety margins were introduced and estimates on the side of caution. Data analysis of the loading of wind farm circuits indicates that sizing can be based on dynamic rather than continuous ratings.

CLNR which was completed at the end of 2014 found the following costs.

Equipment	BaU cost per unit (£)
Primary substation transformer (Remote Distribution Controller, RDC)	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

Conclusions from the various innovation projects carried out in this area suggest that there is great merit in the use of RTTR on overhead lines at HV and EHV. The use of RTTR for secondary transformers has been shown to provide some benefit, but the costs associated with this, against the costs of new secondary transformers, make this a more difficult case to justify at present. The case for RTTR is more compelling at the primary substation level. Four LCNF projects have trialled RTTR in primary substations, with cost results broadly in-line with one another. Deployment costs range from £15 – £30 k per unit, with estimated savings of between £0.3m - £6.2m per deployment. The savings will be realised through reinforcement and replacement deferment (up to eight years). UKPN have estimated that they could save £18.3m for a £3.3m expenditure across all their license areas during RIIO-ED1.

It is therefore concluded that there is significant merit in further investigating the use of RTTR on overhead lines and primary substations at HV and EHV to release capacity for both additional generation and demand customers and the technology is considered sufficiently mature to allow for targeted pilot installations transitioning very quickly to business as usual.

Demand Side Response

Various types of demand side response (DSR) have been trialled by a number of DNOs and benefits have generally been observed to the extent that some DNOs are now making it business as usual as an alternative to network reinforcement. DSR has been envisaged as a solution to deferment of reinforcement spend on 'peaky' networks, where DSR ToU tariffs/DSR payments are more economical than reinforcement and mitigate network capacity shortfalls. Network capacity shortfalls can be caused by load growth or under N-1 conditions. DSR effects on capacity shortfalls under N-1 conditions was assed as part of the UKPN Low Carbon London (LCL) project.

Generally, it has been found that the easier forms of DSR to set up and are to be relied upon are those that are linked to larger industrial and commercial (I&C) customers. At present, engaging with domestic customers, either individually or through the use of aggregators, is not at the stage where it forms business as usual. In the LCL project, the domestic load profiles of participants were influenced by placing them on a ToU tariffs.

For commercial DSR to work as a solution, the amount that is paid to the customer must be greater than the cost to them of operating the generation and any associated management costs with setting up the processes to facilitate signals and responses to the call for DSR.

UKPN have made DSR a cornerstone of their strategy for RIIO-ED1 and are anticipating making a saving of £43m through being able to defer reinforcement at large substations.

DSR has not been selected as one of the most prevalent solutions by the Transform Model, indicating that it is difficult to justify across the network. However, there may well be certain individual network areas where there is considerable industrial and/or commercial load that might be amenable to DSR and NIE Networks should consider it as an alternative to reinforcement in these bespoke cases.

Voltage Management

It has been found that a significant amount of the Northern Ireland distribution network is constrained not by thermal issues, but by those of voltage. This is especially true for more rural networks.

A number of voltage management solutions have been trialled and are at a stage where they are sufficiently mature for a business as usual implementation. The results from the Transform Model indicate two solutions that are prominently selected to resolve voltage issues at HV: switched capacitors and the use of generators to provide network support.

Switched capacitors were trialled within the CLNR project and represent a fairly mature technology. The use of generators to provide network support, by operating in different modes for example, is an area that has not been fully explored to date. Clearly, the availability of such a solution is dependent upon the location of the generators in the network. In theory, if generators are present, it should become easier to implement these solutions in the future with the advent of new European codes for the operation of generators (such as the Requirements for Generators (RfG) which has been initiated by ENTSO-E (European Network of Transmission System Operators for Electricity).

However, it may well be beneficial for NIE Networks to consider some of the other voltage management techniques that have been trialled. For example, WPD conducted a Tier 1 project that showed D-SVC (Distribution Static VAr Compensator) could help control the voltage on an 11kV rural network by marginally reducing the line voltage by 50V and significantly helping to smooth the voltage profile on an 11kV rural network, close to the generator site, by marginally reducing the absolute voltage and significantly helping to smooth the voltage profile.

SSEPD have also conducted several trials involving STATCOMS and found that the initial cost per deployment was £500k, but that is expected to fall to £150k for BaU implementation and to bring an associated benefit of £2m. This benefit is based on the high cost of network reinforcement for various islands, (Orkney, Wight and Western Isles) where the STATCOM could be deployed to resolve the network constraint. However the findings also suggest that the payback period is likely to be short in other geographic areas of deployment too (potentially particularly for rural networks). At LV, on the other hand, the cost-benefit figures for such voltage regulation techniques are not as promising.

ENWL looked to change the voltage at their primary substations to release capacity and hence defer reinforcement (i.e. using voltage management to resolve thermal constraints) through their ‘CLASS’ project. When the CLASS method is applied across all primary substations in the project, ENWL could gain up to 12.8 MVA 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 was claimed to be implemented at one primary substation 57 times faster and 12 times cheaper than traditional reinforcement. 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 250MW of network capacity, and defer the reinforcement of 28 primary substations with an associated cost of £15.9m for up to three years. The CLASS project primary substation screening criteria did not distinguish urban from rural networks.

Clearly in the case of NIE Networks, where the voltage is at the lower end of the allowable range for significant portions of the network, this approach could only be adopted in areas where the network is strong and voltage drop is not an issue (such as central Belfast).

It is therefore recommended that NIE Networks seek to adopt some of the approaches described above concerning voltage management at HV.

Active Network Management

There have been numerous projects exploring different means of active network management. One application of this approach is to better facilitate the connection of distributed generation through the provision of managed connections. This has been trialled extensively by WPD, UKPN and SPEN through projects such as Accelerating Renewable Connections and Flexible Plug and Play. Indeed, it is now fully integrated into business as usual within some DNOs. This approach enables generation to be connected in a timelier manner and also at lower cost, mitigating the need for extensive reinforcement.

A further example of the successful deployment of active network management has been completed by SSEPD in numerous island settings (which could be analogous to the more rural settings to be found in Northern Ireland) such as Orkney, Wight and the Western Isles.

The cost to bring to business as usual is £1m and the potential saving or deferment per deployment is expected to be £2m as compared to traditional reinforcement. The cost per deployment is £355k for generator constraint management and £122k for community demand management.

The outputs from the Transform Model suggest that there is particular merit in adopting an active network management approach at a range of voltage levels. The use of soft open points and the temporary meshing of circuits at HV has been trialled by ENWL in the C_2C project and this is proving beneficial. There are some up-front costs in equipping the 11kV ring main units with the ability to be switched remotely and also in adapting the protection devices on these networks, but the cost savings in deferred reinforcement can then be substantial.

There is also potential benefit to meshing cicuits at LV and it is therefore recommended that a watching brief on the outcomes of UKPN's FUN-LV project should be kept to look for any useful learning in this area.

In general, it is likely that temporary meshing and actively managing the network will bring greater benefit than permanent meshing of networks in Northern Ireland.

It is therefore recommended that NIE Networks considers the use of soft open points and temporary meshing of HV circuits to manage load; and also that it considers the use of active network management for connection of additional distributed generation in future.

Network Performance – Minimising Interruptions

The final area to be considered is that of network performance at LV and HV, i.e. the minimising of interruptions to customers and the duration of those interruptions.

At LV, several DNOs have been trialling and have now integrated to business as usual the use of different reclosers or smart fuse devices. Such devices will trip when a fault occurs, but then attempt to reclose automatically. This allows rapid restoration of supplies in the event of a transient fault and has significant associated savings in the reduction of interruptions to customers.

It is EA Technology's understanding that at least three DNOs in Great Britain are now routinely using a range of these devices on their networks, meaning that they are at a suitable level of maturity for wide scale adoption. NIE Networks have already trialled some of these devices and may already have them as part of a BaU strategy.

At HV, several DNOs are now undertaking a program to perform partial discharge measurements on their cables. Partial discharge measurements have been in widespread use for switchgear for some time, but DNOs are now becoming aware of the potential to identify cable faults before they occur and thereby proactively (rather than retrospectively) change sections of cable and avoid the associated interruptions to customers and higher costs that are incurred when having to repair a faulted cable rather than a planned piece of work to change a piece of unfaulted cable.

It is therefore recommended that NIE Networks considers its strategy regarding the use of LV reclosers and investigates the merits of conducting partial discharge measurements on HV cables to avoid faults.

In Summary

A range of potential innovative approaches are believed to have merit for the network in Northern Ireland. They will bring various benefits to stakeholders, such as lower connection costs and improved network performance. The below table summarises the key areas of DNO operation that these innovative approaches would benefit.

	Real Time Thermal Ratings	Active Network Management	Demand Side Response	Voltage Management	Reducing Network interruptions
Network reliability	✔	✔	✔		✔
Safety				✔	✔
Environment	✔	✔	✔		
Customer Service			✔		✔
Connections	✔	✔	✔	✔	

Contents

Glossary

ANM	Active Network Management
BaU	Business as Usual
CBRM	Condition Based Risk Management
DPCR5	Distribution Price Control Review 5 (the previous Ofgem price review period 2010-2015)
DSM	Demand Side Management
DSO	Distribution Systems Operator
DSR	Demand Side Response
DTR	Dynamic Thermal Rating
DUoS	Distribution Use of System
EAVC	Enhanced Automatic Voltage Control
ENWL	Electricity North West Limited
ESQCR	Electricity Safety, Quality and Continuity Regulations
FLM	Fault Level Monitoring
IDNO	Independent Distribution Network Operator
I&C	Industry & Commercial
IFI	Innovation Funding Incentive
IRL	Implementation Readiness Level
LCNF	Low Carbon Network Fund
LCT	Low Carbon Technology
NIA	Network Innovation Allowance
NIC	Network Innovation Competition
NIEN	Northern Ireland Electricity Networks
NMS	Network Management System
NPG	Northern Powergrid
RIIO-ED1	Revenue = Incentives + Innovation + Outputs Electricity Distribution 1 (current Ofgem electricity distribution price review period 2015-2023)
RTTR	Real Time Thermal Rating
SEPD	Scottish Energy Power Distribution (part of SSEPD)
SPEN	Scottish Power Energy Networks
SSEPD	Scottish and Southern Electricity Power Distribution
TRL	Technology Readiness Level

UKPN	UK Power Networks
WPD	Western Power Distribution

1. Introduction

EA Technology has prepared this report, 'Review of Innovation Strategies and Projects' to help NIE Networks in their preparation for the RP6 business plan submission. NIE Networks expressed a need to better understand the extent of innovation projects carried out by Great British (GB) Distribution Network Operators (DNOs) and particularly under Ofgem funding.

In DPCR5, Ofgem introduced a £500m new fund, the Low Carbon Networks Fund (LCNF), to stimulate a culture change, innovation and trialling of new technologies. In the LCNF funding scheme, up to 90% of project finance was covered by the LCNF, with DNOs and any project partners expected to fund the balance. Of the £500m fund, £320m was allocated to a small number of flagship Tier 2 projects and £79m was allocated to small scale Tier-1 projects. A further £100m was available to DNOs through discretionary awards to both Tier 2 projects, which successfully delivered against a set of pre-agreed criteria, and to those Tier 1 and Tier 2 projects that brought particularly valuable learning to the industry.

The Tier 2 projects were decided on through an Ofgem bidding process each year for a share of the £64m annual fund. Between 2010 and 2015, ~£215m was awarded from the £320m LCNF Tier 2 fund, split between GB DNOs as shown in Table 1. DNOs may be additionally awarded up to a total of £84m through the second tier Successful Delivery Reward (SDR) and the Second Tier Reward (STR) mechanisms should they deliver successful projects.

Table 1. LCNF initially awarded funds for all LCNF Tier 2 Projects. The values exclude in kind contributions from the DNO and project partners, reward funds and funds from change requests.

DNO Group	Total LCNF T2 Funding (£m)
ENWL	30.14
NPG	27.35
SPEN	15.00
SSEPD	36.26
UKPN	55.29
WPD	50.71
Total	**214.75**

The Tier 1 projects are expended from a pre-defined (maximum) fund the DNOs have allocated on a licence by licence basis. Between 2010 and 2015, £29.02m was allocated from the £79m LCNF Tier 1 fund, split between GB DNOs as shown in Table 2. DNOs may be additionally awarded up to a total of £15m through the First Tier Portfolio Reward (FTPR); an incentive for DNOs to actively engage in the objectives of the LCNF and conduct projects that led to exceptional benefits for customers.

Table 2. LCNF requested funds for all LCNF Tier 1 Projects. The values exclude in kind contributions from the DNO and project partners, reward funds and funds from change requests.

DNO Group	Tier 1 Allowance over 5 yrs (£m)	Total LCNF T1 Funding Allocated (£m)
ENWL	6.50	3.02
NPG	10.50	2.88
WPD	21.00	2.33
UKPN	21.50	5.05
SPEN	9.50	4.71
SSEPD	10.00	5.65
Total	**79.0**	**29.02**

In addition to the LCNF, there was continuation of the Innovation Funding Incentive (IFI); introduced in 2005 to encourage the DNOs to conduct R&D. The IFI allowed each DNO to spend 0.5 % of allowed revenues on these activities, which amounted to ~20m per year at the start of DPCR5. The IFI remained active for operators of the electricity distribution networks until April 2015, when it was replaced with the Network Innovation Allowance (NIA). Under IFI, the network operator was allowed to recover 80% of its eligible project expenditure via the IFI mechanism within the network operator's Licence area. Table 3 and Table 4 show the amounts of available IFI funding and the awarded funding for each DNO Group respectively from 2010 to 2015. IFI end of year finance data was not readily available for the 2011/12 financial year and has therefore been omitted. It can be seen from these tables that GB DNOs have received over £50m in innovation funding per annum, between 2010 and 2015, over and above the LCNF funds awarded.

Table 3. Available IFI funding at 0.5% of business revenue for each DNO (£M).

DNO Group	2010/11	2011/12	2012/13	2013/14	2014/15
ENWL	1.79	1.80	2.11	2.34	2.64
NPG	2.67	-	3.08	3.14	3.66
SPEN	3.23	-	3.57	3.74	3.94
SSEPD	3.40	-	-	4.14	4.06
UKPN	4.79	5.39	6.26	6.73	7.02
WPD	5.69	-	6.29	6.29	7.68
Total	**21.56**	**-**	**-**	**26.38**	**29.00**

Table 4. Awarded IFI Funding (£m).

DNO Group	2010/11	2011/12	2012/ 13	2013/ 14	2014/15
ENWL	1.57	1.60	1.69	1.87	2.11
NPG	0.79	-	0.79	0.80	1.03
SPEN	1.47	-	1.73	1.61	3.15
SSEPD	2.38	-	-	3.29	3.67
UKPN	3.34	2.67	3.05	3.86	4.45
WPD	2.72	-	1.18	0.52	1.88
Total	**12.27**	**-**	**-**	**11.96**	**16.30**

Looking ahead into RIIO-ED1, the total funding potentially available through the electricity Network Innovation Competition (NIC) (available for electricity transmission and distribution networks) is £81.9m per annum. In the first year, £68.4m was requested by the bidding transmission and distribution companies and £44.9m was awarded overall, with £18.3m being awarded to GB DNOs. In addition to the NIC funding mechanism, the Network Innovation Allowance (NIA) provides limited funding to RIIO network licensees to fund smaller technical, commercial, or operational projects and the preparation of submissions to the NIC funding scheme. It can be seen from Table 5 that indicative real term NIA funding levels between 2015/16 - 2022/ 23, available to GB DNOs, is £26.3m. Should a similar (minimum) level of 0.5% of annual Distribution Use of System revenue funding be available to NIE Networks, an annual fund of £0.91m would be available for innovation project funding.

Table 5. Indicative available real term NIA funding levels between 2015/16 -2022/ 23.

DNO Group	% of Annual Revenue	Indicative RIIO-ED1 Real Term Annual Funding
ENWL	0.7	£3.0m
NPG	0.6	£4.0m
SPEN	0.5	£3.3m
SSEPD	0.5	£3.6m
UKPN	0.5	£6.1m
WPD	0.5	£6.3m
Total	-	£26.3m

The following sections of this report describe the work carried out by GB DNOs using funding available during the DPCR5. The following sections contain:

1. A review of the Innovation Strategies of the six GB DNOs for RIIO-ED1 (Section 2);
2. Summaries of significant innovation projects (Sections 3, 4 and 5);
3. Comparison of the findings of this investigation against those from NIEN's Transform results (Section 6); and
4. Recommendations specific to NIE Networks (Section 7).

To give a representative view of the industry, there is a breadth of projects covered across the utility management spectrum and the projects range from those started between 2008 and 2016. The strategies and projects are listed alphabetically by DNO in the following two sections.

2. Innovation Strategies of GB DNOs

This section provides an overview of the Innovation Strategies that form part of the GB DNOs' Business Plans from April 2015 to 2023, the RIIO-ED1 period. The information presented has been extracted from the updated Business Plans as published on each company's website.

In the first instance the engineering related innovations from the previous price review period that have been or are being integrated into Business as Usual (BaU) in the next price control are highlighted to indicate the approaches that have sufficiently progressed from trial phase and are believed to be mature enough for consideration as part of NIEN's business strategy for RP6.

There is little information available on the specific means by which stated savings are derived. Any figures given by the DNOs can be assumed to be as a result of comparing the smart intervention under trial with the conventional approach.

It is important to note that some of the savings listed will be as a result of reduced interruptions to customers, as GB DNOs have an Interruption Incentives Scheme (IIS). Under this IIS, DNOs can receive financial rewards for minimising Customer Interruptions (CIs) and customer minutes lost (CML). The precise figures used to calculate this benefit can vary from one DNO to another. However, it should be considered by NIE Networks that any saving of customer interruption in GB is considered to be valued at between £10 - £15.50 while any saved customer minute lost would be worth somewhere between 25p and 37p. This excludes short duration interruptions (those consisting of less than 3 minutes) and those interruptions that are caused by exceptional events (such as severe storms).

It is evident from the following examples that savings appear to be broadly as a result of operation or delivery efficiency and reduction in future network infrastructure costs:

- ENWL say that their connect, and manage and work on promoting energy efficiency has saved labour costs in scenario and load planning, particularly for new LV solar connections.
- ENWL also say they are realising £50m in benefits from CBRM, through cost and delivery efficiency and scope optimisation. CBRM plays a major role in supporting the business plan by providing data to back-up investment decisions.
- Network Management Systems (NMS) offer savings by deferring network reinforcement costs. ENWL amounts these savings to £10m when considering DECC's low uptake scenario.
- Savings from reinforcement deferral are also attributed by UKPN to their employment of Real Time Thermal Ratings (RTTR). They estimate that the application of RTTR will lead to a minimum three year deferral of reinforcement for 20 main or primary substation schemes from ED1 to ED2 which will result in net savings of £15m.
- WPD state that to accept the level of Low Carbon Technologies (LCTs) expected within RIIO-ED1, it would cost £128m more with a passive network.

For further reference and completeness the future plans for each DNO are also described. This will help NIE Networks to strategically align its current and near future propositions with the direction of the industry in GB.

2.1 Electricity North West

During the DPCR5 period Electricity North West LTD (ENWL) invested over £26m in innovation. Between the start of DPCR5 and RIIO-ED1, ENWL estimates the combined innovation expenditure in these periods will release £132.5m of customer benefits by the end of RIIO-ED1; rising to £180m by the end of RIIO-ED2.

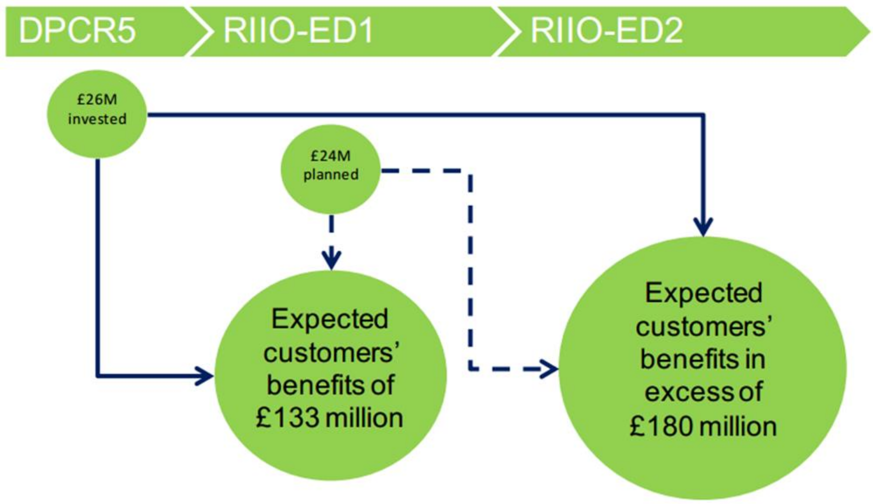


Figure 1. Predicted customer savings from previous and future innovation spending compared against traditional techniques.

ENWL have been granted an innovation funding rate of 0.7% of annual revenue, which equates to an annual innovation investment of £3m across ENWL's investment portfolio. This translates to a slight reduction compared to DPCR5.

2.1.1 DPCR5 Highlights

During DPCR5, ENWL invested £0.2 million to defer significant non-load related investment. Part of this sum was used to by ENWL and Manchester University to research the benefits of in-situ oil regeneration in ENWL's transformers. As a result, ENWL now has the capability of regenerating transformer oil on-site. This innovation is expected to increase the operational life, and therefore reduced the need for removal and replacement, of ENWL's transformers. In RIIO-ED1, ENWL plan to use this technique, combined with innovative online monitoring, to avoid the replacement of over 12 grid and 77 primary transformers, which will save their customers an estimated £33m.

ENWL have developed Demand Side Response (DSR) solutions to allow the network connection of sustainable technologies, whilst deferring network reinforcement. This work took place using the LCNF Tier 2 project funding and used new technologies and novel commercial arrangements. Many of ENWL's developments in this area have become BaU, but will be developed further under their RIIO-ED1 innovation plan; specifically the introduction of more sophisticated DSR methods utilising network management techniques. Under the DECC Low Carbon scenario, network reinforcement deferment, using DSR, is expected to generate £10m in savings for customers.

Novel commercial arrangements have also been used during DPCR5 to reduce the cost and lead times securing network connections. These innovative commercial contracts for both demand and generation customers have been developed as part of the LCNF Capacity to Customers (C_2C) project. One of the ways in which these contracts are facilitated for distributed generation customers, who have a voltage constraint, is to use real-time network voltage measurements to control the use of existing network assets in order to free more capacity for future Distributed Generation (DG) connections.

Finally, ENWL have worked with Kelvatek (the manufacturer of various instruments, including the Bidoyng) to install 3rd party smart technologies to automatically restore customer supplies, in less than 3-minutes, to overcome unidentified transient LV network faults. These technologies have the ability to minimise customer disruption until the source of the transient faults can be identified. ENWL's initial £0.4 million innovation investment has resulted in over £2.3m in price reductions on equipment purchases from suppliers and improved reliability of supply to ENWL customers. A complete list of DPCR5 innovation initiatives can be found in Table 6.

Table 6. Range of innovations undertaken in DPCR5 delivering value for customers and stakeholders.

Stake-holder Priority	Innovation Initiative	Funding Type	Project Cost	Benefit	Saving Projection DPCR5	Benefit/ Saving Projection RIIO ED1
Customer	**Network Operation -** Development of a time domain reflectometry approach to LV fault finding	IFI	£7,000	Delivers faster repairs with less time and excavations to locate the fault saving repair costs and CML	**£3.6m**	**£14.4m**
	Network Operation - Delta V Developments & Trial - Development of a voltage gradient approach to LV faults finding	IFI	£63,000			
	Network Operation - Modular/Master Slave Rezap - Development of an LV autorecloser that will fit into all ENWL's LV fuse pillars and boards	IFI	£316,000	Reduces impact of transient faults by autoclosing post fault		
	Network Operation - FuseRestore/Bidoyng - Development of a device to automatically restore a fuse after a transient fault	IFI	£453,000			
	Network Operation - Smart Fuse	LCNF Tier 1	£350,000	Reduces impact of transient faults by autoclosing post fault		
	Network Operation/Investment Planning - Chromatic Analysis of Insulating Oil - Non-intrusive testing of Insulating Oil	IFI	£116,000	Removes the need for oil samples to be remove from transformers for analysis and allows more frequent oil monitoring		**£50k pa**
	Network Operation - Wide Area Data Gathering - Installation of a Power Line Carrier System	IFI	£95,000	Reduces the reliance on third party telecoms providers and reduces costs and increases security of communications		**£100k**
	Network Operation - Next Generation LV Board/Link Box - LV Network Automation	IFI	£579,000	Release additional capacity from distribution transformers and reduce network losses, load/generation connections at lower cost, improved power quality		**£5.5m**
	Network Operation - Customers - Research into the customer/ DNO interface and how it can be improved	IFI	£283,000	Faster more accurate information provided to customers - improved customer experience		**Qualitative**
	Network Operation - Demand control - Investigation of DNO's capability to offer technical solutions to support transmission network stability	IFI	£31,000	Allows distribution networks to be used to assist with national objectives for the adoption of renewable energy generation without customers being impacted		**Qualitative**
	Network Operation - Composite Link Box Lids - Investigation of composite materials	IFI	£11,000	Provides faster restoration times following faults		**Qualitative**
Reliability	**Investment Planning -** Oil Regeneration - Testing the capability of oil regeneration to improve health index	IFI	£270,000	Study with Manchester University into benefits of regenerating Transformer oil on site to extend their asset life		**£33m**

Stake-holder Priority	Innovation Initiative	Funding Type	Project Cost	Benefit	Saving Projection DPCR5	Benefit/ Saving Projection RIIO ED1
	Investment Planning - CBRM - Developing the ability to use CBRM outputs to define non-load investment programmes	IFI	£540,000	CBRM was initially developed for DPCR4, we have continued to develop this technique which has become the industry standard approach to asset management - improved asset decisions reliability	**>£50m**	**£65m**
	Investment Planning/Network Operation - Vegetation Management - Identification and definition of vegetation growth rates as affected by climate	IFI	£298,000	Enables targeted preparation for the affects of climate change	-	**Qualitative**
	Safety Network/Operation - Transient Resonance Study - Investigation into the effects of switching transformers with long cables	IFI	£70,000	Eliminates the need to provide high voltage switching devices on long cables (avoiding costs)	**£8.7m**	-
	Investment Planning - Network Resilience - Investigation into the potential impacts of climate change on network resilience	IFI	£24,000	Enables targeted preparation for the affects of climate change		**Qualitative**
	Safety/Investment Planning - Polymeric Investigation - Forensic Investigation of failed and new insulators	IFI	£56,000	Improves the reliability of high voltage switchgear		**Ongoing requires quantification**
	Network Planning - Harmonic Cabling Modelling - Analysis of the technical requirements for the connection of non linear loads	IFI	£9,000	Allows the connection of higher levels of generation without network reinforcement	**Avoided Costs**	**Avoided Costs**
	Investment Planning - Stay Rod Testing - Non intrusive testing of below ground structures	IFI	£17,000	Testing completed and proved inconclusive and therefore will not proceed, alternative techniques will be investigated	-	-
	Network Protection and Control - Fit Calibrate HAT's - Forensic investigation of network load measurement systems	IFI	£24,000	Allows more targeted investments and facilitates connections based on available information	-	**Qualitative**
	Network Performance - Nafirs - Academic Investigation of fault data	IFI	£27,000	Used to develop Quality of Supply Investments and their likely effectiveness	-	**Qualitative**
Affordability	**Investment Planning** - Expansion Planning V2 - Development of network models for demand forecasting and pricing	IFI	£372,000	Allows more targeted investments in reinforcement for load growth	-	**Qualitative**
	Network Design - Earthing - Investigation of transfer potential under fault conditions	IFI	£5,400	Reduces investments in underground electrode systems	-	**Qualitative**
	Network Operation/Design - Fault Current Limiter - Development and installation of a super conducting fault current limiter	IFI	£540,000	Avoidance of network reinforcement to mitigate fault levels exceeding equipment safety ratings	-	**£3m**
	Safety/Investment Planning - OLTC Monitoring - Acoustic monitoring of OLTCs	IFI	£277,000	Enhances safety of operatives following high profile OLTC failures and is also used to assess health of asset for more targeted investments	**£750k**	**£500k**

Stake-holder Priority	Innovation Initiative	Funding Type	Project Cost	Benefit	Saving Projection DPCR5	Benefit/ Saving Projection RIIO ED1
	Network Capacity - Dynamic Line Rating - Weather related overhead line ratings	IFI	£323,000	Allows the connection of wind turbines to remote overhead lines	-	**Avoided Costs**
	Network Capacity - Storage - Defining the economic and regulatory benefits of energy storage	IFI	£183,000	Facilitates the connection of low carbon technologies allowing demand management	-	**Qualitative**
	Network Planning - Load Related Risk - Development of load- related output measures to succeed the current Load index (LI) methodology	IFI	£20,000	Allows more targeted investments in reinforcement for load growth	-	**Qualitative**
Sustainability	**Demand Side Management -** DSM Signals - Assessment of DSR price signals	IFI	£15,000	Understand benefits of ENWL's Low Carbon Network Tier 2 project, C_2C- realised through avoiding investment in network reinforcement and Demand Side Response	-	**£10m**
	Network Capacity - Load Allocation - Development of software to project and identity overloads due to the projected take up of low carbon technologies	IFI	£460,000	Improved modelling of inherent capacity on the network as required by local conditions of increased demand and generation	**£1m**	**£600k**

2.1.2 Core Innovations for RIIO-ED1

Moving forward, ENWL have stated that they will only select innovation investments that they feel have a good chance of delivering value in the RIIO-ED1 period, to ensure a successful transition to BaU. The RIIO-ED1 plan will shift focus to combine the DPCR5 innovation areas, recognising that future needs will increasingly require a co-ordinated approach to the forecasted challenges and to meet broader stakeholder priorities.

Through 2015-2019, ENWL plan to focus on completing the network capability initiatives that were in development through DPCR5 and use the extensive amount of load and usage data that will be provided by smart meters. This should further enable the development of ENWL's smart grids through work in the following areas:

- Collection of real-time data on network performance, capacity and load from automated data capture, including data from smart meters;
- Advanced system real-time simulation and modelling techniques, such as its Capacity Headroom Model, to identify and quantify network capacity and identify areas of strain on the network in real time;
- Integration of smart meters into control room systems; and
- Progress development of technologies currently in research through continued collaboration with its partners to achieve RIIO stakeholder priorities.

Between 2019-2023, ENWL's focus will be the delivery of their data strategy and use of smart meter information to drive further efficiency, reliability and low carbon capacity on their network; Specifically:

- Micro level data management of network performance;

- Move from research and development to industrialisation of developed technologies;
- Response to stronger market demand within RIIO-ED1 for DSR and an increased requirement to manage network constraints and balance network supply;
- Development of RIIO-ED2 investment plans based on real time data and demand side response outputs; and
- Roll out of solutions supporting the increased level of heat and transport load on its network.

ENWL's RIIO-ED1 innovation initiatives and the associated timeline are shown below in Table 7.

Table 7. Expected timeline for RIIO-ED1 Innovation Initiatives 2015-2023.

Stakeholder Priority	Innovation Project Initiative	Year\ Voltage	2015	2016	2017	2018	2019	2020	2021	2022
Reliability/ Sustainability	Load Impact Modelling	LV								
		HV								
Reliability/ Affordability	Thermal Capability	LV								
		HV								
Reliability/ Affordability	Asset Management	LV								
		HV								
Reliability Customer service	Automatic Fault Restoration	LV								
		HV								
Reliability/ Sustainability	Development of Autonomy	LV								
		HV								
Affordability/ Sustainability	Network Configuration	LV								
		HV								
Affordability	Reference Networks	LV								
		HV								
Affordability	Network Modelling	LV								
		HV								
Affordability/ Customer service	Feeder Operational Modes	LV								
		HV								
Sustainability	Voltage Management	LV								
		HV								
Sustainability	Feeder Design	LV								
		HV								
Sustainability	New Materials	LV								
		HV								
Sustainability	Data Clouds	LV								
		HV								
Customer service	Demand Side Response	LV								
		HV								
Customer service / Affordability	New Connections	LV								
		HV								
Customer Service	DSO Services	LV								
		HV								
Customer service	High Performance Computing/ Data Manipulation	LV								
		HV								

Under Ofgem's Network Innovation Allowance, ENWL has been awarded an allowance of 0.7% of their annual revenue which corresponds to £3m for 2015/16.

2.2 Northern Powergrid

2.2.1 DPCR5 Highlights

Northern Powergrid (NPG) have managed a diverse range of innovation projects across several business areas. The portfolio of all of NPG's projects from 2006 to date, along with the Net Present Value (NPV) of each, can be seen in Figure 2.

Project	NPV
ACTIV - voltage control system	£223,000
ASL Superconducting FCL 11kV	£96,746
CBRM for switchgear and transformers	£1,015,778
Climate Change - impact on network resilience	£19,630
Conditon based risk management development	£50,000
Demand side management and risk	£736,932
Distribution load estimate methodology	£2,092
EATL Partial Discharge user group	---
EATL Protective Coating forum	---
ENFG Smart Grid study	---
Engineers' forum - Cable	---
Engineers' forum - OHL	---
Engineers' forum - plant	---
Engineers' forum - protection	---
Failure on demand project	£285,029
Gendrive phase balancing device	£15,618
GROND contingency analysis	£12,475
Ground mounted fault passage indicator	£523,655
Health indices (EHV cable)	£476,291
Health indices (OHL and substations)	£1,904,814
Live Alert conductor contact alarm	£227,017
Long underground EHV cables	£121,006
Loss of mains (stability to transients)	£100,000
Loss of mains protection (generation interface)	£109,000
Loss-of-mains protection (reverse reactive power relays)	£31,132
Loss-of-mains protection (RoCoF relays)	£22,830

Project	NPV
Met Office climate change modelling	£29,630
Low voltage Automatic Voltage Control feasibility Study	£884,780
Network risk KTP	£9,085,055
Network Risk Modelling	£24,000
OHL Remote FPI trial	£288,466
Oil degradation study	£91,668
Oil-filled cable leakage prevention	£159,026
Pole Leakage mitigation	---
Radometric Arc fault location	£45,787
Reference Networks	£47,002
Remote indicting fault flow indictaors (RIFFI)	£432,000
Stay rod testing	£74,969
Strategic Technology Programme 1 (Overhead Network)	---
Strategic Technology Programme 3 (Cable Networks)	---
Strategic Technology Programme 4 (Substation & Plant)	---
Strategic Technology Programme 5 (Distributed Energy)	---
Substation environmental monitoring	£45,179
Substation relay information (Skerneside trial)	£9,759
Supergen - Amperes (programme)	£41,038
Supergen - Flexnet (programme)	£2,000,000
Tree Growth Regulator study	£1,000,000
UltraTev PD alarm trial	£191,982
UV camera inspection	£488,215
Woodhouse mast development	£329,743

Figure 2: NPG's portfolio of projects from 2006 to 2015.

The key innovations implemented by Northern Powergrid (NPG) and the learning from these innovations, which is now part of NPG's standard approach, can be seen in Table 8.

Table 8: NPG's key implemented innovations.

Project	Innovation type	Description
Asset health indices	Business process	Allowed pro-active, condition-based monitoring and network risk-management. Many of these methods now form the standard way of managing distribution assets and have since become mandated by Ofgem. £10m per annum in savings as compared with previous asset replacement assessment based on aged.
Network capacity enhancement	Sector-specific technology	New equipment that releases network capacity to reduce or delay the need for more expensive investment – this includes generation management schemes, voltage controlled connections and real time thermal ratings. The learning that has been delivered through these innovations is now factored into NPG's forecasts as part of their standard approach.
Network automation and monitoring	Sector-specific technology	The use of remote control and monitoring and its integration into the control system allowed NPG to improve the reliability and availability of the network. High voltage restoration times have been considerably reduced.
Protective clothing	Business process & Technology	Providing better fire-proof protective clothing for operational staff is an example of taking a well understood technology from a different industry, in this case motor-sport and successfully developing and introducing it to improve safety in operations.
Call centre staff flexibility	Technology	Using voice-over-internet telephony to enable any staff anywhere on the network to instantly become an integral part of NPG's call centre. This has drastically cut call waiting times at busy periods.
Low carbon generation connections	Commercial	Changes in commercial arrangements for connections that get customers faster connections for their low carbon generation.
Providing better information to customers	Business process	Exploitation of web-based technology to provide greatly enhanced information to customers in respect of things like power cuts, confirmation of supplier details at a given property, 'heat maps'.
Web-based services	Business process & Technology	Introducing internet based systems to allow customers to book shrouding and order minor alteration works, with further services soon to move online.
Hard technology development	Sector-specific technology	Include fault passage monitoring (improving network availability), reducing fault currents to improve network headroom (facilitating faster, cheaper connections) and a replacement system for the woodhouse mast overhead line support (reducing cost and minimising environmental impact).

The new wood pole based specification for long span sections is capable of replacing the legacy system without significant impact on wayleaves. It can also be used at higher voltages and/or higher loads. The necessary installation and working equipment has also been developed to provide a total system for field use. This represents considerable full life cycle cost savings.

In terms of network availability, high voltage restoration times have been considerably reduced through for example, automation and monitoring (3000 fault passage indicator devices are now in use) and alternative HV reclosing technology.

Policy has been changed to specify rate of change of frequency protection for customer's generation connections under a wide range of conditions. NPG now routinely offers new generation customers faster and cheaper connections through loss of mains relays. The financial impact of this policy change is a 75% reduction in protection costs. Also, to speed up connections, a fault limiting device is expected to form part of NPG's standard offering when there is a cost effective and commercial off-shelf product available. The device based on trials with a superconducting fault current limiter can provide permanent increase of capacity.

In the next regulatory period, NPG will target its innovation activity towards the four strategic challenges of:

- Low carbon networks;
- Smart metering;
- Web-based services; and
- Affordability.

Table 9: Cost savings by area[1].

	2010-2015 average (£ m)	2015-2023 average (£ m)
Network Investment	183.5	166.8
Network operating costs	93.9	90.6
Workforce renewal	5.3	6.7
Support costs	104.6	111.2
Total (base) costs	387.3	375.3

2.2.2 Core Innovations for RIIO-ED1

Northern Powergrid believe that the low carbon transition and its demand for a smarter network is the area that demands the most significant innovation, both technological and commercial. The company's current view is that some of the most important requirements will include:

- Systems that enable pre-arranged demand-side responses to be triggered in real time as and when network constraints are encountered;
- Cost-effective control systems to allow the use of domestic-scale generation to provide low voltage network support;

[1] NPG (2014) Expenditure. Available: http://www.yourpowergridplan.com/som_download.cfm?t=media:documentmedia&i=1719&p=file. Last Accessed: 4 January 2016

- Methods of engaging customer groups on a local level to create community-scale benefit from aggregated demand response;
- Smart switching device applications and use of power electronics to improve low-voltage network reliability and flexibility;
- Active network management techniques and use of state estimation to control the network more dynamically by building on the foundations of our Customer Led Network Revolution (CLNR) project
- The use of AC/AC converters and fault-current limiters for reconfiguring distribution networks.
- Development of smart techniques for meshing high- and low-voltage networks to increase available capacity; and
- Integration of smart-metering data into network design processes and tools to provide more accurate views of available network capacity for new or modified connections and more targeted investment to reduce electrical network losses.

Table 10[2] contains Northern Powergrid's current view of the key innovation activities that it envisages will make up the majority of its innovation programme for the next 10 years. The breakdown does not represent a firm activity schedule.

Table 10. NPG’s Innovation Roadmap included in Northern Powergrid's Business Plan

[2] The Innovation Roadmap included in Northern Powergrid's Business Plan includes a "toolkit" under each of the priority areas (e.g. network environmental footprint includes: self-healing cables, substitute technologies, eco-design and power system efficiency). The outputs from the initiatives are also mapped against Ofgem's output categories.

Priority	2013-14	2015-19	2020-23
Network environmental footprint	• Self-healing technology for pressure filled cables to reduce leaks • Pursue eco-designs for low-carbon substation	• Smart meters facilitate faster fault response • Technology solutions for low voltage restoration • Fault anticipation systems	• Replacements for SF6 • Reduce losses by power correction factor • Composite material to increase and/or reduce environmental footprint
Network reliability and availability	• Network automation • On-site condition monitoring • Alternative HV reclosing technology to reduce network stress	• Reduce losses via smart metering data • Technologies to improve phase imbalance • Develop alternatives for pole preservation	• Sensor technologies to improve thermal rating and fault location • Acoustic sensors to monitor asset health
Network management and flexibility	• Development of Active Network Management (ANM) and state estimation engines • EHV/HV generation for network support • Energy storage for network support	• HV circuit monitoring for ANM systems • Generation support at LV via use of switched capacitors • Alternative LOM generator protection schemes • Mesh networks • Automation	• Fault current limiters in mesh networks to improve network flexibility • Self-islanding networks • Power electronics applications and data analytics to improve network management
Demand side response	• Trial of I&C DSR contracts and tariff driven DSR • EV smart charging trials • Customer engagement in DSR	• Energy efficiency measures to manage demand growth • DSR planning tool to assess impact on network security • Community rewards for aggregate DSR • I&C capacity auctions • I&C tariffs for peak demand management	• Technologies to support DSO role • Smart meter data-enabled domestic/SME tariffs for peak demand management

Priority	• 2013-14	• 2015-19	• 2020-23
Network planning and design	• LCT network planning and design decision support tools • HV reliability analysis tools based on actual circuit performance data	• Geo-spatial tools for asset and network planning • Power system design tools • Planning and real time data exchange with transmission system operator • Upgrade asset planning tools for new condition data	• Operational decision support tool for dynamic networks • Outage risk management decision support tools
Communication and engagement	• Power cut App improves information to customers • Micro websites keep local communities informed • Expert stakeholder groups to challenge business plans • On-line customer service training	• Push notification of power cut information • On-line communities test new services • Local heat maps let customers see connections capacity • Instant customer satisfaction surveys	• Open systems standards allow enhanced information sharing between communities
IT-enabled process improvements	• On-line self-services • Hand-held technologies improves power cut updates	• Vector records on an open standard improve external sharing of records • On-line systems allow customers to track progress • Geo-spatial views of work enhance co-ordination of activities • Electronic payment of guaranteed standards	• Open access gives opportunity for community-led solutions for local network issues
Social obligations	• Better power cut support with more and enhanced customer support vans • Extended reach - new four hour category definition of vulnerability	• Proactive contact with friends or family for extra personal support • Good neighbour scheme to increase PSR • Introduction of vulnerable household tool kits • Real time multi-agency sharing of PSR data • Use of web and onsite leaflets to signpost PSR customers to support agencies	• Enhanced large scale data analysis on smart meter data e.g. to support welfare checks • Collaboration with other organisations to identify heating solutions for fuel poor • Partnerships to explore options for rural, off-grid fuel-poor households

2.3 Scottish Power Energy Networks

2.3.1 DPCR5 Highlights

In their Innovation Strategy, Scottish Power Energy Networks (SPEN) have highlighted the following technology innovations as case studies for innovations being implemented into BaU:

- Dynamic Thermal Rating (DTR);
- Active Network Management (ANM); and
- Fault Level Monitoring (FLM).

The first of these, DTR, will be deployed in ED1 as part of the reinforcement solution set. It is believed to create 30% additional capacity on existing overhead lines at a significantly lower cost to constructing a new circuit.

ANM is now being considered as a solution for optimising the network, particularly in areas of high distributed generation. There is an anticipated saving of 20% to the cost of generation connection as well as associated time savings.

To support the above two technical innovations there is a commercial arrangement under the Accelerating Renewable Connections (ARC) LCNF Tier 2 project. SPEN are in the process of offering non-firm connection agreements on a BaU basis rather than by exception. The speed and cost of this connection type is preferential to the firm connections.

FLM aids asset management - replacing assets before failure and avoiding replacements before end of life. It should be noted that FLM is being deployed by two DNOs in ED1 and the device that is being deployed costs tens of thousands of pounds and is expected to save millions of pounds.

Other activities which are resulting in benefits in ED1 are in Table 11.

Table 11: ED1 benefits of innovation activities by ED1.

Activity	Benefit
Partial Discharge Mapping	PD Mapping allows the identification of potential 33kV faults before they occur, and directs asset replacement.
Smart Enabled Primary/Secondary Groups	Future-proofing substations.
HV STATCOM	Power electronics applied to control system voltage and minimise reinforcement.
Online condition monitoring of primary breakers	Optimised condition monitoring to improve maintenance and replacement.
Secondary sub monitoring	Increase network visibility of power flows and emerging issues for improved load indexing.
Soule switch	Manual switches will be replaced with automated switches to improve fault response.
Fault passage indicators	Identify faults faster to reduce duration of power cuts.

For a broader look at SPEN's focus areas the innovation road map covering the period 2010 to 2023 is shown in Table 12.

Table 12: SPEN's innovation roadmap.

Innovation area	2010-15	2015-17	2017-19	2020-23
Automation	Trials by SPEN & other DNOs	Substations designed to be automation ready	Application of automation for managing load flow	Increased automation intelligence for self-healing networks
Demand side response	Demonstration projects underway by other DNOs; SPEN demonstration in 13/14	Further pilot projects to quantify benefits		Development of relevant standards to enable as BaU
Energy storage	Projects being undertaken by other DNOs	Observe demonstrations and adopt learning	Demonstration project to build on learning	Build business case and confidence as market evolves
Using smart meters	Simulation project in 2013/14	Initial systems constructed to manage data as it becomes available	Use data to improve customer service and operation of network	Advanced application of data for improved asset management & demand response
ANM	SPEN project in the Scottish Borders. Other DNO projects being observed	Reflect learning into policies, applying where relevant across business practices.	ANM contracts become normal practice for generation connections	Linkage of ANM with other technologies (e.g. dynamic ratings) as normal practice
Monitoring and managing fault levels	Development of Fault Level monitoring and Limiters	Deployment of Fault Level monitors at sites. Continued development of the technology	Management of fault level through automation and monitoring	Deployment of fault current limiter as part of BaU to mitigate reinforcement costs
Dynamic rating of network in real time	Project in North Wales on 132kV OH network. Application to cables & transformers being tested in other projects	Application of dynamic rating to mitigate initial reinforcement schemes. Demonstrate alternative means of dynamic rating.	Use of dynamic rating as standard alternative to replacing highly loaded substations	Integration of dynamic rating with other solutions including ANM

2.3.2 Core Innovations for RIIO-ED1

Under the Network Innovation Allowance SPEN has been awarded an allowance of 0.5% of annual revenues (£3.3m in 2015/16) which it plans to split as in Figure 3.

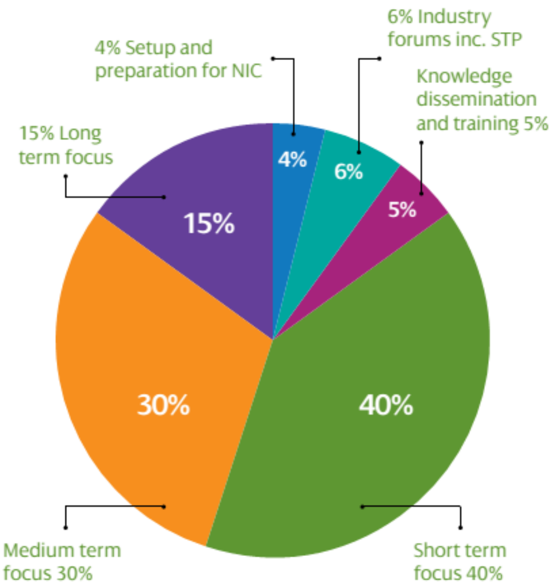
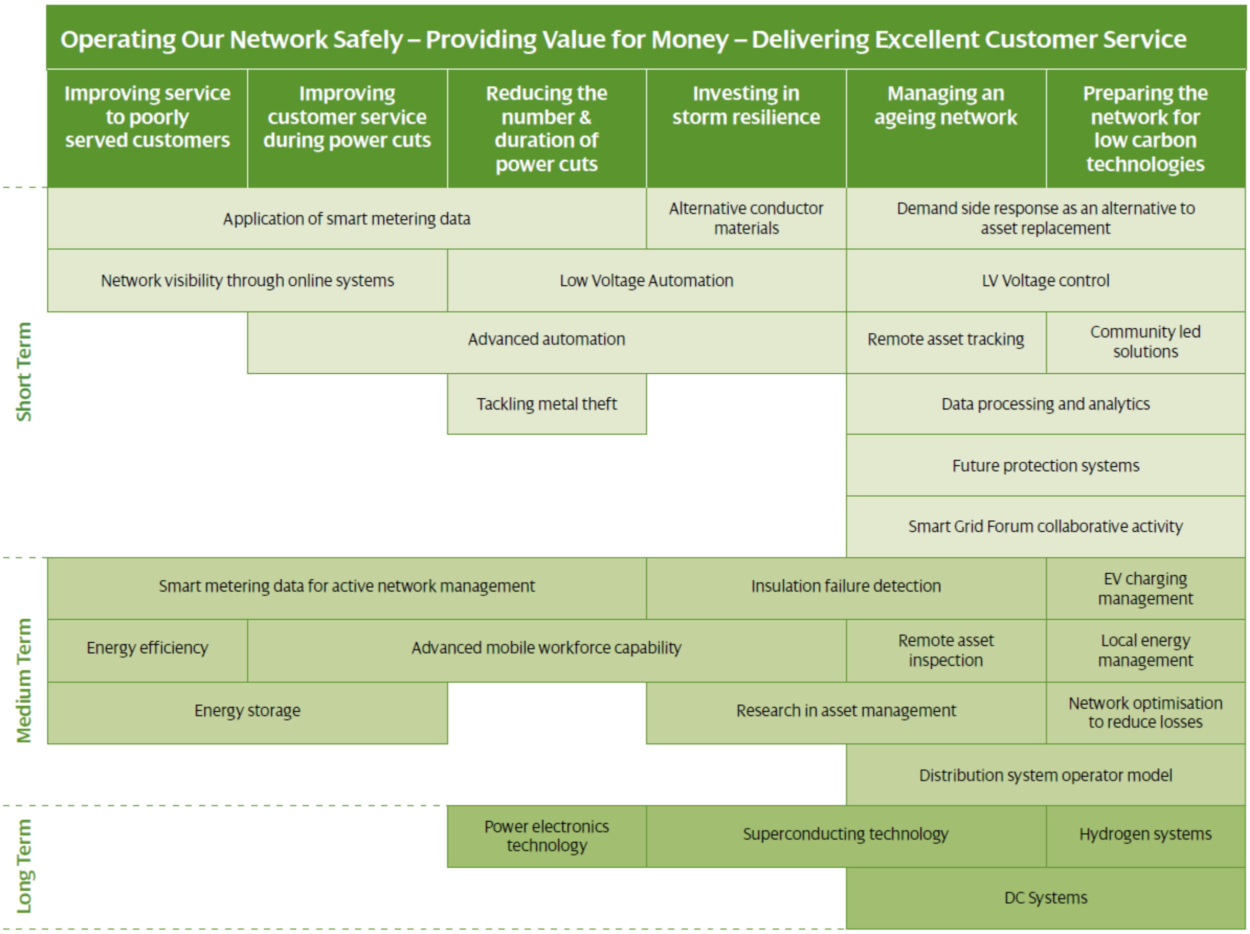


Figure 3: SPEN NIA spend.

Proposals for the Network Innovation Allowance

SPEN are focussing their NIA innovation activity on their six specific priorities and are proposing a portfolio of short, medium and long term deliverables as shown below



Proposals for the Network Innovation Competition

At this stage, particular areas of interest include:

- Advanced application of Smart Metering data;
- Demonstrating the DSO concept and the future role of the DNO;
- Consumer involvement in the network through DSR & exploring other possible services;
- Facilitating the smart city and community;
- Loss reduction solutions;
- Energy solutions for vulnerable and off gas grid customers; and
- Medium voltage DC systems to improve connectivity.

This is not exhaustive and is likely to change over the period depending on the success of other projects.

In 2015 ANGLE DC, a project wanting to demonstrate a novel network reinforcement technique by converting an existing 33kV AC circuit to DC operation, was awarded funding. The technique could be used by DNOs as an efficient solution to create network capacity headroom and facilitate GB's objective for the shift towards a low carbon economy.

Alignment with Business Plan Outputs

SPEN's innovation activities align with their business plan outputs as follows:

Key theme	Innovation activity
Network reliability	Development of new automation schemes on the LV network to restore customers faster using embedded intelligence.
Customer satisfaction	Application of smart metering data to proactively provide improved information on what is happening on the network, particularly during fault conditions.
Connections	Development of DSR solutions to assist in allowing for faster connection to the network.
Environment	Development of alternative conductor & insulation materials to reduce the use of oil in equipment.
Safety	Development of new approaches to combating metal theft through alternative detection, such as using technology currently being developed by the EIC.
Social obligations	Provide communities with information from smart meter data and incentives to change their energy consumption behaviour for their own and the network's benefit.

2.4 Scottish and Southern Energy Power Distribution

SSEPD notes that their most successful IFI and LCNF projects have typically taken 5-years to mature to a BaU solution. RIIO-ED1 is seen by SSEPD as a chance to take innovative project outputs to BaU solutions in the areas of active network management, energy storage and low voltage network monitoring and modelling.

2.4.1 Core Innovations for RIIO-ED1

SSEPD's Innovation Strategy discusses three main themes they believe will drive the need for innovation during RIIO-ED1. These are:

- The need for value and choice for customers;
- The need for flexibility in GB's low carbon transition; and
- The need to realise the full value of existing innovative solutions.

The three high-level themes provide an overarching justification for innovation during RIIO-ED1. In addition, SSEPD have identified six specific factors that will drive the need for innovation during RIIO-ED1:

- Customer and wider stakeholder needs;
- Integrating the low carbon solutions required to achieve national emissions targets
- New technology opportunities;
- Legislative and regulatory developments;
- Mandated opportunities such as the smart meter roll out; and
- Climate change.

SSEPD's innovation strategy is designed to address these drivers while maximising value for money, in accordance with the priorities expressed by their stakeholders.

SSEPD have used their innovation focus matrix and stakeholder consultation feedback to map their current innovation project portfolio against business drivers drawn from their business plan to produce a prioritised set of 20 core innovations for RIIO-ED1. SSEPD believe these will deliver the greatest, most cost-effective benefits for their customers and their business. These are listed in Table 13.

Table 13. SSEPD's 20 core innovations for RIIO-ED1

RIIO-ED1 primary output	Core innovations for RIIO-ED1	
Connections	Active network management - community demand management	
	Active network management - generator constraint management	
	Demand-side management	thermal energy storage
	Dynamic circuit thermal rating	
	Fault current limiters	
	Local smart EV charging infrastructure	
	LV solid-state voltage regulator	
	Static synchronous compensators (STATCOMs)	
Customer service	Advanced distribution automation - network configuration	
	Weather impact and response modelling tools	
Environment	Bidirectional hybrid generation plant	
	Wood pole alternative	
Reliability	Automatic demand response with commercial customers	
	Energy efficiency approaches	
	LV network modelling	
	LV network monitoring	
Safety	Conductor sag and vibration monitoring	
	Live line tree felling	
	Arc suppression coil and residual current compensation earthing	
Social obligations	Enhanced supply monitoring and support for vulnerable customers	

Thematic portfolio:

Orange	Active network management
Blue	Energy storage management
Green	LV network monitoring and modelling

To avoid duplicating the effort of other DNOs, SSPED selected three themes that they view are of greatest relevance and cost-efficiency to their customers and networks; representing areas where they have built up significant experience and shown industry leadership. Table 13 is colour coded in accordance to these innovation themes, with each having a portfolio of projects related to each which they intend to build upon during RIIO-ED1. Nine of the core innovations are drawn from these portfolios and are highlighted in Table 13. The synergies that exist between the three portfolios are expected to support the development and deployment of these innovations during RIIO-ED1.

Table 14 shows a break-even analysis, which shows SSEPD's estimations of the potential paybacks from deploying their 20 core innovations during the RIIO-ED1 period. Areas that may be of interest to NIE Networks are: ANM, DSR, Fault Current Limiters (FCLs), STATCOMs and RTTR of overhead lines. These areas require low levels of investment for deployment in BaU circumstances and low deployment numbers to achieve the associated payback on investment. Another area of interest may be alternative materials for overhead lines, which could be attractive to DNOs with predominantly rural networks. SSEPD will be reviewing and updating their innovation strategy through annual strategic reviews and rolling out innovative solutions on an incremental basis, based on case-by-case network needs.

Table 14 Break-even analysis to demonstrate the potential payback from deploying the 20 core innovations in high-cost conventional instances during RIIO-ED1. Note that the estimated costs and savings are subject to significant internal and external uncertainties, and should be treated as indicative.

Core innovation for RIIO-ED1	Estimated cost to bring to business-as-usual	Estimated cost per deployment	Potential saving or deferment per deployment	Number of deployments to pay back	Assumptions
Active network management - generator constraint management	£1,000,000	£355,000	£2,000,000	1	Based on high cost network reinforcement situations, e.g. Isle of Wight, Orkney, Western Isles
Active network management - community demand management	£1,000,000	£122,000	£2,000,000	1	Based on high cost network reinforcement situations, e.g. Isle of Wight, Orkney, Western Isles
Demand-side management - thermal energy storage	£4,000,000	£750,000	£2,000,000	4	Based on assumptions in SSEPD's Integrated Plan to manage supply and demand on Shetland
Local smart EV charging infrastructure	£3,000,000	£4,000	£30,000	116	Saving/deferment due to avoided underground network reinforcement
LV solid state voltage regulator and power conditioning	£1,000,000	£1,500	£15,000	75	Expected saving/deferment due to avoided overhead line reinforcement
Fault current limiter	£3,000,000	£1,000,000	£1,500,000	6	Expected saving/deferment due to avoided high-cost switchgear replacement
STATCOM	£150,000	£500,000	£2,000,000	1	Based on high cost network reinforcement situations, e.g. Isle of Wight, Orkney, Western Isles

Core innovation for RIIO-ED1	Estimated cost to bring to business-as-usual	Estimated cost per deployment	Potential saving or deferment per deployment	Number of deployments to pay back	Assumptions
Weather impact and response monitoring	£100,000	£0	£40,000	3	Benefit based only on avoided staff deployment
Bi-directional hybrid generation plant	£300,000	£450,000	£600,000	2	Based on £30,000 annual fuel saving over 5-year asset (£150,00 total) and £450,000 cost of conventional generator
Wood pole alternative	£500,000	£0	£100	5000	Saving based on £100 saving per pole on transporting, storing and handling conventional (non-innovative) alternative
Energy efficiency approaches	£1,000,000	£300,000	£2,000,000	1	Based on high cost network reinforcement situations, e.g. Isle of Wight, Orkney, Western Isles
Automatic commercial demand-side response	£2,000,000	£1,150,000	£1,500,000	6	Each deployment assumed to serve 20 buildings
Dynamic circuit thermal rating	£500,000	£250,000	£1,500,000	1	Each deployment assumed to include multiple feeders
LV network modelling	£2,000,000	£250	£15,000	136	Cost per deployment is planning time to analyse data. Saving/deferment due to avoidance of overhead line reinforcement
LV network monitoring	£500,000	£6,000	£15,000	56	Saving/deferment due to avoidance of overhead line reinforcement
Live line tree felling	£500,000	£6,250	£7,500	400	-

2.4.2 Proposed NIA Spend

SSEPD acquired NIA funding allowance of 0.5% of annual revenues (around £3.6m for 2015/16). At the time of submission SSEPD estimated that their NIA funding would broadly be spent as in Table 15 in order to continue the development and expansion of their innovation portfolio to meet the needs of their customers, wider stakeholders and their business.

Table 15. Estimated high-level breakdown of network innovation allowance for SSEPD

Expenditure Element	Approximate percentage of NIA	Assumptions
Continuing small-scale innovation projects at existing rate using well established sources and new sources	50%	Based on continuing current expenditure of around £4 million per year on IFI-scale projects
Progressing innovations to a state of readiness for business-as-usual	14%	Based on an expenditure of around £250,000 per BaU project
LCNF Tier 1-scale demonstration projects	13%	Based on continuing current expenditure of around £1m per annum on Tier 1-scale demonstration projects
Increased volume and complexity of learning dissemination and knowledge management to ensure the benefits of innovation are fully realised	13%	Based on holding knowledge-sharing events and courses, maintaining knowledge registers and engaging with stakeholders in relation to increasingly complex innovative solutions. Also increased legal costs associated with securing the value of IP
Meeting new challenges and complexities that emerge during RIIO-ED1 as well as revisions in DECC scenarios driving SEE to explore new areas of innovation	10%	Corresponding to the as-yet unknown challenges that will drive innovation during RIIO-ED1

2.5 UK Power Networks

2.5.1 DPCR5 Highlights

In Appendix A.1 of Annex 9 of their Business Plan [1], UK Power Networks (UKPN) have listed the innovative solutions to be delivered in RIIO-ED1 along with their TRL, Business TRL and Resilience to Economic and LC Scenarios (RtELCS) (measured on a 0-15 scale, with 0 highly sensitive and 15 highly resilient). Table 16 shows a summary of savings expected during RIIO-ED1, split by the innovation area and UKPN licence area.

Table 16. Summary of smart savings considered in the UKPN RIIO-ED1 business plan.

Smart Grid Solution	EPN	LPN	SPN	Total – All Licence Areas	Running Total
Benefit from existing Smart Grid network designs and practices	£ 5m	£ 20m	£ 5m	£30m	£30m
Savings in LV reinforcement compared to forecast volumes	£11.8m	£9.9m	£13.4m	£35.1m	£65.1m
Saving from Demand Side Response schemes	£11.8m	£13.9m	£17.7m	£43.4m	£108.5m
Savings in overhead line reinforcements	£8.6m	-	-	£8.6m	£117.1m
Savings from Dynamic Transformer ratings	£7.7m	£3.1m	£4.2m	£15.0m	£132.1m
Savings from Partial Discharge monitoring of switchgear	£1.9m	£ 2.5m	£ 4.6m	£ 9.0m	£141.1m
Sum of savings	£46.8m	£49.4m	£44.9m	£141.1m	£141.1m

2.5.2 Core Innovations in RIIO-ED1

UKPN has developed a process known as the Smart Network Plan (SNP), within which innovation solutions are planned to be captured, tested, developed, rolled-out and embedded into UKPNs normal business operations during the RIIO-ED1 and ED2 periods. The SNP comprises of three key business implementation steps:

1. Capturing and categorising innovation ideas into ED1 and ED2 innovation trays;
2. Systematic assessment and development of innovation solutions; and
3. Implementation of innovation solutions.

The second implementation step is deemed necessary because innovation solutions are often viewed as ‘poor fit’ within existing approaches due to sparse information, uncertainties of future costs, and potential new risks. The higher the uncertainty and risk associated with a particular innovation, the further back in time the innovation will be pushed, i.e. into the ED2 period.

2.5.3 Innovation Roadmap

UKPN's internal network innovation strategy, known as the Future Network Development Plan, determines how innovative network solutions are organised into themes and how these themes translate into deliverables via a series of stages. The innovation activities are organised into seven themes as listed in Table 17 and describe the actions that need to be carried out to deliver innovations in a cost effective and timely manner.

Table 17. Summary of UKPN's Future Netowrk Development Plan's innovation accitvty by theme.

Theme		Comments
1	Managing asset risk and improving fault performance	Critical success factors in the service that UKPN offers to current and potential customers
2	Understand current & future performance of the 11kV & LV network	
3	New options to release capacity at 11kV, 33kV and 132kV	
4	Develop commercial solutions and products	
5	Understand the condition of our assets	
6	Leveraging industrial & commercial DSR & dispatchable generation	More interactive relationship, either directly or through energy suppliers, aggregators & other market entities
7	Managing residential and SME consumer demand	

Theme 1 (Managing asset risk and improving fault performance) will correspond to all activities of innovation that UKPN needs to carry out in order to fulfil its central function of serving existing customers and managing risks to its electrical assets.

UKPN's capability themes align with the six primary output categories within Ofgem's RIIO framework as follows:

Output categories \ Capability themes	Leveraging I&C DSR and DG	Understand performance of 11kV and LV network	New options to release capacity at 11/33/132kV	Understand the condition of our assets	Develop commercial solutions and products	Managing residential and SME consumer demand	Managing asset risk and improving fault performance
Capital efficiency	●	●	●	●	●	●	
Reliability and availability				●			●
Operational efficiency		●		●			
Connections	●		●				
Driving sustainable networks	●	●	●		●	●	
Customer satisfaction			●	●		●	●
Environment			●	●			●
Safety				●	●		●
Social obligations							●

Table 18 shows the capabilities to be delivered as part of UKPN's innovation solutions. It represents UKPN's current best view based on the challenges on the business and the readiness of solutions and is derived from the Future Network Development Plan.

Table 18. Capabilities to be delivered as part of UKPN's innovation solutions.

RIIO-ED1 deliverable	Success measure	Go Live	Using the following tools defined by the Smart Grid Forum	Resilience to economic and low carbon scenarios 15 = highly resilient, 0 = highly sensitive	
Enhanced control systems resilience	Reliability and availability	2015-17	Ensured security of critical systems Ensured protection of customer data	11	🟢
Enhanced system security through procured ancillary services	Reliability and availability, capex efficiency	2015-17	Generation constraint management – HV connected HV connected Electrical Energy Storage (EES) – large	10 3	🟢 🔴
Increased plant and line utilisation	Enabling connections; reliability and availability, capex and opex efficiency	2015-17	Advanced control systems Real-time Thermal Ratings (RTTR) for EHV Overhead Lines RTTR for EHV/HV transformers RTTR for EHV Underground Cable Dynamic Network Reconfiguration – EHV	10	🟢
Facilitating higher levels of DG penetration	Enabling connections	2018-20	Dynamic Network Reconfiguration – EHV Generation constraint management – EHV connected HV Non-superconducting fault current limiters	10	🟢
Improved network visualisation	QoS, capex and opex efficiency	2018-20	Design tools Advanced control systems HV Circuit Monitoring (along feeder)	10	🟢
Increased supply resilience	Reliability and availability	2018-20	Dynamic Network Reconfiguration – HV Dynamic Network Reconfiguration – EHV	10	🟢
Power outage management	Reliability and availability	2018-20	Smart Metering infrastructure – DNO to DCC 2 way A+D	15	🟢
Voltage quality management	Capex efficiency, enabling connections	2018-20	HV Circuit Monitoring (along feeder)	11	🟢
Enhanced network flexibility and interoperability	Capex and opex efficiency	2021-23	Comms FABRIC Advanced control systems HV/LV Transformer Monitoring	8 8 10	🟠 🟠 🟢
Enhanced system integrity	Reliability and availability, capex and opex efficiency	2021-23	HV Circuit Monitoring (along feeder) w/ State Estimation Smart Metering infrastructure – DCC to DNO 1 way HV Circuit Monitoring (along feeder)	8 11 11	🟠 🟢 🟢
Improved load and loss load factor	Enabling connections; capex efficiency	2021-23	Generator network support – HV connected Generation constraint management – EHV connected DNO to residential HV connected EES – large	6 10 5 3	🟠 🟢 🟠 🔴
Losses optimisation	Capex and opex efficiency	2021-23	DNO to HV commercial DSR DNO to residential Dynamic Network Reconfiguration – LV	7 5 8	🟠 🟠 🟠
Provision of upstream system balancing services	Opex efficiency	2021-23	Generation constraint management – HV connected Generation constraint management – HV connected HV connected EES – large	10 10 3	🟢 🟢 🔴
Smart management of Distributed Energy Resources	Enabling connections, capex and opex efficiency	2021-23	Enhanced Active Voltage Control (AVC) – LV circuit voltage regulators Enhanced AVC – HV/LV Transformer Voltage Control Smart Metering infrastructure – DCC to DNO 1 way HV Circuit Monitoring (along feeder)	3 6 11 11	🔴 🟠 🟢 🟢
Smart management of Electric Vehicles (EVs) and heat pumps	Enabling connections, capex and opex efficiency	2021-23	DSR – Products to remotely control loads at consumer premises DNO to residential DNO-controlled EV charging – LV domestic connected	6	🟠
System voltage optimisation	Capex efficiency	2021-23	Static Synchronous Compensator (STATCOM) – EHV	6	🟠

The deliverables are listed in the form of solutions in the Transform Model. In several cases technology solutions make multiple appearances. The entries are colour coded to emphasise this aspect.

2.5.4 Proposed NIA Spend

UKPN have been granted an NIA allowance of £6.1 million for 2015/16 (0.5% of allowed revenues). The company propose to bid for the majority of their funding through the competitive NIC mechanism.

2.6 Western Power Distribution

2.6.1 DPCR5 Highlights

The innovation projects undertaken in the last price review period under the LCNF Tier 1 funding stream are in Table 19 and for IFI funding in

Table 20. Further details on Western Power Distribution's (WPD) LCNF Tier 2 projects can be found in the proformas in section 3.6.

Table 19: Examples of WPD's LCNF Tier 1 innovation projects in DPCR5.

LCNF Tier 1	Change
National Grid Systems Integration & Security	The connection of more intermittent generation on the system will become increasingly important for data to be exchanged (reliably and securely).
11kV Voltage Control	Demonstrated Static VAR Compensators (SVCs) at 11kV are an effective way of smoothing voltage on rural networks to allow distributed generation to connect.
Substation Sensor Trial & "best buy" report	98% accuracy is achievable on retro fit LV monitoring equipment.
PV's in Suburbia	Results showed that dense concentrations of solar panels will present some issues around harmonic content, power factor and the threshold of neutral current thermal limits. These findings are helping to advise new planning principles in conjunction with the LV Templates and Early Learning projects.
Smart Hooky – Britain's Smartest Energy Community	Power line communications solution enable communication to customers' homes directly and improve understanding of individual demand profiles.
Seasonal Deployment of DG	Due to current market arrangements and the greater utilisation of generation than expected, it was found to be uneconomic to make use of mobile generation in this way. The project was therefore halted in the summer of 2013.
Active Fault Level Management	The learning has already fed into the Tier 2 FlexDGrid project and a live measuring device was installed on a network in Birmingham in December 2013.
ECHO (ending 2016)	Provides insight into the financial, technological and behavioural aspects of DSR.

Table 20: Examples of WPD's IFI projects with their associated change to BaU.

IFI Projects	*Change to BaU*
Condition inspection of overhead primary circuit lines by helicopter	Advanced inspection techniques, fully incorporated into company policies and regular helicopter inspection activities.
Non-intrusive testing of tower foundations	Development of new technologies that are now used during condition assessment of towers.
Control system automation algorithm (self-healing networks)	Rollout of the algorithm to the WPD region. The functionality has led to this type of functionality becoming a core offering within Network Management Systems (NMS).
Understanding networks with high penetrations of DG	Identified ways to change conventional network design to maximise the penetration of micro generation. The research and modelling activity subsequently led to validation projects through LCNF projects.
Impact of climate change and weather analysis	New methodologies and probabilistic predictions to assess specific energy industry impacts
Harmonic issues on distribution networks	The learning allowed WPD to further develop ENA planning guidelines and continues to inform the on-going industry review of the industry standards such as the ENA's Engineering Recommendation G5/4.
Electric Vehicles	The project confirmed that the impact on distribution network from a modest uptake of small electric vehicles is low.
Generating value from smart meter data	This project helped inform WPD's RIIO-ED1 Smart Metering Strategy. Particularly on methods of undertaking data mining on the vast pool of data that will be available following the smart meter roll out, and how the information produced can be of maximum benefit.
Earthing information system	A Geographic Information System (GIS) to assist DNOs in the installation of rural ground earthing systems. Carried out in conjunction with UKPN and the British Geological Survey, it provides a graphical presentation of ground conditions and estimates the likelihood of suitable earthing resistance being met. The system has recently been further developed and is now provided as an overlay in WPD's GIS systems used regularly by network planners.
CBRM	A tool to determine optimum replacement triggers for network assets. CBRM data is also being used to optimise maintenance periods based on condition.

The day-to-day business innovations picked out as examples in WPD's Innovation Strategy are: ENMAC mobile, condition inspection of overhead primary circuit lines by helicopter, LV monitoring, pre-installed LV monitoring, dynamic line ratings, A mix of smart technology solutions and enablers and processes.

ENMAC (an advanced network management system) has been in use since 2007 and became BaU in 2013. The network management functionality trialled in the LCNF Tier 2 project Flexible Approaches for Low Carbon Optimised Networks (FALCON will be implemented into WPD's ENMAC control system, and the prototype system subsequently decommissioned. The new functionality will become available to be implemented across the WPD networks from 2015, leading to the widespread rollout of load balancing automation schemes as loads grow with the increase in adoption of LCTs.

WPD have also been heavily involved in more detailed LV monitoring. Following the installation and operation of data monitors and communication equipment at 951 substation sites in 2011, WPD have published the collated data set and accompanying conclusions to inform LV network design. The LV Templates are being used in South Wales and are expected to be rolled out to other licence areas. Their novelty is in their ability to predict LV generation and load and new findings about the impact on network voltage. Since 2010, WPD have required their LV distribution cabinets at substations to be configured with a more accurate CT (current transformer) to allow easy connection of monitoring equipment. Switchgear orders since 2009 have been specified to be prewired for automation too.

Between 2015 and 2018 WPD will be deploying Dynamic Line Rating (DLR) solutions (also known as RTTR) and Flexible Generation Capacity Agreements for generation projects at 11 sites. This is in addition to their original prediction of two locations per licence area.[3]

2.6.2 Core Innovations for RIIO-ED1

WPD's future innovation developments can be described across six broad areas;

- *Low carbon networks* - supporting future electricity demand and generation requirements;
- *Smart meters* - maximising the benefits from more detailed network data;
- *Smart grids* - developing new techniques and utilising enhanced data to help develop more dynamic network control;
- *Environment* - reducing the business impact of the company on the environment and reducing technical losses;
- *Customer service* - developing smarter ways of delivering better customer service; and
- *Business efficiency* - searching out better processes, equipment and technology that ensure the company continues to be efficient.

The objectives of WPD's innovation are to:

- Develop new smart techniques that will accommodate increased load and generation at lower costs than conventional reinforcement;
- Improve performance against one or more of our core goals of safety, customer service, reliability, the environment or cost effectiveness;
- Ensure solutions are compatible with the existing network;
- Deliver solutions into business as usual; and
- Provide value for money.

[3] P22 WPD Final Strategy

In addition to their innovation strategy, WPD have strategies for smart grids, smart meters, losses and climate change adaption. These can be summarised as follows:

Strategy	Key Areas	Examples / Comments
Smart grid	Accommodating load on the network	• Passive accommodation of load • Application of templates • Monitoring and state estimation • Active network management
	Smart grid connection agreements	• Customers applying for load or DG connections will be offered smart solutions in line with the solutions above.
	Flexibility - application of different solutions	• Ensuring that solutions are flexible to deal in uncertainties in uptake of LCTs
	Templates and modelling	• Building on LV Templates project and incorporating smart meter data to improve network planning
	Network automation	• Network reconfiguration or meshing networks • Use of wind turbines / invertor fed PV as voltage control ancillary service • Use of STATCOMS
	Demand Side Management (DSM) and DSR	• Engagement with domestic and I&C customers to test different commercial arrangements • Standard set of terms and conditions with suppliers
Smart meters	Fault management	• Possibility of automation of fault reporting • Remotely identify if fault is on the network or at customer's premises
	Network planning	• Improved load profiles to inform load related investment decisions
	Connections	• Reduced time to connect new loads / generation
	Asset management	• Ability to monitor voltage and load to assess need for reinforcement
	Future applications	• Identification of issues resulting from increased volumes of LCTs connected to the network
Losses	Understanding losses	• Impact of changing power factor or LCTs on losses
	Addressing losses	• Install oversized transformers and cables where appropriate
Climate change adaptation	Risk assessment and reporting to DEFRA	• On-going support of R&D to better understand the impact of climate change on assets
	Extreme weather events	• Lightning protection to cable terminations and pole mounted automatic switchgear

Strategy	Key Areas	Examples / Comments
	Temperature increase impact on OHLs	• Increased ground clearances
	Flooding	• Flood risk assessments and mitigation measures where appropriate

2.7 Overview

Figure 4 shows an overview of the GB DNO Innovation plans indicating how many DNOs are actively pursuing each of the innovation areas. It can be seen that voltage control/management, DSR and dynamic ratings feature heavily in the GB DNO innovation strategies for the RIIO-ED1 period.

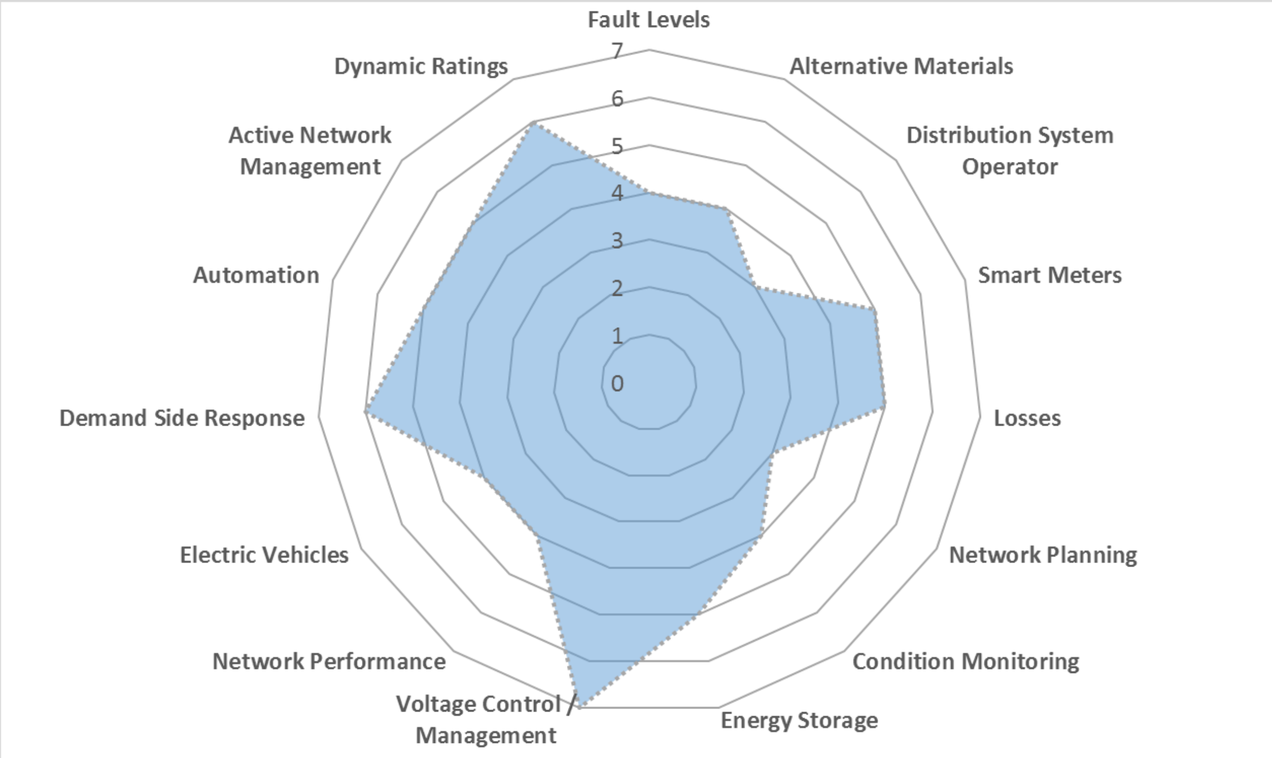


Figure 4: DNO Innovation plans

3. LCNF Tier 2 Project Proformas

Between April 2010 and 2015 Ofgem offered funding to large scale trials of new technology, operation and commercial arrangements. Disclaimer: the non-uniformity seen in the each of the 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.

shows a list of projects awarded funding split by the following colour coding: complete (green); underway (orange); recently begun (blue).

Table 21: LCNF Tier 2 projects by DNO.

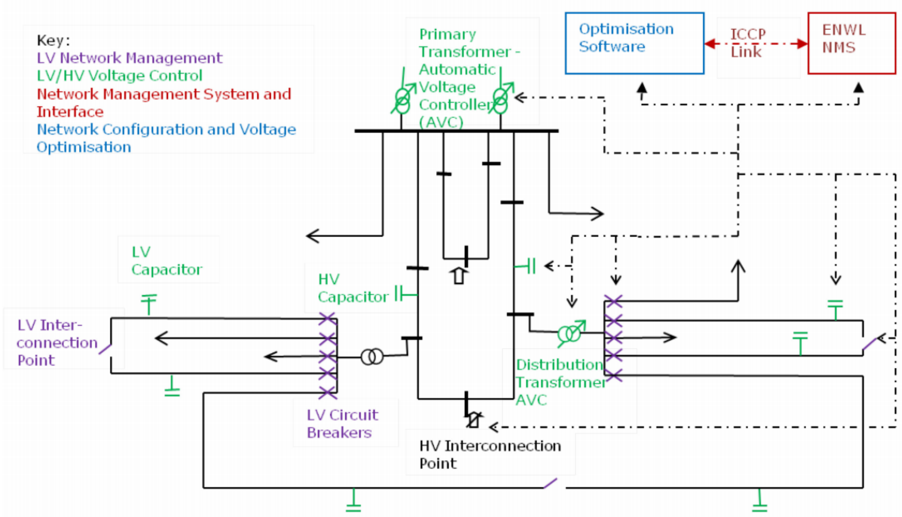
DNO	Project Title	Start	End
ENWL	(C2C) Capacity to Customers	Jan-12	Dec-14
	(CLASS) Customer Load Active System Services	Jan-13	Sep-15
	(eta) Smart Street	Jan-14	Dec-17
	(FLARE) Fault Level Active Response	Jan-15	Aug-18
NPG	(CLNR) Customer-Led Network Revolution	Jan-11	Dec-14
SPEN	Flexible Networks for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

Disclaimer: the non-uniformity seen in the each of the 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.

3.1 Electricty North West

Table 22. Smart Street eta Proforma.

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 Title	**Smart Street eta**
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 Business Case	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

Project Title	Smart Street eta
Outputs/ Implementation	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 are: • 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 23. Customer Load Active System Services (CLASS) proforma.

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 • The CLASS method uses existing assets with no detriment to their asset health.

<table>
<tr><th>Project Title</th><th>Customer Load Active System Services (CLASS)</th></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 rowspan="2">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>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 5: Summary of CLASS trials.
</td></tr>
<tr><td>Project Business Case</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</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.

Table 24. Capacity to Customers proforma.

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 C_2C 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 C_2C customers; • Network data: Detailed analysis of the benefits of the C_2C 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.
Key tech/process trialled	• HV network automation – closing the Normal Open Point (NOP) between two adjacent HV circuits; and • PowerOn Fusion.

Project Title	**Capacity to Customers (C_2C)**
Project Business Case	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	The C_2C Method will: • Release significant capacity to customers from existing infrastructure; • Enable improved utilisation of network assets through greater diversity of customers on a closed network ring; • Reduce like-for-like power losses initially but this benefit will gradually erode as newly released capacity is utilised; • Improve power quality resulting from stronger electrical networks; • facilitate lower reinforcement costs for customers for the connection of new loads and generation; • Facilitate a reduction in the carbon costs of network reinforcement; • 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; • Interconnection of C_2C operation to release more demand capacity than radial C_2C operation; and • Use of post-fault demand response in security of supply requirements.

Table 25. Fault Level Active Response proforma

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

Project Title	**Fault Level Active Response (FLARE)**
	• 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	• 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	• 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).

Table 26. 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	• 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

Project Title	Fault Level Active Response (FLARE)
Outputs/ Implementation	• 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).

3.2 Northern Powergrid

Table 27. Customer Led Network Revolution proforma

Project Title	Customer-Led Network Revolution
Company	Lead: NPG, Partners: British Gas, Durham University and EA Technology
Project Funding	£31m - LCNF Tier 2 inc. partner contribution
Project Drivers:	• 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.
Project Objectives	• 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: **LO1**: To understand current, emerging and possible future customer (load and generation) characteristics. **LO2**: To what extent are customers flexible in their load and generation, and what is the cost of this flexibility? **LO3**: To what extent is the network flexible and what is the cost of this flexibility? **LO4**: What is the optimum solution to resolve network constraints driven by the transition to a low carbon economy? **LO4**: What are the most effective means to deliver optimal solutions between customer, supplier and distributor?
Key Tech/Process Trialled	Electrical Energy Storage (EES) Enhanced Automatic Voltage Control (EAVC) RTTR DSM
Project Business Case	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.

Project Title	**Customer-Led Network Revolution**

NPV net financial benefits over period 2020-2050 £billion in 2014 prices	Original business case	Revised business case	
		Low	High
Network capital cost savings	£2.31	£3.25	£17.70
Direct customer benefit	£0.36	£1.30	£7.00
Carbon emission savings	£2.48	£0.32	£0.94
Generation capital cost savings	£1.14	£0.12	£0.37
Total	**£6.30**	**£4.99**	**£26.01**

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

Timescales	January 2011 - December 2014
Current status	Complete
Outputs/ Implementation	• 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. 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;

Project Title	Customer-Led Network Revolution

- 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).

In the following table, TRL refers to Technology Readiness Level and IRL refers to Implementation Readiness Level

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	

Project Title	**Customer-Led Network Revolution**

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	

3.3 Scottish Power Energy Networks

Table 28. Accelerating Renewable Connections proforma

Project Title	**Accelerating Renewable Connections (ARC)**
Company	Lead: SPEN, Partners: Community Energy Scotland, Smarter Grid Solutions and the University of Strathclyde.
Project Funding	£7.742m - LCNF Tier 2 inc. partner contribution
Project Driver	Facilitate increased penetration of renewable generation gaining access to the distribution network in a timely manner.
Project Objectives	• 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.
Key Tech/Process trialled	• ANM; and • Commercial arrangements.
Project Business Case	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.

Project Title	Accelerating Renewable Connections (ARC)

Activity	Project Budget at Dec 2014 £k	Actual Project at Dec 2014 £k	Variance £k	Comments
Labour	2,247.0	567.2	(1,679.8)	Our labour requirements continue to be efficient and we have been able to deliver the project at a reduced labour costs to date
Equipment	1,175.0	660.0	(515.0)	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.
Contractors	1,633.0	557.2	(1,075.8)	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
IT	906.0	43.0	(863.0)	2015 will see a significant increase in spend associated with IT. This will support the delivery of the Online Curtailment Assessment Tool.
Travel & Expenses	17.0	21.9	4.94	Travel is slightly ahead of forecast spend due to increased stakeholder engagement activity within the trial area and attending various events
Contingency & Others	275.0	31.1	(243.9)	This reflects costs associated with the delivery of increased stakeholder engagement activity throughout the project16
Total	**6,253.0**	**1,880.5**	**4,372.6**	

The above table is from an ARC 6 monthly report published in December 2014.

Timescales	January 2013 – December 2016
Current status	Underway
Outputs/ Implementation	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 29. Flexible Networks for a Low Carbon Future proforma

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

<table>
<tr><th>Project Title</th><th>Flexible Networks for a Low Carbon Future</th></tr>
<tr><td></td><td>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.</td></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</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>
Cost comparison between traditional and innovative solutions for network capacity expansion.</td></tr>
<tr><td>Timescales</td><td>January 2012 – December 2014</td></tr>
<tr><td>Current status</td><td>Complete</td></tr>
</table>

<table>
<tr><th>Project Title</th><th>Flexible Networks for a Low Carbon Future</th></tr>
<tr><td>Outputs/
Implementation</td><td>

A 20% increase in network capacity through a number of innovative measures.
A saving of £8.1m against traditional network solutions.

<table>
<tr><th>Innovation</th><th>Potential capacity headroom release</th></tr>
<tr><td>Enhanced network monitoring</td><td>8% on average</td></tr>
<tr><td>Enhanced primary transformer thermal rating</td><td>10 -14%</td></tr>
<tr><td>33kV Overhead line RTTR system</td><td>Up to 11%</td></tr>
<tr><td>Flexible network control</td><td>6 - 11%</td></tr>
<tr><td>Integration of voltage regulators</td><td>Enabler</td></tr>
<tr><td>Energy efficiency</td><td>Negligible</td></tr>
<tr><td>Voltage optimisation</td><td>Demand: 1% for 1% voltage reduction
Generation: > 850W per customer for LV networks with embedded PV generation</td></tr>
</table>
Capacity headroom release for Flexible Networks methods trialled.
<table>
<tr><th>Item</th><th>Expenditure (£k)</th></tr>
<tr><td>Labour for installation and maintenance</td><td>51</td></tr>
<tr><td>Monitoring Equipment (Whitchurch)</td><td>264</td></tr>
<tr><td>Monitoring Comms (Whitchurch)</td><td>40</td></tr>
<tr><td>Monitoring Equipment (St Andrews)</td><td>571</td></tr>
<tr><td>Monitoring Comms (St Andrews)</td><td>42</td></tr>
<tr><td>Monitoring Equipment (Ruabon)</td><td>227</td></tr>
<tr><td>Monitoring Comms (Ruabon)</td><td>32</td></tr>
<tr><td>Dynamic rating equip. (Whitchurch)</td><td>16</td></tr>
<tr><td>Dynamic rating equip. (St Andrews)</td><td>203</td></tr>
<tr><td>Dynamic rating equip. (Ruabon)</td><td>10</td></tr>
<tr><td>Control equip. (Whitchurch)</td><td>53</td></tr>
<tr><td>Control equip. (St Andrews)</td><td>363</td></tr>
<tr><td>11kV Voltage Regulators (enabler)</td><td>128</td></tr>
</table>
Technology specific expenditure.
</td></tr>
</table>

3.4 Scottish and Southern Energy

Table 30. Low Energy Automated Networks proforma

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.
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	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:

Project Title	**Low Energy Automated Networks**
	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	• 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 31. Solent Achieving Value from Efficiency proforma

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;

Project Title	**Solent Achieving Value from Efficiency (SAVE)**
	• 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	• 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; • 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	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

Project Title	Solent Achieving Value from Efficiency (SAVE)
	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 32: My Electric Avenue proforma

Project Title	I^2EV (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	• Innovation 1: Commercial: ○ 3rd party delivery of an innovation project • Innovation 2: Technical: ○ Decarbonising the transport sector; and ○ 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	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
Outputs/ Implementation	• 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; • ‘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 33: New Thames Valley Vision proforma.

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 Objectives	• Applying proven data analysis from the Energy Demand Research Project (EDRP) to understand the different customer types connected to the distribution network, and their effect on network demand;
	• Understanding how the behaviour of different customer types allows informed network investment decisions to be made;
	• Demonstrating 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.

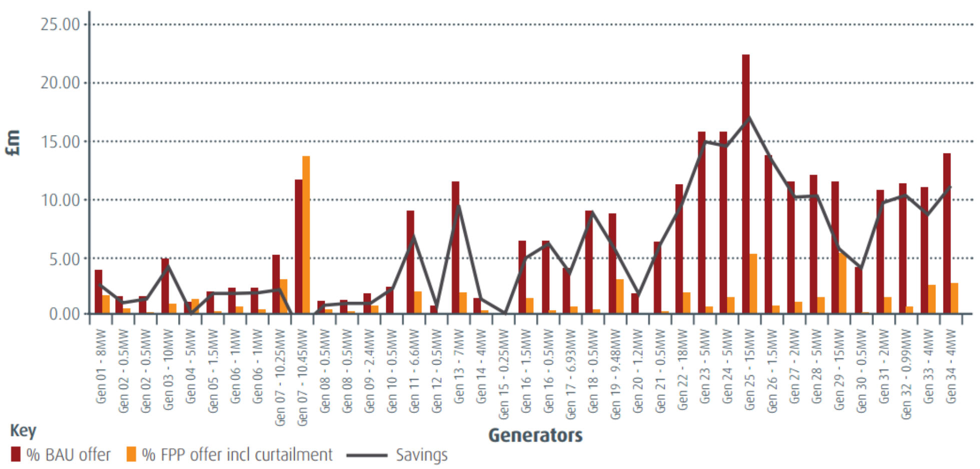
Key tech/process trialled	The project will demonstrate that common mathematical and statistical techniques used in other areas, such as consumer retail, can be applied to electricity consumers and fed into network planning processes. Such analysis will help to: • Target investment and the strategic placement 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	SSE are confident that NTVV will provide a range of benefits for DNOs as energy is decarbonised. 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

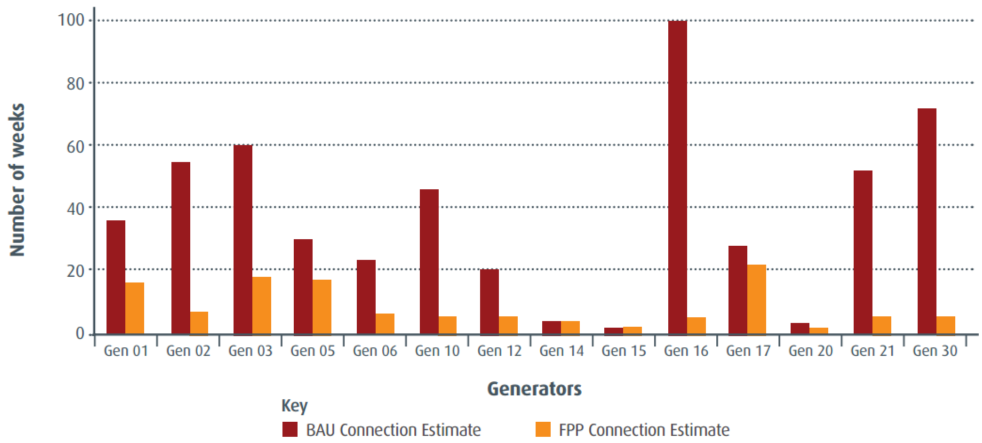
Project Title	New Thames Valley Vision (NTVV)
	• Scottish Hydro Electric Distribution Ltd - £143m (based on the difference between £302m of novel deployment costs to £440m of conventional reinforcement). Further to this SSE anticipates that NTVV will yield more immediate benefits including: • Accelerated 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; • 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	The Learning Objectives (LO) are as follows: **LO-1**: An understanding of what SSEPD needs to know about customer behaviour in order to optimise network investment. **LO-2**: Anticipation of how SSEPD can improve modelling to enhance network operational, planning and investment management systems. **LO-3**: Understanding to what extent modelling can reduce the need for monitoring and enhance the information provided by monitoring. **LO-4**: Understanding of how might a DNO implement technologies to support the transition to a Low Carbon Economy? **LO-5**: Understanding which commercial models attract which customers and how will they be delivered?

3.5 UK Power Networks

Table 34: Flexible Plug and Play proforma.

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 Title	**Flexible Plug and Play (FPP)**
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. 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	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. Note: The curtailment report includes 10% error factor margin (this is the same as the safety margin detailed in SDRC 9.6).  *The total cost of a flexible and BaU connection offer.* 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

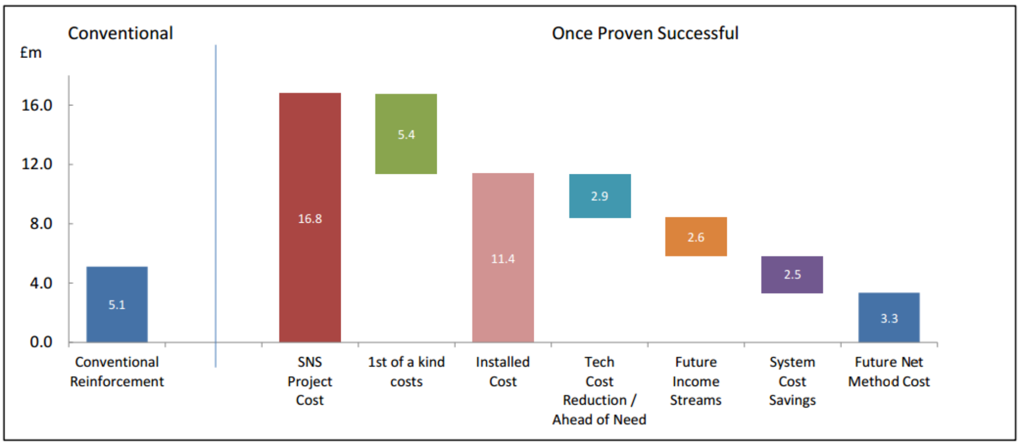
<table>
<tr><th>Project Title</th><th>Flexible Plug and Play (FPP)</th></tr>
<tr><td></td><td>
of ~65% or £5.4m per project. This further reinforces that flexible connections do not only provide a short-term benefit, but even after 20 years of curtailment they provide a long-term viable alternative.
The average connection time saving is approximately 29 weeks.


Time to connect a generation customer, comparing BaU with FPP offers.
</td></tr>
<tr><td>Timescales</td><td>January 2012 - December 2014</td></tr>
<tr><td>Current status</td><td>Completed</td></tr>
<tr><td>Outputs/
Implementation</td><td>
Strategic Investment Model - novel desktop network planning tool which was designed, developed and validated using realistic scenarios and data from trials. The SIM was used to analyse the benefits of smart technologies and smart commercial arrangements. Its applications in optimising smart grid technology investment options and analysing the costs and benefits of alternative distribution network planning strategic decisions.
Integrate Flexible Plug and Play connection offers (as per UKPN’s Low Carbon Network Fund Project) into BaU by Q2 2015.
</td></tr>
</table>

Table 35: Smarter Network Storage proforma.

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;

<table>
<tr><th>Project Title</th><th>Smarter Network Storage (SNS)</th></tr>
<tr><td></td><td>• 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.</td></tr>
<tr><td>Project Objectives</td><td>• 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.</td></tr>
<tr><td>Key tech/process trialled</td><td>• 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.</td></tr>
<tr><td>Project Business Case</td><td>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.</td></tr>
<tr><td>Timescales</td><td>January 2013 – December 2016</td></tr>
<tr><td>Current status</td><td>Underway</td></tr>
<tr><td>Outputs/ Implementation</td><td>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:</td></tr>
</table>

Project Title	**Smarter Network Storage (SNS)**
	• 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 36: Low Carbon London proforma

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.

<table>
<tr><th>Project Title</th><th>Low Carbon London (LCL)</th></tr>
<tr><td>Key tech/process trialled</td><td>• 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.</td></tr>
<tr><td>Project Business Case</td><td>Benefits of “Smart”
<table>
<tr><th>Benefit/Cost</th><th>Value (£)</th></tr>
<tr><td>Direct benefits</td><td>£1.5m</td></tr>
<tr><td>DNO benefits (residential & commercial DSR)</td><td>£0.12 bn</td></tr>
<tr><td>DNO benefits</td><td>£0.9-1.9 bn</td></tr>
<tr><td>System carbon benefits</td><td>£8.6 bn</td></tr>
<tr><td>Gross benefits</td><td>£8.6 bn</td></tr>
<tr><td>Costs</td><td>£2.3 bn</td></tr>
<tr><td>Net benefit</td><td>£7.3-8.3 bn</td></tr>
</table>
Project learning directly informed £43.5m in UKPNs ED1 savings, meaning it pays for itself 2.5 times within the ED1 period.</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</td><td>• 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.</td></tr>
</table>

Table 37: Flexible Urban Networks proforma.

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 Title	**Flexible Urban Networks (FUN-LV)**
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 Cost Benefit Analysis of using PEDs against traditional network reinforcement methods.
Project Business Case	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. 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	• Enhanced Network Assets (LV automation and soft open points); • Communications, System Integration and Data Management; • Network Awareness and Process Improvements; • Cost Benefit Analysis; and • Learning dissemination.

Table 38: KASM proforma

Project Title	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 Business Case	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

Project Title	**KASM**
Current status	Underway
Outputs/ Implementation	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 39: VCEE proforma.

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 Title	**VCEE - Vulnerable Customers and Energy Efficiency**
Project Business Case	£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	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.

3.6 Western Power Distribution

Table 40: Network Equilibrium proforma

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	• Ensure network stability; and • Smart grids.

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; and • Flexible power link
Project Business Case	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	The expected benefits are: • The Carbon Benefit (expressed in terms of DG capacity released), which results from each method, the project, and for GB as a whole; • 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) within distribution and transmission networks will result in benefits to the GB Environment, such as in Areas of Outstanding Natural Beauty; • The avoidance of upstream network reinforcement in the transmission system is a quantifiable benefit for National Grid and other transmission system operators (TSOs); • GB DNOs will benefit from the amendment and/or creation of new standards for voltage control and power flow management within electricity networks;

Project Title	Network Equilibrium
	• WPD will create design specifications, procurement specifications and other policy documents which will be of direct benefit to other GB DNOs; • Existing DG customers will benefit from reduced downtime, due to electricity network outages; • 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.

Table 41: Flexible Approaches for Low Carbon Optimised Networks.

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	The objectives of FALCON were closely aligned with those of the UK Low Carbon Transition Plan and ED1. In addition to enabling the uptake of low carbon technologies, FALCON sought to determine the viability of delivering faster and cheaper 11kV connections and reduced DUoS charge increases for all. It also sought to generate learning applicable to all DNOs, shared through established LCNF dissemination channels.

Project Title	**Flexible Approaches for Low Carbon Optimised Networks (FALCON)**
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. 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	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 CO2e by 2050 (accounting for an additional £36m of benefits).
Timescales	November 2011 – November 2015
Current status	Complete
Outputs/ Implementation	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.

Project Title	**Flexible Approaches for Low Carbon Optimised Networks (FALCON)**
	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 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

Table 42: Low Carbon Hub.

Company:	**WPD**
Project Title:	Low Carbon Hub (LCH)
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.

Company:	**WPD**
Project Objectives	• Host a workshop with generation developers interested in connecting to the LCH; • 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 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.

Company:	**WPD**
	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. **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	• As of February 2015 34 Alternative Connections (a new commercial agreement) offers had been made in East Lincolnshire and have facilitated an additional 48.75MVA of additional generation connections; • ANM settings derived from Trim, Trip, Sequential Trip and Global Trip limits to constrain and release generation within the ANM scheme (operational since April 2014); • 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. Both the ring network and the DVC method has shown how additional CTs can be incorporated into existing networks (Alford, Chapel St Leonards and Ingoldmells), how additional VTs are best incorporated into AIS sites (Alford & Ingoldmells), how additional VTs are best incorporated into GIS sites (Trusthorpe) and how additional VTs are best incorporated into hybrid AIS/GIS sites (Chapel St Leonards); • The Network Enhancements (reconductoring a circuit with a larger conductor) have increased the summer capacity of the circuits from 16MVA to 41MVA and it

Company:	WPD

	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 TRL has been estimated to be TRL 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. The project has also shown that where the fixed asset ratings are not the limiting factor and sheltering is not an issue, wind farm data could be used in conjunction with weather stations and/or Met Office data to make the use of dynamic line ratings technique more flexible, reliable and mitigate any potential failure of weather stations. The existing limitation for additional generation connections across the East Lincolnshire network was due to voltage rise, meaning the circuits did not operate beyond the static ratings and into the enhanced ratings during the project;
	• Dynamic Voltage Control has shown there are substantial opportunities to optimise target voltage settings by using an algorithm to review the voltage profiles and power flows across the network. The technique has the highest value in locations where there is a significant difference between maximum and minimum demands, there are different demand profiles across the network, or when the feeders are of a similar length or have similar voltage profiles but large levels of intermittent generation are connected. 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; VVT is suitable for steady state measurement but not for protection purposes. 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 (This latter price includes the purchase and installation of the 33kV VT, structure, plinth and multicores back to the RTU);
	• Development of a UK technical recommendations for:
	  ○ Installing optical fibre on existing wood pole OHL;
	  ○ Installing optical fibre on new wood pole OHL;
	  ○ Installing microwave or radio links for networks;
	• 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; and
	• Development of a stronger relationship with distributed generators.

Table 43: 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

Project Title	**LV Network Templates**
	performance of the LV network against the European power quality standard EN50160. Therefore, we do not have a clear 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	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 44: 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:

Project Title	**Flexible Approaches for Low Carbon Optimised Networks (FALCON)**
	• 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. 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.

Project Title	Flexible Approaches for Low Carbon Optimised Networks (FALCON)
	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	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	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 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

Project Title	**Flexible Approaches for Low Carbon Optimised Networks (FALCON)**
	across reinforcement projects, is then applied to give national costs of infrastructure investment under smart grid trials

Table 45: 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 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, 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
Project Driver	Reduce need for network reinforcement Facilitate connection of low carbon devices at reduced cost
Key tech/process trialled	Home energy storage with demand response New variable tariffs DC networks
Project Business Case	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	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

Project Title	SoLa Bristol
	£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.

4. LCNF Tier 1 Project Proformas

Table 46: T1 ENWL Smart Fuse

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	Completed December 2014
Outputs/ Implementation	• 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 47: T1 SPEN Temperature Monitoring

<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</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>Completed March 2015</td></tr>
<tr><td>Outputs/ Implementation</td><td>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.

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.

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:
• Data analysis of a 12-month period;
• Requirements for integration of DTS and DCR systems into an ANM system architecture; and</td></tr>
</table>

Project Title	Temperature Monitoring Wind Farm Cable Circuits
	• Policy documents and technical specifications for future DTS and DCR systems for BaU application.

Table 48: T1 SPEN Implementation of RTTR

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	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	Completed June 2013
Outputs/ Implementation	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;

Project Title	Implementation of Real-Time Thermal Ratings
	• 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 49: T1 UKPN Distribution Network Visibility

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)
Timescales	Completed December 2015

<table>
<tr><th>Project Title</th><th>Distribution Network Visibility</th></tr>
<tr><td>Outputs/
Implementation</td><td>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.</td></tr>
</table>

Table 50: T1 UKPN PV Connection Assessment Tool

Project Title	Validation of PV Connection Assessment Tool
Company	UKPN
Project Funding	£367,000 – LCNF Tier 1
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	Completed November 2014
Outputs/ Implementation	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.

Project Title	Validation of PV Connection Assessment Tool
	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 51: T1 WPD Smart Hooky

Project Title	Smart Hooky
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.

Project Title	Smart Hooky
	• 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	Completed October 2013
Outputs/ Implementation	• Substation monitoring has been installed in 11 substations with 46 load monitoring nodes installed in customer premises. • 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 52: T1 WPD Suburban PV Impact

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. • Through this project, CN will explore the following aspects: • 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

Project Title	**Suburban PV Impact**
	• 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	Completed November 2013
Outputs/ Implementation	• 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. • 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.

5. Other Innovation Projects

The Electricity Network Innovation Competition (NIC) is an annual opportunity for electricity network companies to compete for funding from Ofgem for the development and demonstration of new technologies, operating and commercial arrangements. During 2015, Ofgem received seven submissions for the 2015 Electricity NIC, seeking a total of £68.4m in funding. Ofgem selected five projects for funding, totalling £ 44.9m [3]. These projects were:

ANGLE DC (Scottish Power Manweb Plc) **–** aims to demonstrate a novel network reinforcement technique by converting an existing 33kV AC circuit to DC operation.

Future Intelligent Transmission Network Substation (FITNESS) (Scottish Power Transmission) – aims to deliver the pilot GB live multi-vendor digital substation instrumentation system to protect, monitor and control the transmission network using digital communication over fibre to replace copper hardwiring, reducing cost, risk and environmental impact, and increasing flexibility, controllability and availability.

New Suite of Transmission Structures (NeSTS) (Scottish Hydro Electric Transmission) - aims to create a new breed of overhead line supports that are smaller, better for the environment and could save up to £174 million for customers before 2050.

Offline Substation Environment for the Acceleration of Innovative Technologies (OSEAIT) (National Grid Electricity Transmission) **-** aims to modify an existing 400kV electricity substation into a field trial facility. This off-grid site will fully replicate a live substation environment to host electricity related innovation projects. This will be available for utilities to fast track the implementation of innovative new ideas on the electricity network.

Celsius (ENWL) **–** aims to be an innovative, cost-effective approach to managing potentially excessive temperatures at distribution substations, which may constrain the connection of low carbon technologies. By delivering new solutions to manage these 'thermal pinch points', Celsius could release additional capacity from existing assets, reducing long-term costs for customers and avoiding early asset replacement. This project is described in more detail in Table 53 with the expected BaU deployment savings to 2050.

Table 53. Project Celsius proforma.

Project Title	**CELSIUS**
Company:	Electricity North West Limited
Project Funding:	£5.554m - NIC
Project Driver	The predicted increase in demand resulting from the adoption of Low Carbon Technologies (LCTs) means ENWL need to review the way their assets are managed to ensure any costs incurred are efficient. Greater network currents, due to increased LCT loads cause more heat to be generated in network assets. To ensure that networks are operated safely, electricity assets have an assigned capacity rating to indicate the maximum amount of energy they can carry. If the substation load exceeds this rating often, assets are replaced with new, higher capacity equipment. This can be expensive and disruptive to customers.
Project Objectives	Celsius will reduce the overall costs of accommodating increased load on the distribution network. Moving forward into business as usual, Celsius will maximise the value of the smart meter programme by using smart meter data, aggregated at substation level, to indicate where to deploy the Celsius Method.
Key tech/process trialled	Maximising the use of existing assets is central to Electricity North West's innovation strategy, an approach which Celsius continues. Celsius will increase understanding of the thermal behaviour of distribution substations. With greater knowledge of the behaviour of these assets, network operators can support the connection of increasing numbers of LCTs more quickly and at lower cost. Develop and demonstrate a two-step intervention approach. Firstly, using load monitoring and improved technology to measure temperatures, Celsius will gather data across a range of environmental, load and seasonal factors on 520 distribution substations, selected to be representative of 80% of the GB substation population. The data gathered will be analysed to:

Project Title	CELSIUS
	• Explore the relationship between asset temperature, load characteristics and the surrounding environment; • Establish a set of reliable, thermal coefficients between the measured external temperature and the internal asset hotspot temperature; and • Reveal latent capacity which can be released quickly with no further intervention. The second intervention will release additional capacity through a range of retrofit cooling techniques. Celsius will explore a range of techniques to increase capacity and demonstrate the benefits of each. The techniques will be applied on 100 of the monitored distribution substations. This will result in a 'buy order' of cooling interventions for network operators to choose from.
Project Business Case	The project savings will be available to all customers across GB. ENWL's business case indicates this saving to be around £583m by 2050. The method will also enable DNOs to respond much more quickly to potential constraints arising from the connection of clusters of LCTs, releasing 13,162 MW of capacity.
Timescales	Jan 2016 - April 2020
Current status	Not started
Outputs/ Implementation /Impact	Celsius will enable network operators to release capacity at a fraction of the cost of traditional reinforcement, reducing costs for increased load for GB customers by around £0.6 billion by 2050 and releasing 13GW of capacity. The main expected outputs for the project are: • Reports detailing the enhanced understanding of asset temperature and its relationship with load and environmental factors; and • Recommendations and tools for the implementation of Celsius to business as usual. These are expected to include: • A functional specification for a reliable, low cost monitoring sensor pack for distribution substation assets, including cables and transformers; • A Thermal Ratings Tool that will calculate the capacity of an asset based on measured external temperature values. This will allow a network operator to better understand the operating temperature of assets and when to deploy an intervention; • A range of retrofit cooling solutions to apply when the Thermal Rating Tool indicates an intervention is required; • Studies to prove that the retrofit cooling techniques are acceptable to customers; and • Proposed changes to ER P15 'Transformer Loading Guide' and ER P17 'Current Rating Guide for Distribution Cables'.

6. Applicability to NIE Networks

NIE Networks has recently commissioned EA Technology to develop a Northern Ireland specific version of the Transform Model. This work has enabled NIE Networks to gain a deeper understanding of the likely challenges posed by the integration of low carbon technologies, and how these challenges can be mitigated.

As part of the outputs from the Transform Model, there is a list of solutions that are recommended to be deployed to most efficiently integrate the low carbon technologies at low cost, while retaining network integrity. These solutions are selected to resolve the constraints experienced by the distribution network in Northern Ireland and, as such, are thought to be directly relevant to the types of feeders that are prevalent within it.

It is therefore informative to examine the outputs from the Transform Model to see which of the 'smart' solutions are selected most often as this provides a useful indication of which approaches are likely to yield the greatest benefit, and therefore can be regarded as having the greatest merit in being explored further through part of a targeted and coordinated innovation strategy.

The innovative solutions that are selected most often by the model (as of May 2016) are as follows:

- Permanent meshing of urban networks at LV;
- Real time thermal rating for overhead lines at HV;
- Active network management at HV;
- Temporary meshing (use of soft open points) at HV;
- Generator providing network support (e.g. by operating in PV mode) at HV;
- Permanent meshing of networks at EHV;
- Active network management at EHV;
- Permanent meshing of suburban networks at LV; and
- Generator providing network support (e.g. by operating in PV mode) at HV.

It is clear from the above list that the voltage level most frequently targeted for the deployment of innovative solutions is HV (11kV and 6.6kV). The outputs of the Transform Model analysis indicated that HV was the voltage level requiring the greatest level of investment as the adoption of low carbon technologies increases. It therefore seems sensible to focus any targeted innovation projects at this area. It is also noteworthy that the solutions that are selected over the shorter timeframe (i.e. in the latter part of the next regulatory period) are the real time theremal rating and active network management solutions. Therefore, it would seem logical that these should be some of the focus areas for innovation activity.

It is also worth noting that in order to deploy these solutions, a number of 'enabling technologies' will be required. These are devices that do not contribute to releasing network capacity or resolving constraints themselves, but are vital pieces of the overall system to allow the smart solutions to work effectively. Therefore any targeted innovation approach and later transition to business as usual for the solutions outlined above will also require the capability to fully deploy, integrate and manage additional devices on the network. The enabling technologies that are deployed to allow the above solutions to operate effectively are as follows:

- HV circuit monitoring;
- EHV circuit monitoring;
- Dynamic network protection at HV;
- Advanced control systems at HV;
- Ring Main Units fitted with actuators;
- Last mile communications to/from devices;
- Weather monitoring;
- Advanced control systems at EHV;
- LV circuit monitoring; and
- Advanced control systems at LV.

Depending on which of the above solutions are selected for deployment in targeted pilots and latterly business as usual, a number of these enabling technologies are also required. For example, if using real time thermal ratings, then some monitoring of the asset loading will be required, as will ambient temperature monitoring. Therefore any innovation program needs to incorporate all of these elements to ensure its success. Similarly, more actively managing networks and running them in different operating configurations (such as would be brought about through the use of soft open points) will require the network protection to be able to cope with these different conditions.

In some cases it is the deployment of these enabling technologies that can pose as great a challenge as the deployment of the solution. For example, an active network management system is effectively an algorithmic solution, but for it to work effectively the assets must be able to respond as required. Therefore it is in the installation of the devices with remote control functionality and the upgrading of protection systems etc. that is where the greatest expense (and arguably the greatest difficulty) lies in the deployment of this solution.

7. Recommendations for NIE Networks

Table 54 summarises the key innovation areas that are recommended for further exploration by NIE Networks, indicating the key business areas where they are likely to have the greatest positive impact. Further detail is then provided in the commentary below for each of these innovation areas.

Table 54 Summary of recommended innovation areas mapped to thematic business outputs

	Real Time Thermal Ratings	Active Network Management	Demand Side Response	Voltage Management	Network interruptions
Network reliability	✔	✔	✔		✔
Safety				✔	✔
Environment	✔	✔	✔		
Customer Service			✔		✔
Connections	✔	✔	✔	✔	

7.1 Real Time Thermal Ratings

RTTR, also known as Dynamic Thermal Ratings (DTR), when applied to HV overhead lines was the top ranked solution selected by the Transform Model for the Northern Ireland network. It has been trialled successfully in a number of innovation projects by several DNOs (NPG, WPD, and SPEN). For HV overhead lines NPG's assessment puts the technology at a readiness level of 9 and an implementation readiness level of 9 also, with the only caveat being around ESQCR guidelines. (Further clarity required on the assessment of 'sufficiency' and 'maximum likely temperature of an overhead line' which are probabilistic rather than deterministic.) This suggests that there are no substantial immediate barriers to the adoption of the technology into business as usual.

There is a synergy between the use of RTTR and enabling increased capacity of some distributed renewable generation. In higher winds, when more power is generated by wind farms, the overhead lines can carry more power because of additional cooling. NPG's CLNR project found additional unused capacity of up to 74%. SPEN's Tier 1 projects found an average uplift ranging from 1.24 to 1.55 times the static summer rating with potential average additional annual energy yield ranging from 10% to 44% protection equipment ratings were taken into account and, for business acceptance, safety margins were introduced and estimates on the side of caution. Data analysis of the loading of wind farm circuits indicates that sizing can be based on dynamic rather than continuous ratings.

CLNR which was completed at the end of 2014 found the following costs.

Table 55: CLNR costs for RTTR.

Equipment	BaU cost per unit (£)
Primary substation transformer (Remote Distribution Controller, RDC)	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

Conclusions from the various innovation projects carried out in this area suggest that there is great merit in the use of RTTR on overhead lines at HV and EHV. The case for its use on underground cables is less compelling and this, coupled with the higher costs of installation for underground circuits, and the fact that there are far fewer underground than overhead circuits in Northern Ireland, leads to the conclusion that it is probably not in NIE Networks' interest to pursue RTTR for cables at this time.

The use of RTTR for secondary transformers has been shown to provide some benefit, but the costs associated with this, against the costs of new secondary transformers, make this a more difficult case to justify at present. The case for RTTR is more compelling at the primary substation level. Four LCNF projects have trialled RTTR in primary substations, with cost results broadly in-line with one another. Deployment costs range from £15 – £30 k per unit, with estimated savings of between £0.3m - £6.2m per deployment. The savings will be realised through reinforcement and replacement deferment (up to eight years). UKPN have estimated that they could save £18.3m for a £3.3m expenditure across all their license areas during RIIO-ED1.

It is therefore concluded that there is significant merit in further investigating the use of RTTR on overhead lines at HV and EHV and primary substations to release capacity for both additional generation and demand customers and the technology is considered sufficiently mature to allow for targeted pilot installations transitioning very quickly to business as usual.

7.2 Demand Side Response

Various types of demand side response (DSR) have been trialled by a number of DNOs and benefits have generally been observed to the extent that some DNOs are now making it business as usual as an alternative to network reinforcement. DSR has been envisaged as a solution to deferment of reinforcement spend on 'peaky' networks, where DSR ToU tariffs/DSR payments are more economical than reinforcement and mitigate network capacity shortfalls. Network capacity shortfalls can be caused by load growth or under N-1 conditions. DSR effects on capacity shortfalls under N-1 conditions was assed as part of the UKPN LCL project.

Generally, it has been found that the easier forms of DSR to set up and be able to rely upon are those that are linked to larger industrial and commercial (I&C) customers. At present, engaging with domestic customers, either individually or through the use of aggregators, is not at the stage where it forms business as usual. In the LCL project, the domestic load profiles of participants were influenced by placing them on a ToU tariffs.

The engagement with large customers has often taken the form of asking them to reduce demand at certain times of day by running more of their available on-site generation (thereby not affecting the productivity of their business). This was achieved by sending a DSR request via a comms link connected to the NMS. Confirmation was then returned via the same comms channel, informing the DNO that the DSR measure for a particular site, had been implemented.

For commercial DSR to work as a solution, the amount that is paid to the customer must be greater than the cost to them of operating the generation and any associated management costs with setting up the processes to facilitate signals and responses to the call for DSR.

UKPN have made DSR a cornerstone of their strategy for RIIO-ED1 and are anticipating making a saving of £43m through being able to defer reinforcement at large substations.

DSR has not been selected as one of the most prevalent solutions by the Transform Model, indicating that it is difficult to justify across the network. However, there may well be certain individual network areas where there is considerable industrial and/or commercial load that might be amenable to DSR and NIE Networks should consider it as an alternative to reinforcement in these bespoke cases.

7.3 Voltage Management

It has been found that a significant amount of the Northern Ireland distribution network is constrained not by thermal issues, but by those of voltage. This is especially true for more rural networks.

A number of voltage management solutions have been trialled and are at a stage where they are sufficiently mature for a business as usual implementation. The results from the Transform Model indicate two solutions that are prominently selected to resolve voltage issues at HV: switched capacitors and the use of generators to provide network support.

Switched capacitors were trialled within the CLNR project and represent a fairly mature technology. The use of generators to provide network support, by operating in different modes for example, is an area that has not been fully explored to date. Clearly, the availability of such a solution is dependent upon the location of the generators in the network. In theory, if generators are present, it should become easier to implement these solutions in the future with the advent of new European codes for the operation of generators (such as the Requirements for Generators (RfG) which has been initiated by European Network of Transmission System Operators for Electricity (ENTSO-E).

However, it may well be beneficial for NIE Networks to consider some of the other voltage management techniques that have been trialled. For example, WPD conducted a Tier 1 project that showed Distribution Static VAr Compensators (D-SVC) could help control the voltage on an 11kV rural network by marginally reducing the line voltage by 50 V and significantly helping to smooth the voltage profile on an 11kV rural network, close to the generator site, by marginally reducing the absolute voltage and significantly helping to smooth the voltage profile.

SSEPD have also conducted several trials involving STATCOMS and found that the initial cost per deployment was £500,000, but that is expected to fall to £150,000 for BaU implementation and to bring an associated benefit of £2,000,000. This benefit is based on the high cost of network reinforcement for various islands, (Orkney, Wight and Western Isles) where the STATCOM could be deployed to resolve the network constraint. However the findings also suggest that the payback period is likely to be short in other geographic areas of deployment too (potentially particularly for rural networks). At LV, on the other hand, the cost-benefit figures for such voltage regulation techniques are not as promising.

ENWL looked to change the voltage at their primary substations to release capacity and hence defer reinforcement (i.e. using voltage management to resolve thermal constraints). When the CLASS method is applied across all primary substations in the project, ENWL could gain up to 12.8 MVA 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. 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 250MW of network capacity, and defer the reinforcement of 28 primary substations with an associated cost of £15.9m for up to three years. The CLASS project primary substation screening criteria did not distinguish urban from rural networks. The screening process intentionally excluded primary substations with DG over a capacity of 50% of maximum demand at the primary. Predominantly rural networks with high levels of DG, but lower than 50%, may have been trialled under the CLASS method, but finding these primary substations and the associated results presents a body of work beyond the scope of this document.

Clearly in the case of NIE Networks, where the voltage is at the lower end of the allowable range for significant portions of the network, this approach could only be adopted in areas where the network is strong and voltage drop is not an issue (such as central Belfast).

It is therefore recommended that NIE Networks seek to adopt some of the approaches described above concerning voltage management at HV.

7.4 Active Network Management

There have been numerous projects exploring different means of active network management. One application of this approach is to better facilitate the connection of distributed generation through the provision of managed connections. This has been trialled extensively by WPD, UKPN and SPEN through projects such as Accelerating Renewable Connections and Flexible Plug and Play. Indeed, it is now fully integrated into BaU within some DNOs. This approach enables generation to be connected in a timelier manner and also at lower cost, mitigating the need for extensive reinforcement.

A further example of the successful deployment of active network management has been completed by SSEPD in numerous island settings (which could be analogous to the more rural settings to be found in Northern Ireland) such as Orkney, Wight and the Western Isles.

The cost to bring to BaU is £1m and the potential saving or deferment per deployment is expected to be £2m as compared to traditional reinforcement. The cost per deployment is £355,000 for generator constraint management and £122,000 for community demand management.

The outputs from the Transform Model suggest that there is particular merit in adopting an active network management approach at a range of voltage levels. The use of soft open points and the temporary meshing of circuits at HV has been trialled by ENWL in the C_2C project and this is proving beneficial. There are some up-front costs in equipping the 11kV ring main units with the ability to be switched remotely and also in adapting the protection devices on these networks, but the cost savings in deferred reinforcement can then be substantial.

There is also potential benefit to meshing cicuits at LV and it is therefore recommended that a watching brief on the outcomes of UKPN's FUN-LV project should be kept to look for any useful learning in this area.

In general, it is likely that temporary meshing and actively managing the network will bring greater benefit than permanent meshing of networks in Northern Ireland.

It is therefore recommended that NIE Networks considers the use of soft open points and temporary meshing of HV circuits to manage load; and also that it considers the use of active network management for connection of additional distributed generation in future.

7.5 Network Performance – Minimising Interruptions

The final area to be considered is that of network performance at LV and HV, i.e. the minimising of interruptions to customers and the duration of those interruptions.

At LV, several DNOs have been trialling and have now integrated to BaU the use of different reclosers or smart fuse devices. Such devices will trip when a fault occurs, but then attempt to reclose automatically. This allows rapid restoration of supplies in the event of a transient fault and has significant associated savings in the reduction of interruptions to customers.

It is EA Technology's understanding that at least three DNOs in Great Britain are now routinely using a range of these devices on their networks, meaning that they are at a suitable level of maturity for wide scale adoption. NIE Networks have already trialled some of these devices and may already have them as part of a BaU strategy.

At HV, several DNOs are now undertaking a program to perform partial discharge measurements on their cables. Partial discharge measurements have been in widespread use for switchgear for some time, but DNOs are now becoming aware of the potential to identify cable faults before they occur and thereby proactively (rather than retrospectively) change sections of cable and avoid the associated interruptions to customers and higher costs that are incurred when having to repair a faulted cable rather than a planned piece of work to change a piece of unfaulted cable.

It is therefore recommended that NIE Networks considers its strategy regarding the use of LV reclosers and investigates the merits of conducting partial discharge measurements on HV cables to avoid faults.

Global Footprint

We provide products, services and support for customers in 90 countries, through our offices in Australia, China, Europe, Singapore, UAE and USA, together with more than 40 distribution partners.

Our Expertise

We provide world-leading asset management solutions for power plant and networks.
Our customers include electricity generation, transmission and distribution companies, together with major power plant operators in the private and public sectors.

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- Make smarter investment decisions
- Build smarter grids
- Achieve the latest standards
- Develop their power skills

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