REPORT

Network Transformation Roadmap: Innovation Gap Analysis and Plan

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Safer, Stronger,
Smarter Networks

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Executive summary

Background to the Project

The Electricity Network Transformation Roadmap (NTR) project is being delivered through a partnership between the Energy Networks Association (ENA), the peak electricity network industry body, and Australia's national science agency CSIRO.

This work forms part of Work Package 6. In particular, the focus of this piece of work is on the innovation that has been carried out to date in Australia and internationally, looking at how this can help inform the grid of the future. From this, identification of the key gaps in research and development where further innovative activities should be prioritised to deliver best value.

Global Learning

Significant research, development and deployment is occurring on global power networks as new techniques and technologies are being investigated to manage changes in demand and generation in the most cost-effective manner. Numerous projects are in flight or near completion, providing a wealth of information that can be taken and applied in different markets – effectively short-cutting much of the development. Areas identified in this report as rich technological areas include the following:

- Demand / Generation Response
- Dynamic ratings
- Electrical energy storage
- Network management
- Voltage management
- Other areas for consideration including:
    - Fault Level Management
    - Network simulation and modelling
    - Energy efficiency
    - Smart meters and Time of Use tariffs

Details of which have been provided in this report and the accompanying appendices.

It is however noted that whilst the physics of the power system are consistent wherever an engineer may look, the business case and economics for deployment are often highly specific for each markets. Local factors such as customer use patterns, network topologies, communications infrastructures and Regulatory models can all have an impact on precisely which solution should be used in a given situation. Specific economic modelling must therefore be carried out alongside technical assessments in order to ensure the right solutions are used in the right circumstances.

Key Innovation Requirements

From work that has been conducted in parallel and engagement with appropriate stakeholders, a number of technical challenges that the grid will face in the future have been identified. These challenges are listed below:

- Management of voltage on local networks and excessive variation caused by swings between generation and demand

- Regulation of frequency at a system level and contending with a multitude of smaller generators that will operate in parallel and are at risk of islanding

- The need for distributed intelligence to facilitate decentralised control with greater volumes of technological deployments deeper into the network offering more visibility of network conditions and greater optionality for local control and decision making

- Constraint management at a local level will require the ability to flex the local grid to a larger degree than previously to alleviate power flow issues and reconfigure networks in real-time

- Optimising the use of the various types of demand side response to achieve the aims of system balancing and constraint management, while ensuring that demand side response initiated for retailer hedging does not have an adverse effect on system and network performance

A number of these issues have been considered through international projects and there are some areas where the learning can be applied to the Australian context.

Recommendations

The mapping exercise undertaken above has indicated some of the key priorities for innovation. Opportunities should be sought to explore these subjects and trial the various techniques in real-world environments. Where this is building on existing learning, any opportunities to trial the approaches as part of a holistic system should be maximised. For example, if there is a new area of network being constructed to serve a housing development, the opportunity could be taken to install, at marginal cost in comparison to retrofit, some of the technologies described here. This would allow greater learning to emerge around how the various techniques interact with each other and how they could be managed and controlled in the most efficient manner.

Key areas of priority to investigate for innovation projects are therefore:

- Voltage management on local networks

- Frequency control and replacements for RoCoF

- Use of decentralised control techniques through distributed intelligence

- Management of local constraints through active network management and dynamic asset rating

- Demand side response use cases, including arbitrage between them

Innovation in these areas will address some of the key challenges identified in other Network Transformation Roadmap activity and needs to be started in the immediate term such that the learning is ready to be encapsulated in business as usual in advance of the innovations being required on a day-to-day basis and to avoid the networks being overtaken by the pace of change.

This is particularly true for potential interactions with customer-side technologies (such as electric vehicles or storage units) where there may be significant benefits to be realised through standardising the way these devices can communicate with the network and/or other actors, but such benefits can only be realised if this is implemented before wide-scale take-up of the technologies occurs.

The identified areas also rely on some enabling technologies to allow them to function, which should be trialled as part of any innovative schemes to ensure they are holistic and take a systems engineering approach. This includes the use of more advanced, adaptive protection schemes and any associated communications requirements.

Contents

Appendices

1. Introduction

1.1 Background

The Electricity Network Transformation Roadmap (NTR) project is being delivered through a partnership between the Energy Networks Association (ENA), the peak electricity network industry body, and Australia's national science agency CSIRO. The project has been informed by the plausible 2050 scenarios defined by the Future Grid Forum, and is seeking to collaboratively develop an integrated program of actions and measures to guide Australia's electricity transition over the critical 2017–27 decade.

The Roadmap project recognises that modern electricity systems are a complex 'ecosystem' of technical, regulatory, economic and social sub-systems, all of which are experiencing varying degrees of change. The specific 'Work Packages' that develop new content within the Roadmap project broadly include the following within a strongly customer-oriented framework:

- Regulatory frameworks;
- Commercial networks and business models;
- Pricing and market structures;
- Customer-side technologies; and,
- Grid-side technologies.

This work forms part of Work Package 6 (the other components of which include work on grid design and operation and the need for standards development). In particular, the focus of this piece of work is on the innovation that has been carried out to date in Australia and internationally, looking at how this can help inform the grid of the future. From this, identification of the key gaps in research and development where further innovative activities should be prioritised to deliver best value.

1.2 Outline of Approach

This document has been structured in the following way:

Section 2 provides an overview of the available technology areas and considers the learning generated for each of these by a range of innovation Projects:

- Section 2.1 summarises the key technological areas for deliberation when considering the development of a Future Smart Grid. review of key innovation projects in the smart grid arena;
- Section 2.2 summarises the key findings from Australian Innovation Projects;
- Section 2.3, the UK's Low Carbon Networks (LCN) Fund; and
- Section 2.4 the Future Power System Architecture Project (FPSA) and section 2.5 some key European ones.

Section 3 identifies gaps between innovation undertaken to date within Australia, and hence the existing expertise, and where critical experience, understanding and technical capability should be gained as a priority. These 'gaps' were identified considering the total wealth of available experience undertaken to date, what has not yet been trialled in Australia and whether it is applicable to the Australian network; this is depicted in Figure 1.

Figure 1 Key innovation activity considerations

Finally, conclusions are presented in section 4.

2. Review of Learning

A brief overview of the broader technology areas is provided in 2.1 below, with a summary of the learning relating to each area identified to date from Australian Innovation projects including the Electricity NTR Phase 1, (section 2.2.6), and Ofgem's Low Carbon Networks (LCN) Fund projects, (section 2.2.1). The LCN Fund Projects are distinguished between Tier 1 (small scale) Projects and Tier 2 (larger, competitively funded) Projects.

2.1 Technology Areas

2.1.1 Demand / Generation Response

Innovation projects have deployed demand side response as a technical and commercial smart grid intervention to address distribution network constraints relating to limited network capacity and power quality issues (e.g. voltages outside of the statutory limits). Projects have trialled different demand side response techniques that enable the reduction of load by either:

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

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

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

Proven techniques for network redesign (e.g. temporary meshing by closing normal open points) have been applied in conjunction with new customer commercial arrangements to release this inherent capacity and maximise the utilisation of the installed network capability. Thus, to ensure that security of customer supply is maintained and that supplies can be restored during fault outages, new post-fault demand response contracts, allowing network operators to reduce the consumption of contracted customers on the relevant circuits, have been developed and trialled.

For new customers connecting to the network the new commercial arrangement offers the option to sign up to a managed contract in exchange for a reduced connection charge (i.e. equivalent of the saving of reinforcement costs). The contract allows the network operator to manage the customer's consumption at the time of a fault and hence enables the network operator to get all customers back online in as short a time as possible.

The application of new demand side response mechanisms to provide frequency management capability to the transmission system operator have been explored. The mechanisms were designed to reduce demand at primary substations via voltage control within very short timescales. Innovation activities have trialled the following demand side response mechanisms for frequency response:

- Primary transformer: the disconnection of one of a paired arrangement of transformers at primary substations will result in the voltage supplying the substation load to instantaneously reduce triggering a demand reduction. The disconnection of a primary transformer has been achieved by automatic on-site detection of a low frequency signal.

- Tap Changer Operation: Change of secondary network supply voltage at a primary substation by raising or lowering the tap positions of the power transformers and consequently changing the level of demand.

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

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

2.1.2 Dynamic ratings

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

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

Several of Great Britain's Low Carbon Network Fund Tier 1 and Tier 2 projects have trialled Real-Time Thermal Ratings (RTTR) of overhead lines, cables and transformers as a smart grid solution to defer network reinforcement and manage increasing levels of demand and/or generation.

Some innovation activities have developed methodologies and algorithms for the quantification of the dynamic rating values and subsequently implemented them in the RTTR system. The algorithms have been tested and quality assured against the real-time monitored temperature and loading data.

Significant data analyses were subsequently performed on the calculated and monitored data to determine the network capacity that could be unlocked by using the RTTR system.

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

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

2.1.3 Electrical energy storage

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

A number of innovation projects have explored the deployment of large scale (many MW) energy storage as an effective way of overcoming a wide range of constraints on distribution networks, thus avoiding the need for traditional reinforcement and increasing utilisation.

The projects have also recognised that deploying storage for a single network application is usually economically inefficient. Thus, the deployment of large scale energy storage on distribution networks as a system-wide source of flexibility by providing reserve and response support to the balancing and stability of the transmission system was also studied. Trialling innovative technical and commercial techniques provided the means for storage to be used to solve distribution network constraints, whilst ensuring the value of the flexibility is maximised for the benefit of the wider system and customers.

Specifically, the innovation activities undertaken within the projects focussed on:

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

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

- Peak shaving: reduction of the overall peak demand by providing additional energy to offset demand at peak times;
- Reactive power compensation: provision of reactive power from the power-conversion-system of the storage device to correct power factor, reduce losses and improve the real power capacity of the network circuits;

- Voltage support and stabilisation: through dynamic provision or absorption of energy, the voltage on the local network can be maintained within statutory limits more dynamically;

- Ancillary services: provision of reserve services such as a short-term operating reserve (STOR) market; provision of static frequency response to maintain system stability in the event of unplanned outages or changes in demand/generation; and provision of dynamic frequency response to support real time deviations in system frequency.

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

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

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

2.1.4 Network management

Innovation activities have led to the implementation of Active Network Management (ANM) solutions supporting the flexible management of network constraints through the monitoring and control of smart grid devices and distributed generators. The deployment of ANM has tested and proved the scope for integration and interoperability of various smart grid solutions and enabling technologies,[1] in real distribution networks, to address network operational challenges and improving redundancy and resilience. A range of network challenges and associated smart grid solutions and enablers trialled in projects with ANM applications are described below:

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

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

- Voltage constraints: distributed generation raises voltage levels on distribution networks. Modification to the operation of transformer tap changers during times of high generation

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

output and/or the management of generator active and/or reactive power enables the connection of higher levels of generation while maintaining network voltages within acceptable limits. Several projects have trialled different automatic voltage control schemes.

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

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

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

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

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

2.1.5 Voltage management

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

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

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

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

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

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

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

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

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

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

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

2.1.6 Other areas for consideration

The below technological and procedural areas require consideration as part of any scenario planning as they can benefit or hinder any technology or approach falling within the above categories although they are not drawn out as specific areas of innovative learning in the below report.

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

LCN Fund projects have developed and trialled advanced fault level management solutions that provide a range of innovative fault level mitigation techniques that can be adaptively controlled. These techniques avoid the need to prematurely replace capital intensive assets in the network (e.g. switchgear, transformers and cables), while also improving the utilisation of electricity network capacity. This facilitates the timely and cost-effective connection of customers' generation and demand and enhances security of supply. Exploration of the deployment of several complementary methods to address the fault level management problem is underway at present, but no learning is yet available.

- Enhanced fault level assessment: this method has investigated the existing fault level calculation techniques and the connection assessment methodologies used to quantify the impact of demand or generation connections to the electricity network. The connections assessment process considers the impact of new connections on voltage, power flows and fault level under worse-case network operating conditions. The method has provided refined analysis techniques to understand the areas of the network that are likely to exhibit fault level issues. A Fault Level Index has been created, similar to the equipment Load and Health Indices, to characterise substations and determine where to deploy fault level monitoring and mitigation equipment. The learning captured from these enhanced assessments provide customers with more accurate and refined network connection offers.
- Real-time management of fault level: this method has deployed new real-time fault level monitoring techniques to measure the prospective fault level on a periodic basis. Real-time fault level measurement devices have been placed in the distribution network, to gather fault level data for various network running configurations and conditions and to determine the fault level. Real-time fault level management provides increased visibility and confidence in network operating conditions that could allow the safety margin to be reduced without compromising the safety of the network operator employees and the public. This fault level headroom gain translates to allowable additional capacity for customers' connections.

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

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

There is other related activity currently planning the testing and trialling of near real-time fault level assessment and adaptive mitigation techniques to overcome the fault level challenges faced by network operators. The project is seeking to demonstrate that fault current can be managed at lower cost using existing assets and new commercial techniques. Planned activities include deploying innovative intelligent software, namely the Fault Level Assessment Tool, to continually assess the fault level in distribution networks. Where this is found to be higher than a pre-set threshold, the tool will issue commands to enable a fault level mitigation technique that will operate in the event of a fault to manage the fault current safely.

Three key techniques, designed to regulate fault level current in distribution networks, are currently being explored for real-world trial deployment: adaptive protection, fault current limiting service (i.e. commercial solution) and fault current limiting devices (known as IS-limiters). The new fault level mitigation techniques are only intended to operate in those rare occurrences when they are enabled and a fault occurs. Standard protection will operate for faults when the technique is disabled. This active response ability enables the extension of the useful life of protection equipment avoiding the need for costly reinforcement.

Network simulation and modelling

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

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

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

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

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

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

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

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

Customer field trials are currently being developed to establish the extent to which energy efficiency measures can be considered as a cost effective, predictable and sustainable tool for managing peak demand as an alternative to network reinforcement. In particular, it will evaluate the potential for network operators to investigate different types of energy efficiency opportunities that will incentivise customer behaviour change resulting in reduction of peak and overall demand on the electricity distribution network. Four energy efficiency interventions are being trialled to test their effectiveness in reducing and/or time-shifting electricity demand:

- LEDs: the provision of low energy LED light sources to reduce overall power consumption, especially at evening peaks;
- Enhanced engagement campaign: the provision of innovative information and media communications drawing on usage monitoring data (collected from the sample households during the baseline stage) and aimed at reducing overall consumption;

- DNO Time of Use (ToU) rebates: this intervention will combine the ‘enhanced engagement campaign’ above with network operator offered ToU incentives at different times of day to incentivise time-shifting of demand; and

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

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

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

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

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

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

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

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

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

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

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

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

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

2.2 Australian Innovation

A review of Australian electricity network innovation projects has been carried out to inform the innovation gap analysis. The review is non-exhaustive and focussed on information available in the public domain. The selected projects provide a representative view of the state of Australia's network innovation schemes and trials, a review of these projects is presented in Appendix I with a brief description in Table 1 below.

Table 1 Australian Innovation Projects Overview

Project	Company	Description
Virtual Power Station	CSIRO	A project to link dispersed renewable generation with energy storage and load control systems through web-based communications. Aiming to improve capacity, voltage and power quality constraints through levelling.
Eddy Home Energy App	CSIRO	A project to develop a tool to monitor and control domestic energy appliances in order to reduce overall and peak energy demand. Leading to a commercial product that is currently available.
Smart Grid: Smart City	Ausgrid	A study of the costs and benefits of smart grids, evaluating several technology types including voltage control, network monitoring and fault detection. Informing government investment decisions.

Project	Company	Description
Power Factor Correction (PFC) Pilot	Ergon Energy	A pilot study to reduce local peak demand on the network due to poor power factors of large connected customers. The pilot improves the power factor of these customers to improve efficiency and reduce demand.
Electric Vehicles: Driving EVolution	Ergon Energy	A trial to gain an understanding of EV customer driving and charging behaviour. Monitoring the behaviours of customers on various tariffs and analysing barriers to EV uptake.
Newington Grid Battery Storage Trial	Ausgrid	A trial to connect distribution level storage to mitigate local asset load at peak demand times. Also testing battery performance and monitoring power quality issues
Lower South East 275kV Line Uprating	Electranet	A transmission scale project to uprate a 275kV overhead line from 100˚C to 120˚C. A permanent uprating demonstrating acceptance of dynamic uprating.
Hot Water Load Control Trials	Ausgrid	A pilot scheme to explore the technical feasibility of controlling electric hot water systems <100 litres directly at the appliance. Also to determine optimum control schedules and monitor customer response to control.

The following sections present key learning points developed during these innovation projects, which are relevant to the areas identified in section 2.1, (Technology Areas).

2.2.1 Demand / generation side response

Key learning to date

- It has been shown that residential demand response can be commercialised for consumers who benefit from reduced energy bills; this style of solution also contributes to reducing demand at peak times.

- Network reinforcement works can be deferred or avoided in areas of network constraint by reducing peak load through demand/generation responses.

- Customers are receptive of having their loads controlled by a third party and are unlikely to override load control instances as long as they occur infrequently. Uptake of residential load control systems are higher if the schemes are incentivised.

- Residential demand control solution costs, including customer engagement and acquisition costs mean that the total cost of providing the solution is relatively high per kilowatt of demand reduction achieved.

- To improve the effectiveness of these responses they should be paired with network monitoring equipment and only deployed in appropriate areas.

Applicable projects

The projects undertaken within Australia that have generated learning relating to this area of innovation are listed below, and can be found in the referenced appendix.

Australian Innovation Project	Appendix
Virtual Power Station	Appendix 1
Eddy Home Energy App	Appendix 1
Electric Vehicles: Driving EVolution	Appendix 1
Hot Water Load Control Trials	Appendix 1

2.2.2 Dynamic ratings

Key learning to date

- Real time thermal rating of underground (UG) feeders showed significant potential to increase asset utilisation. Applicable projects. This presents the opportunity to avoid network augmentation/reinforcement by exceeding asset nominal rating.

- The costs of trialling dynamic rating technology is dominated by the cost of data transmission and the labour involved in installation and remediation works. The benefits of the technology are limited by the inflexibility of back-end systems and operational processes.

- Benefits can be improved if the system operator instigates a network-wide communication platform which can be shared by all ‘smart grid’ technologies and processes changed to take advantage of real-time ratings.

Applicable projects

The projects undertaken within Australia that have generated learning relating to this area of innovation are listed below, and can be found in the referenced appendix.

Australian Innovation Project	Appendix
Lower South East 275kV Line Uprating	Appendix 1
Smart Grid: Smart City	Appendix 1

2.2.3 Electrical energy storage

Key learning to date

- It is possible to use a grid-connected battery storage system to reduce the load on a network asset at peak demand times, ideally the storage should provide 4-6 hours of demand reduction. It is also critical to geographically locate the battery in an area that defers network need. [2]

- Containerised battery storage systems run as master controllers and are not easy to integrate into the various systems that exist across a DNOs network.

- Limited standards for residential batteries storage systems lead to significant variations in system quality and control systems. The majority of systems offer domestic solar shifting but only consider the batteries state of charge rather than a house or network-scale evaluation.

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[2] Ausgrid Demand Management, 2015, “Newington Grid Battery Trial Report”. Available: https://www.ausgrid.com.au/Common/Industry/Demand-management/Energy-use-research-and-reports/~/media/Files/Industry/Demand%20Management/Ausgrid_Newington_Grid_Battery_Report_Final.pdf

- Energy storage can be used to effectively mitigate power quality issues including reactive power inefficiencies and maintaining voltages within statutory limits. There is currently little public material describing EES being trialled for this purpose in Australia.

Applicable projects

The projects undertaken within Australia that have generated learning relating to this area of innovation are listed below, and can be found in the referenced appendix.

Australian Innovation Project	Appendix
Newington Grid Battery Storage Trial	Appendix 1
Smart Grid: Smart City	Appendix 1

This is an area of innovation which has been heavily studied both within Australia and internationally. Although only two projects are referenced in the above table, outputs from other Australian battery trials have been included in the key learning points, including:

- AusNet - Service Grid Energy Storage system trial
- Ergon Energy – Centralised Energy Storage System
- Citipower – Buninyong Battery
- ENA – The Great Energy Quest[3]

2.2.4 Network management

Key learning to date

- Smart grid technologies should be evaluated on an individual location/network area basis, as the type of deployed technology will vary depending on the network operation and constraints.

- Rooftop solar PV should be managed/controlled in areas of high penetration to avoid exceeding statutory voltage limits and in combination with storage for peak levelling.

- Fault detection and restoration technology offers a significant opportunity for network benefits and should be appropriately incentivised. This technology can immediately improve customer experiences and in some cases is more appropriate than LV network monitoring.

- High penetration of EVs on local electricity networks will require network intervention to avoid reinforcement works. This can be achieved through reducing the load from EVs at peak times, controlled and uncontrolled (T11 and T33) tariffs have been found to achieve this reduction.

Applicable projects

The project undertaken within Australia that have generated learning relating to this area of innovation are listed below, and can be found in the referenced appendix.

Australian Innovation Project	Appendix
Virtual Power Station	Appendix 1
Smart Grid: Smart City	Appendix 1
Power Factor Correction (PFC) Pilot	Appendix 1
Electric Vehicles: Driving EVolution	Appendix 1
Newington Battery Grid Trial	Appendix 1

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[3] ENA Australia, 2015, "The Great Energy Quest". Available: http://www.ena.asn.au/sites/default/files/ena_the_great_energy_quest_september_2015.pdf Accessed: Aug 2016

2.2.5 Voltage management

Key learning

- Power factor correction (PFC) technology has been shown to deliver demand savings that exceed forecast expectations[4]. PFC has been shown as an economically viable alternative to network reinforcement through savings from increased efficiency of power delivery.

- Managing Active Volt-Var Control (AVVC) has the potential to reduce peak demand by up to 5% and reduce energy consumption by 1-2%.[5]

- Making use of AVVC it would be possible to design feeders less conservatively as the system could control voltages within limits. There are currently issues regarding the technological readiness level of the systems and the ease of integration with existing networks.

- There are economic and environmental benefits to customers and network operators from delivering voltages within the correct range and from improving power factor.

Applicable projects

The project undertaken within the Australia that have generated learning relating to this area of innovation are listed below, and can be found in the referenced appendix.

Australian Innovation Project	Appendix
Virtual Power Station	Appendix 1
Smart Grid: Smart City	Appendix 1
Power Factor Correction (PFC) Pilot	Appendix 1

2.2.6 NTR Stage 1

As part of Australia’s continued commitment to electricity network innovation, the Energy Networks Association (ENA) has embarked on a program to develop a Network Transformation Roadmap (NTR) in collaboration with CSIRO and a broad stakeholder base. This roadmap will set out guidance for the perceived critical changes in the Australian energy system in the period leading to 2025. These changes describe the movement of the network from large central generators with passive customers, to one with large amounts of embedded generation and better suited to delivering the needs of future customers. The first stage of the NTR was completed in late 2015.

The major findings from the Stage 1 of the NTR are presented in the first three chapters;

1. Customers at the centre of Australia’s future grid

Customer focus is at the heart of the roadmap and it begins by exploring the customer needs that future electricity systems must serve, rather than technological or business considerations. The chapter analyses why customer orientation is critical for future energy enterprises in a context where business models continue to transform, competitive landscapes keep expanding and new coalitions of market actors are evolving. Key findings include:

- Australian customers continue to expand their electricity dependence due to an increasingly digitised world.
- The way customers consume electricity services is changing. They now have greater choice in how they access electricity, this is driving change in electricity systems operation.

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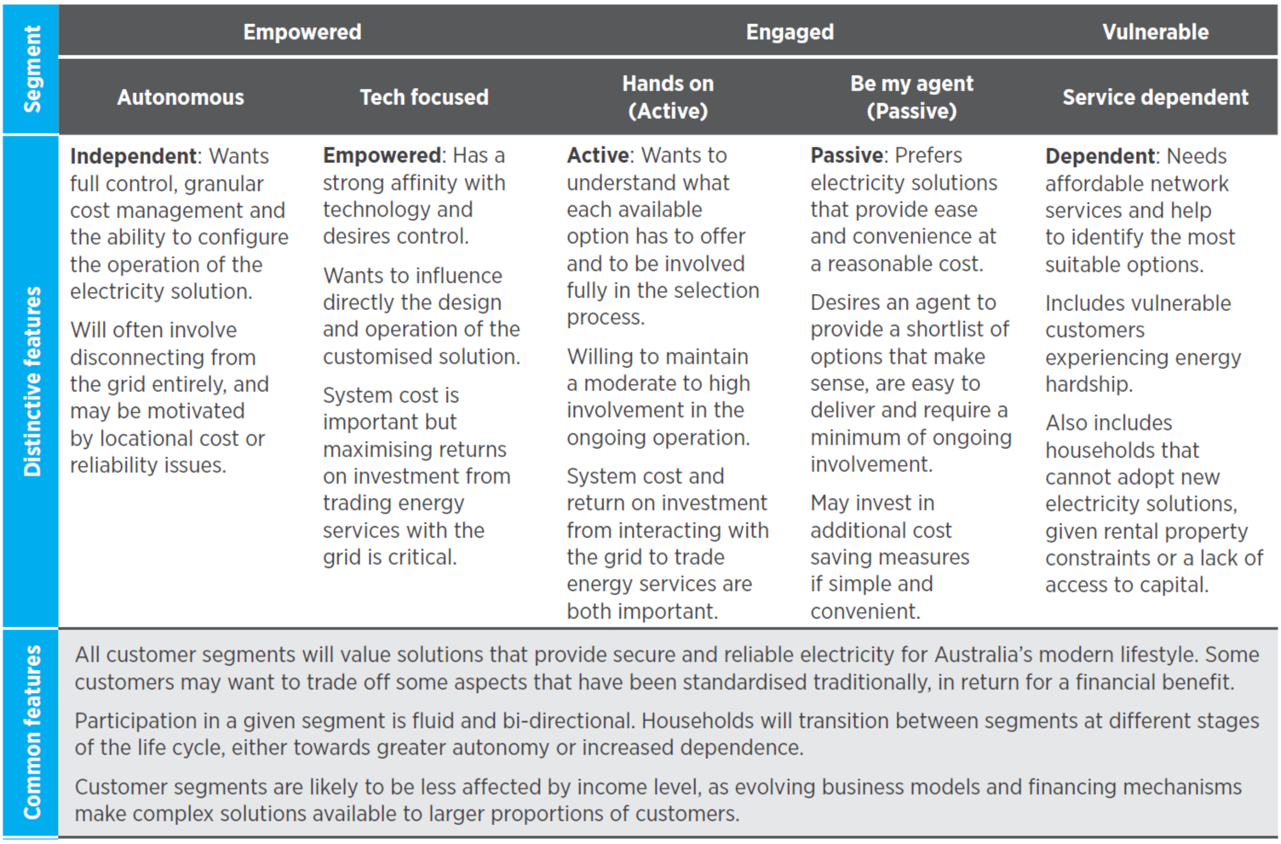
[4] Ergon Energy, 2015, “Power Factor Correction Pilot”. Appendix 1.

[5] Smart Grid Smart City, 2015, “Technical Case Studies; Active Volt Var Control (AVVC)”. Available: http://www.industry.gov.au/Energy/Programmes/SmartGridSmartCity/Documents/Active-Volt-Var-Control.pdf

- Possible future customer types and what they will value, have been developed, these are not considered ‘perfect’. These can help network operators and other market actors identify where change is needed most. These customer types are shown below.
- Customer-oriented organisations will likely thrive in an increasingly competitive future; electricity networks must understand what future customers are likely to value.
- Stage 2 should consider the new levels of collaboration and inter-operability between market actors to facilitate future customer needs.



Segment	**Empowered**		**Engaged**		**Vulnerable**
	Autonomous	**Tech focused**	**Hands on (Active)**	**Be my agent (Passive)**	**Service dependent**
Distinctive features	**Independent**: Wants full control, granular cost management and the ability to configure the operation of the electricity solution. Will often involve disconnecting from the grid entirely, and may be motivated by locational cost or reliability issues.	**Empowered**: Has a strong affinity with technology and desires control. Wants to influence directly the design and operation of the customised solution. System cost is important but maximising returns on investment from trading energy services with the grid is critical.	**Active**: Wants to understand what each available option has to offer and to be involved fully in the selection process. Willing to maintain a moderate to high involvement in the ongoing operation. System cost and return on investment from interacting with the grid to trade energy services are both important.	**Passive**: Prefers electricity solutions that provide ease and convenience at a reasonable cost. Desires an agent to provide a shortlist of options that make sense, are easy to deliver and require a minimum of ongoing involvement. May invest in additional cost saving measures if simple and convenient.	**Dependent**: Needs affordable network services and help to identify the most suitable options. Includes vulnerable customers experiencing energy hardship. Also includes households that cannot adopt new electricity solutions, given rental property constraints or a lack of access to capital.
Common features	All customer segments will value solutions that provide secure and reliable electricity for Australia’s modern lifestyle. Some customers may want to trade off some aspects that have been standardised traditionally, in return for a financial benefit. Participation in a given segment is fluid and bi-directional. Households will transition between segments at different stages of the life cycle, either towards greater autonomy or increased dependence. Customer segments are likely to be less affected by income level, as evolving business models and financing mechanisms make complex solutions available to larger proportions of customers.				

Figure 2 Plausible residential customer segments in 2025 [REF: ENA, 2015, “Electricity Network Transformation Roadmap, Interim Program Report”, Pg. 35.]

The evaluation of the above customer types led to the development of four scenarios which the future grid may take the form of. It is recognised that it is unlikely that a single scenario will be adopted nationally as this does not take account of Australia’s varied network, rather individual network areas/zones may begin to realise a specific scenario. The scenario titles and customer types are shown in Table 1 below:

Table 1 Four Future Scenarios

Scenario	Name	Customer Description
Scenario 1	Set and Forget	Passive; prefers agents to manage their services.
Scenario 2	Rise of the Prosumer	Engaged; active involvement in service selection and management.
Scenario 3	Leaving the Grid	Lacking trust in utilities; disconnection as an unintended response to incentives.
Scenario 4	Renewables Thrive	Warmth, familiarity and preference for renewables and storage.

2. What's driving Australia's electricity sector transformation?

The forces driving transformation in the Australian electricity industry are based on an updated view of assumptions presented by the Future Grid Forum in 2013. It is expected that distributed energy resources (DER) will continue to expand leading to 2025. This expansion will include customers who have traditionally been less able to access DER solutions. It is predicted that the increased density of DER solutions will be able to deliver system benefits. Particularly when used in combination with demand management technologies and energy storage to reduce peak load and enhance grid use. Modelling undertaken during Stage 1 identified that continued growth of DER could reduce the efficiency of the electricity systems without substantial change to the network infrastructure and operational regime. Key learning included:

- Confirmation that customer adoption of distributed generation is increasing, especially rooftop solar photovoltaic (PV) systems. This, together with global carbon abatement efforts are the main transformation drivers.

- Rapid uptake of energy storage systems (residential/grid connected batteries) and electric vehicles are also likely to bring subsequent transformation to electricity systems.

- Stage 2 of the program should focus on developing material cases for the 'no regrets' options to be included in the Roadmap. Including technological advancements, organisational structures/collaboration and business models.

3. Technical challenges and opportunities of distributed energy resources

This chapter identifies that DER can impose both technical challenges on traditional electricity systems and equally deliver benefits to those systems. Effective integration of DER can deliver benefits for both customers and the electricity network by reducing peak load, combatting voltage constraints and reducing customer energy bills. Stage 1 of the program identified options capable of providing benefits both now and in the future, along with critical gaps in existing Australian Standards that must be addressed to gain full benefit from DER. Key learning included:

- Energy storage is a versatile form of DER and can be used to manage a large variety of challenges relating to the existing grid, and those arising from increasing penetration of DER.

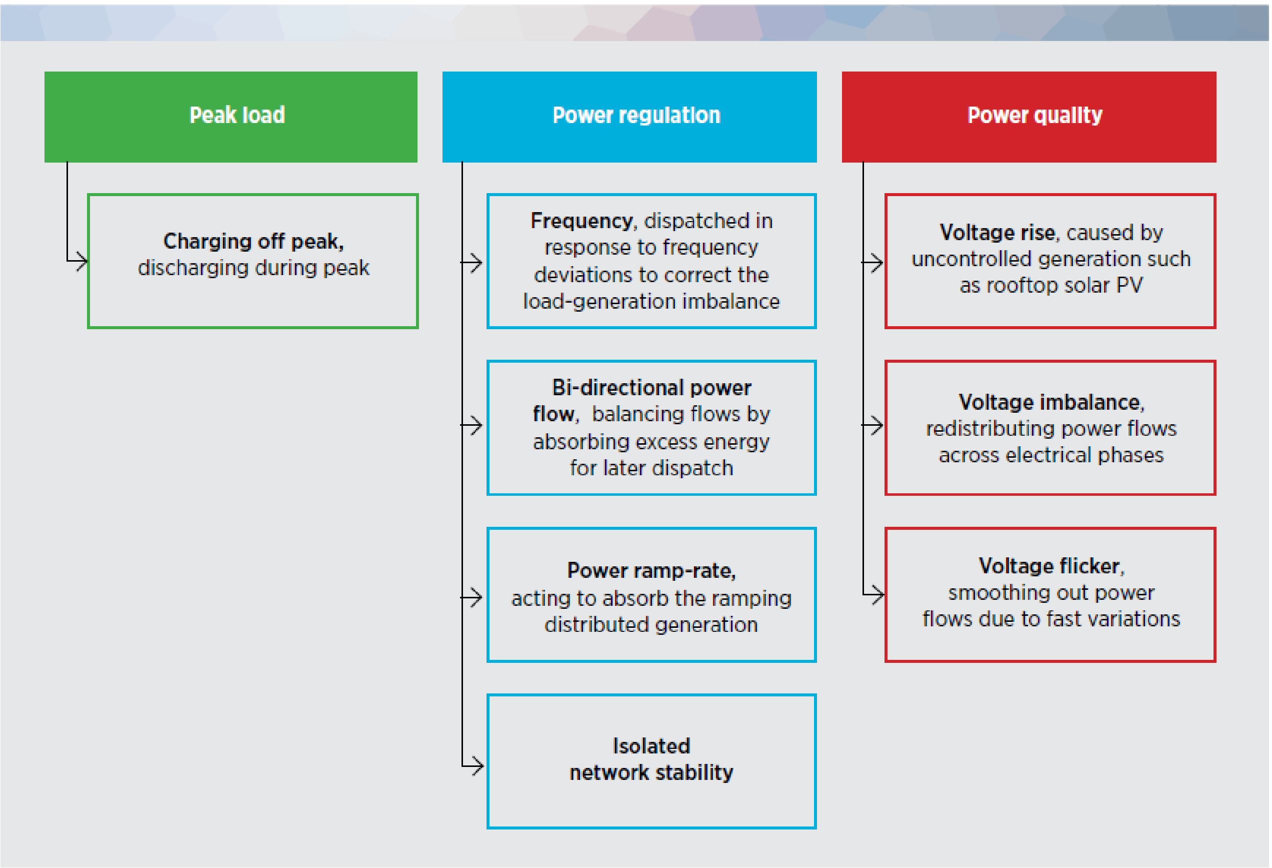


Figure 3 How Storage Can Accommodate DER [REF: ENA, 2015, "Electricity Network Transformation Roadmap, Interim Program Report", Pg. 77.]

- Customers can become active participants to ensure their DER (PV and storage) are integrated to maximise the value of electricity services for all participants.

- Network service providers are well placed for coordinating the integration of DER into the electricity grid in a way that maximises performance and shared benefits for all customers.

- Adaptive/dynamic systems are critical to predicting and controlling loads in an integrated grid. They are able to bring multiple benefits to both networks and customers.

- A number of new technical standards are critical to the efficient and safe deployment of technology enablers of the integrated grid. They include, for example, storage safety standards, electric vehicle and similar distributed storage standards, inverter standards, protection relay standards and smart meter standards.

- Stage 2 of the Roadmap should set out to:
  - Identify potential solutions for delivering the new technologies, organisational structures and business models to facilitate the Smart Grid and supporting industry leading up tp 2025 and beyond.
  - Consider the impact of DER on Australia's LV and MV networks including the operational and maintenance issues and performance of grid-connected energy storage.
  - Identify gaps in the electricity supply industry workforce.

The final three chapters of Stage 1 are to be the focus of the second stage of the program, they introduce:

4. Business models for an evolving electricity future

The current stance is based on the recent Accenture review of how transformational forces are impacting network business model evolutions. The review focused on distribution networks, and considered international case studies, future roles and business models relevant to Australian networks. The chapter presents four business model approaches:

- Platform Enabled,
- Intelligent Grid,
- Beyond-the-Meter Services and
- Information Services.

It has been found that globally, progressive utilities are planning multiple business model evolutions. In order to remain at the forefront the Australian electricity network must also respond with a unique approach. There is no ‘one size fits all’ approach to future business models for electricity networks, and no ‘optimal final state’ business model suitable for all networks.

5. Price and incentives for a transformed electricity system

Stage 1 of the program has focused on developing options for the network pricing reform needed in a transformed electricity industry. It has considered how pricing could evolve in the coming years to reflect an equitable two-way exchange of value and services between networks and customers. It has also considered the overall structure of future price signals and how network price signals can be reliably transmitted to customers.

6. Priority directions for electricity policy and regulation

This Chapter states that elements of the current regulatory framework are robust and will remain relevant, while others are not ‘fit for purpose’ in the range of expected future scenarios. These ‘unfit’ components risk delivering poor customer and societal outcomes. It also notes that a regulatory regime that is outpaced by technology and market developments cannot protect consumers.

2.3 Low Carbon Network (LCN) Fund

This will include summaries of key projects in the UK that have examined the use of a range of innovative technologies/processes to tackle various network issues.

Included in this section will be some overarching views of the level of effort expended in different areas, such as the overview of technology areas trialled (section 2.1 above).

2.3.1 Demand / generation side response

Key learning to date

- Implementation can significantly accelerate deployment of variable generation such as wind farms and solar PV
- Can release significant capacity from existing infrastructure
- Utilisation of network assets can be improved
- Network reinforcement can be avoided or deferred, giving cost and carbon savings
- Provides another means to support the network in post-fault scenarios
- Implemented correctly, customers are willing to accept loss of control over EV charging
- Requires utilisation of specific commercial arrangements
- Enables deferment or forgoing of electricity consumption
- Can be utilised to provide frequency management capabilities

Applicable projects
The projects undertaken within the UK for the LCN Fund that have generated learning relating to this area of innovation are listed below, and can be found in the referenced appendix.

LCN Fund Project	Referenced Appendix
ARC	Appendix 3
BRISTOL	Appendix 3
C_2C	Appendix 3
CLNR	Appendix 3
FALCON	Appendix 3
FNLCF	Appendix 2
FPP	Appendix 3
LCL	Appendix 2
My Electric Avenue	Appendix 3
SAVE	Appendix 3

2.3.2 Dynamic ratings

Key learning to date

- Implementation of dynamic ratings can release significant additional capacity in network infrastructure
  - This is particularly applicable in situations of high wind speed when applied to wind farms connected via OHLs as the increased wind cooling factor allows for greater energy transmission
- Implementation can significantly accelerate deployment of variable generation such as wind farms and solar PV
- Requires utilisation of specific commercial arrangements, linked to rating calculation methods
- All assets will likely experience periods where the dynamic rating is greater than the static, and periods where it is below.
- Deployment of dynamic rating of 11kV OHL is not recommended due to high variability, difficulty in generating reliable real-time values and complexity of integrated widespread application
- Deployment for dynamic rating of distribution transformers could be considered if reliable transformer modelling can be achieved.

Applicable projects

The projects undertaken within the UK for the LCN Fund that have generated learning relating to this area of innovation are listed below, and can be found in the referenced appendix.

LCN Fund Project	Referenced Appendix
CLNR	Appendix 3
FALCON	Appendix 3
LCH	Appendix 2

2.3.3 Electrical energy storage

Key learning to date

- Distributed energy storage systems can help keep lights on during power outages, whether attached to the local network or located in properties
- Energy storage can provide the following benefits:
  - mitigate or reduce short term peaks in energy demand caused by EVs or HPs, or to absorb
  - reactive power compensation
  - voltage management support

Applicable projects

The projects undertaken within the UK for the LCN Fund that have generated learning relating to this area of innovation are listed below, and can be found in the referenced appendix.

LCN Fund Project	Referenced Appendix
BRISTOL	Appendix 3
CLNR	Appendix 3
FALCON	Appendix 3
NTVV	Appendix 3
SNS	Appendix 3

2.3.4 Network management

Key learning to date

- ANM provides much of the enabling technology that allows implementation of equipment detailed in other sections
- ANM can release significant network capacity to customers from existing infrastructure through improving the utilisation of the assets
- ANM can facilitate lower, or defer reinforcement costs for the network
- A range of network challenges and associated smart grid enablers trialled with ANM applications include:
    - Thermal constraints
    - Reverse power flows
    - Voltage constraints
    - Flexible network configurations
    - Generator control mechanisms
- Effective network management requires suitable communication infrastructure to be in place.
- Automated and distributed intelligence systems can reduce the need to communication infrastructure but do not allow it to be disregarded entirely.
- Distributed intelligence systems can also enable faster network reconfigurations in the event of outages, providing adaptive protection and fault detection capabilities.

Applicable projects

The projects undertaken within the UK for the LCN Fund that have generated learning relating to this area of innovation are listed below, and can be found in the referenced appendix.

LCN Fund Project	Referenced Appendix
ARC	Appendix 3
C_2C	Appendix 3
CLNR	Appendix 3
FALCON	Appendix 3
FPP	Appendix 3

FUNLV	Appendix 3
LCL	Appendix 3
LV Templates	Appendix 3
My Electric Avenue	Appendix 3
ETA	Appendix 3

2.3.5 Voltage management

Key learning

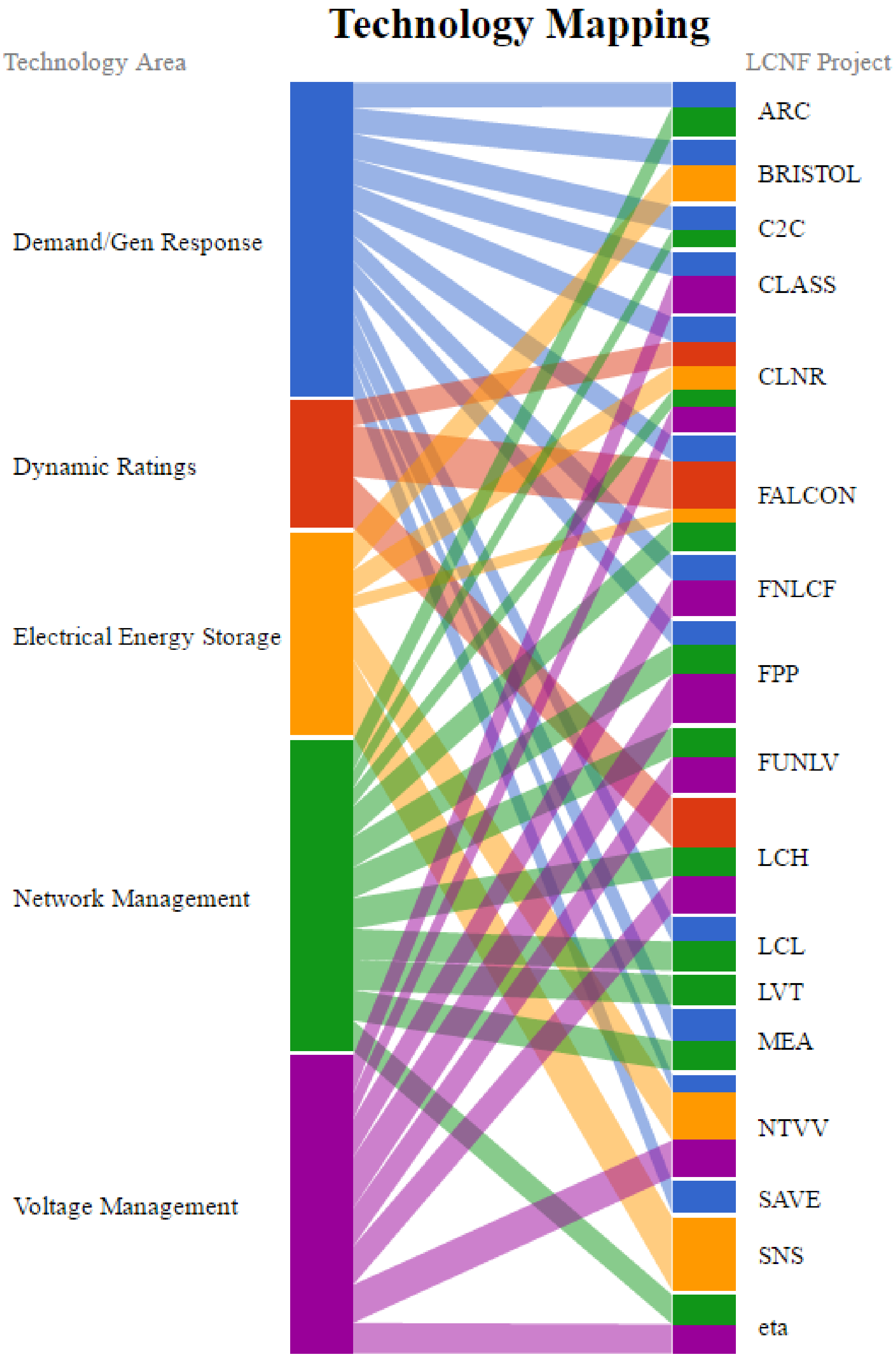
- Voltage management can provide benefits to:
  - New connections for load and generation
  - Peak demand management
  - Optimisation of losses
  - Conservation of energy
- Areas with high concentrations of distributed generation can experience high voltages at times of peak generation
- In-line voltage regulators on primary networks: can boost or buck the voltage along a feeder to compensate for any voltage drop due to demand or voltage rise as a result of generation
- Switched capacitors banks in primary networks: compensate for reactive power on the circuit, which can reduce voltage drops, particularly for long spans of overhead line
- Voltage regulators in low voltage networks: regulators can manage voltages on individual feeders
- Small variations in voltages does not adversely affect customers
- Voltage management can defer or mitigate the need for conventional reinforcement techniques
- It can provide rapid reduction in system load.
- It can boost demand in distributed generation dominated networks, reducing or mitigating issues associated with reverse power flows.

Applicable projects

The projects undertaken within the UK for the LCN Fund that have generated learning relating to this area of innovation are listed below, and can be found in the referenced appendix.

LCN Fund Project	Referenced Appendix
CLASS	Appendix 3
FNLCF	Appendix 3
FPP	Appendix 3
FUNLV	Appendix 3

LCH	Appendix 3
NTVV	Appendix 3
ETA	Appendix 3



2.4 Future Power System Architecture (FPSA)

The ‘power system architecture’ of any country is the underlying structure of the electricity system – how each component and how the stakeholders are organised and interact. The FPSA Project[6] was commissioned by the UK’s Department for Energy and Climate Change (DECC) to assist government, officials and industry professional to anticipate the likely changes to the industry over the next 15 – 20 years, and assess their significance to the current architecture.

It was led by the UK’s Energy Systems Catapult and the Institution of Engineering and Technology (IET), and makes use of system engineering techniques to examine credible evolutionary pathways and determine where new functionality is likely to be required.

2.4.1 The premise for the analysis

The 2030’s power system will be a sophisticated and intelligent infrastructure enabling diverse technologies utilising novel techniques whilst enabling active consumer participation and establishment of new business models. These will be achieved whilst simultaneously realising greater, efficient, utilisation of assets and maintain overall system resilience and stability.

The project assumes that the scenario where UK Government’s decarbonisation objectives are achieved, and remains consistent to the Climate Change Act and International Commitments. This includes the following major trends by 2030

- Intermittent renewables increase in deployment, achieving 46% of network capacity, accounting for 39% of electricity generated.
- Distributed generation achieves a total of 27% of available capacity.
- Electrification of heat and transport is achieved, with 3.3 million EVs and 6.6 million heat pumps deployed.
- Over 29 million smart meters installed.
- Major changes to system operations, including:
    - Reduced system inertia
    - Greater international interconnections

2.4.2 Evolutionary pathways

Regardless of the scenario eventually realised, the FPSA Project also considered the credible pathways that have the potential to wholly or in part, influence the final shape of the UK’s PSA by the 2030’s. These are detailed:

- **Power Sector Adaptation:** Businesses within the industry continue to operate as usual, with incremental changes occurring.
- **Power Section Leadership:** The industry leads in engaging with customers.
- **Customer Empowerment:** The industry facilitates and empowers customers and new parties to enable change and innovation.
- **Community Empowerment:** The industry empowers energy communities and local markets.

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[6] http://www.theiet.org/sectors/energy/resources/fpsa-project.cfm?origin=reportdocs

2.4.3 Drivers of new or extended functionality

The FPSA Project identified thirty-five new or significantly modified functions, considered essential to meet the current UK objectives for 2030. These functions were grouped within seven major 'drivers' to enable appropriate interconnectivity.

1. **The flexibility to meet changing, but uncertain requirements.**

   The power sector must be capable of identifying and responding to material challenges and network 'tipping points' as they emerge. The forecast uptake of domestic distributed generation and storage, the use of EVs and proliferation of smart tariffs and home automation will have an uncertain impact of the power system. It is not certain how the power system will evolve to accommodate these new technologies and business models.

2. **The change in mix of electricity generation**

   The increased proliferation of renewable energy includes particular technical characteristics (e.g. weather dependent intermittency and low stabilising inertia) that will potentially reduce stability and security of the national power system. New forms of stabilising inertia or frequency response capability will be required.

3. **The use of incentives to enable customers to benefit and the system to operate more efficiently.**

   Customers will be able to save or earn money whilst contributing to decarbonisation and system balancing.

4. **The emergence of new parties providing new services to customers**

   The emergence of smart cities, technology user groups, aggregators and similar will require new methods of interaction with the power system, reflecting the opportunities available but whilst mitigating the risk of destabilising effects.

5. **The active management of networks, generation, storage and demand**

   The increase in intermittent and distributed generation, and new loads such as EVs and heat pumps will require active management to prevent costly network reinforcement.

6. **The recovery from major events or emergencies**

   As the power system becomes increasingly complex, decentralised and more interactive with its customers, anticipating, modelling and managing major events will become more challenging. Recovery from prolonged outages will require much more sophisticated coordination to reintroduce load and reconnect distributed generation and storage.

7. **The emerging need for coordination across energy vectors**

   A significant element of the UK's decarbonisation strategy is the electrification of heat and transport. Coordination across all energy vectors will become more important as interaction between these markets deepens.

2.4.4 Key conclusions and recommendations

Conclusions

The project has drawn four conclusions as a result of the analysis undertaken, these are briefly summarised below.

- Substantial new or extended functionality is required to meet the power system objectives. The thirty-five separate functions apply over different timeframes and are interdependent. The necessary interaction and coordination implies that if applied together, a transformative change to the power system architecture will result. Serious risks to achieving the objectives can be mitigated through the implementation of a coherent programme of deployment rather than relying in incremental adjustment or small scale initiatives.

- Substantial implementation challenges from technical, market and commercial perspectives are present with the new functionality requirements. These arise primarily from the greater complexity introduced to the system by new technologies and commercial models, and more actors within the industry.

- The planned timescales for decarbonisation of the industry are achievable, but only if special focus and urgency is attributed to ensuring success. Defining, designing, developing, risk-assessing and testing solutions, prior to deployment under business-as-usual practices in less than 15 years is a highly demanding schedule.

- The current stratification of system architecture is radically different to the approaches required in the future. Interactions spanning the whole grid are required, from smart appliances within customer properties to the largest power stations will be common place, requiring a paradigm shift in an industry that currently compartmentalises generation, transmission, distribution and consumers.

Recommendations
The Project's six recommendations are summarised below:

- Align power system architecture development with major policy commitments. In delivering the fifth carbon budget (2028–2032), the Government should ensure it has a programme and necessary capabilities to deliver the system architecture needed to support the likely mix of technologies required (or that will evolve) to meet the budget.

- Ensure that there is an implementation framework for delivery of the required functionality, with particular responsibility for end-to-end operability, taking account of other developments in energy sector reform.

- Deepen and extend the functional analysis through further elaboration and refinement of functional requirements, assessment of barriers to implementation and analysis of timing pressures and interdependencies. Commence work on identifying the technical, market and commercial options for delivery.

- Develop a transition route map of least-regret actions to ensure market mechanisms are maximised and government intervention minimised to meet the technical requirements identified by the thirty-five functions.

- Extend the evaluation and identification of R&D and innovation requirements to cover all the functionality identified and formulate a supporting innovation programme aligned to the transition route map and coordinated within the existing innovation machinery.

- Maintain the momentum developed in the FPSA project by formalising and supporting cross-industry and inter-agency working to take this demanding agenda forward, with clear accountability for leading and coordinating change.

2.5 Other Key International Projects / Learning

2.5.1 DISCERN

The target of DISCERN is to assess the optimal level of intelligence in the distribution networks and to determine the replicable technological options that will allow a cost-effective and reliable enhancement of observability and controllability of the future distribution networks in Europe.

The below information is extracted from the project website[7] where all project publications and the full list of recommendations can be found for further information.

Specific Objectives
Establish a family of demonstration projects focused on the MV/LV network and develop an assessment framework based on KPIs that allows the comparison of technical solutions for monitoring and controlling the distribution network.

- Identify, assess and compare the technological options for monitoring and control systems in the distribution network.
- Test and validate optimal technological solutions by means of real time simulations (e.g. Real Time Digital Simulator [RTDS]) and small scale field tests.
- Facilitate the knowledge exchange with innovative European projects testing various smart grid functionalities in the area of network operation, monitoring and control.
- Develop recommendations for the cost-effective application of advanced distributed sensors, monitoring and control systems to increase the intelligence of electricity distribution networks based on KPIs.
- Map relevant standards and contribute to standardisation activities.

Tangible Results

- DISCERN will achieve a number of tangible results which will have significant impact especially on the operations of DSOs in Europe:
- Concepts for the determination of optimal levels of intelligence in the distribution network to maintain the security of supply and to ensure the feed-in of DER (Distributed Energy Resources) leading to a more rational network management.
- Recommendations based on KPIs on cost-effective best-practise solutions to achieve optimal levels of intelligence in the distribution network.
- Multiple scalable and replicable solutions for the application of advanced distributed sensors, monitoring and control systems to increase the intelligence of electricity distribution networks.

Key recommendations
The key recommendations from the practical experience gained through the DISCERN demonstration sites are extracted from the Project's Final Report[8], and include:

- The deployment of Fault Passage Indicators (FPIs) is recommended as these significantly reduce outage times, particularly on long overhead lines, as the fault can be located much more quickly when only a smaller section of the line has to be investigated. The installation of FPIs is straight forward and can often be done without a power outage. To improve the cost efficiency of deployment, where possible FPIs could be installed at the same time as remote controlled disconnectors are installed or exchanged.
- The use of sensors and monitoring devices to provide LV network observability is of great value to DSOs. Devices installed in secondary (distribution) substations can be used to collect measurements for each phase at feeder level, providing data on load profiles and power quality. This data can be used in its own or together with data from smart meters to provide information for operational decision making and fault identification reducing outage times, and for planning decisions to inform future network investment.

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[7] http://www.discern.eu/index.html
[8] http://www.discern.eu/datas/Discern_Final_Report.pdf

- When designing the communication infrastructure for smart meter deployment, it is important to consider different methods and systems for data gathering so that options are available for deployment in differencing network situations. This will allow the solution to be successfully deployed across a network of varying topologies and dispersions of customers, and where intermittent or location specific communication issues are experienced, ensuring that the process of data gathering is as reliable and economically efficient as possible.

- The Advanced Metering Infrastructure deployed at LV network level for smart meters can be used to estimate and distinguish between technical and non-technical losses. Loss estimations provide very valuable information on the targeting of loss reduction activities to achieve costs savings, as well as providing a view on the relative proportion of non-technical losses (e.g. theft) in relation to overall system losses.

2.5.2 ADDRESS

ADDRESS Overview
ADDRESS[9] is a large-scale Integrated Project co-founded by the European Commission under the 7th Framework Programme, in the Energy area for the "Development of Interactive Distribution Energy Networks".

ADDRESS stands for **Active Distribution network with full integration of Demand and distributed energy RESourceS** and its target is to enable the Active Demand in the context of the smart grids of the future, or in other words, the active participation of small and commercial consumers in power system markets and provision of services to the different power system participants.

ADDRESS is framed in the Smart Grids European Technology Platform, whose vision for the electricity networks of the future may be expressed in just 4 words: flexibility, accessibility, reliability, economy.

The project started on June 1st 2008 and lasted 5 years (2008 - 2013). It was carried out by a Consortium of 25 partners from 11 European countries, carefully selected to meet the needs of the project in terms of skills, competencies and understanding of the problem and possible solutions, each of them bringing specific knowledge of at least one aspect of the supply chain. Enel Distribuzione is the Coordinator.

The total budget was 16 M€, with 9 M€ financing by the European Commission.

The ADDRESS vision
Reaching the objectives and exploiting the results of the ADDRESS project can help the European Smart Grids Technology Platform vision to become a reality: a network that is flexible, reliable, accessible and economic. ADDRESS seeks to ADD value to each of the vision issues:

To add FLEXIBILITY

- Enhancing consumers (prosumers: customers who consume produce electricity with a proactive behaviour) flexibility and adaptability enabling active demand

- Providing real-time optimisation of energy flows at local and global level

To add RELIABILITY

- Developing technologies for distributed control and real time network management

- Exploiting load flexibility to achieve safer operation of the network and increase power system efficiency

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[9] http://www.addressfp7.org/

To add ACCESSIBILITY

- Proposing solutions to remove commercial and regulation barriers against active demand and the full integration of DG (Distributed Generation) and RES (Renewable Energy Resources)

To add ECONOMY

- Enabling profitable participation in the power economy by all market actors to provide local and global savings and increase the competitiveness in the energy market that will imply energy bill reduction

- Combining active demand with DG and RES to allow sustainable growth and energy consumption

2.5.3 NY-REV

REV Goals

REV[10] is a strategy to build a clean, resilient, and affordable energy system for all New Yorkers. It is transforming New York State's energy policy and initiatives to make sure energy efficiency and clean, locally produced power are at the core of the State's energy system.

REV is changing the way government and utilities work to make clean energy financially beneficial to everyone. And most importantly, REV is putting customers first by designing new initiatives to impact real people and provide individuals and communities with the opportunity to take an active role in achieving the following State energy goals by 2030.

Below is an overview of the key activities underway as part of the REV Program, extracted from the REV Program website.

Key Activities

- **Clean Energy Fund**

  Delivering on New York State's commitment to reduce ratepayer collections, drive economic development, and accelerate the use of clean energy and deployment of energy innovation to modernize New York's electric grid. The Clean Energy Fund will attract more private capital into New York's emerging clean energy economy, reduce the cost of clean energy by accelerating the adoption of energy efficiency in order to reduce load, and promote the adoption of renewable energy. This investment will deliver over $39 billion in customer bill savings over the next decade.

- **Clean Energy Standard**

  Meeting Governor Cuomo's aggressive commitment that requires 50% of New York State's electricity come from renewable sources by 2030.

- **NY-Sun**

  Helping finance 3,000 megawatts worth of solar projects in the next 10 years. NY-Sun is investing in communities that need it, committing $13 million to projects in low- to moderate-income communities. That means cheaper and cleaner energy for everyone.

- **K-Solar**

  Helping K-12th grade schools statewide go solar at reduced costs. This will save schools money on their electric bills, allowing them to spend less on utilities and more on educating

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[10] https://www.ny.gov/programs/reforming-energy-vision-rev

New York’s children. So far, 323 school districts have registered into the program to date (over 40% of all the public school districts in NYS).

- **NY Prize**

  Offering $40 million in awards to communities that build their own local energy systems, known as microgrids. The less electricity traveling long distances across electrical lines, the cheaper and more reliable it can become.

- **BuildSmart NY**

  Working to cut energy use in State buildings 20% by 2020. The government’s plan to lead by example is not just good for the environment, it will save taxpayers tens of millions of dollars on State electricity bills.

- **NY Green Bank**

  Working with partners in the finance community to invest $1 billion in clean energy technologies and projects. NY Green Bank is the largest green bank in the country with a goal to make both public and private sector financing available for clean energy projects, and to keep reinvesting those funds in building New York’s clean energy future.

3. Innovation Requirements Identified by NTR

3.1 Identification of Gaps

From work that has been conducted in parallel and engagement with appropriate stakeholders, a number of technical challenges that the grid will face in the future have been identified. These challenges are listed below:

- Management of voltage on local networks and excessive variation caused by swings between generation and demand
- Regulation of frequency at a system level and contending with a multitude of smaller generators that will operate in parallel and are at risk of islanding
- The need for distributed intelligence to facilitate decentralised control with greater volumes of technological deployments deeper into the network offering more visibility of network conditions and greater optionality for local control and decision making
- Constraint management at a local level will require the ability to flex the local grid to a larger degree than previously to alleviate power flow issues and reconfigure networks in real-time
- Optimising the use of the various types of demand side response to achieve the aims of system balancing and constraint management, while ensuring that demand side response initiated for retailer hedging does not have an adverse effect on system and network performance

A number of these issues have been considered through international projects and there are some areas where the learning can be applied to the Australian context. Equally, there are areas where additional work is required, and this is highlighted in the following section.

3.2 Mapping Innovation Learning

The points identified in the section above as likely to represent the greatest challenges to the network can now have appropriate innovation mapped against them. In some cases, there has been innovation activity in Australia that can be expanded on, or from other global locations which could be transposed and refined for the Australian grid.

Voltage management on local networks

There have been projects investigating the use of power factor correction and active Volt-Var control in Australia that have been demonstrated to deliver benefits. Internationally, projects have also explored the installation of automatic voltage control at distribution transformer level through the use of tap-changing capabilities.

Regulation of frequency

This is an area where it appears that there are still significant gaps. There have been some deployments of syncrophasor technology internationally, but as RoCoF protection is highly unlikely to remain fit for purpose in the future, this appears to be an area where further trials would be beneficial. There has been some exploration around changing the governor settings on smaller generators with the intention of preventing them from operating in islanded mode when the frequency becomes too high while attempting to keep them connected during low frequency events such that they can help try to return the frequency to the appropriate level (‘frequency forcing’) but innovation activities in the area of frequency control still require considerable investigation.

Distributed intelligence

As yet, this remains an underexplored area. There have been many instances of deploying advanced substation monitoring, but a lack of any subsequent processing and automation as a result of this monitoring has been reported. Clearly for this concept to work efficiently, there is the need for reliable communications deep within the network and this is an area of difficulty encountered by many projects. However, given the likely importance of decentralised control in the future, it is an area that merits further exploration.

There have been some instances of its deployment such as the My Electric Avenue project that autonomously controlled network connected assets in the form of electric vehicle chargers. Other projects in the area of distributed intelligence are in the pipeline but are yet to reach maturity.

Local constraint management

Several projects have explored using more active techniques to manage local networks, both in operational and also planning contexts.

Various techniques are available such as meshing networks at times of high load that would otherwise run in a ‘split’ or ‘radial’ sense normally. This has been trialled at low voltage and at 11kV with some success and investigations should be made as to the feasibility of applying this to urban settings in Australia.

Dynamic rating of assets is another key area that has seen numerous projects from low voltage up to transmission. The Lower South East 275kV line uprating project is likely to be a highly beneficial starting point, but expansion of this approach, at different voltages and with the addition of further distributed intelligence can increase the benefits realised by the network.

There have been some projects and academic research investigating the benefits of using dynamic ratings at LV (potentially in concert with local meshing) to maximise utilisation of assets at times of high load or high generation export.

At higher voltages a number of companies in the UK now offer managed generator connections as business as usual. These rely on actively managed export by way of dynamic ratings that govern the maximum export at different times of day depending on local network and weather conditions. These novel commercial contracts in partnership with adaptive network control functionality permit the connection of more generation in a cost-effective manner while not compromising the integrity of the network. (Examples include “Flexible Plug and Play” and “Low Carbon Hub”.)

Demand side response

A number of projects both in Australia and internationally have explored various aspects of demand side response. However, the multi-faceted nature of this topic means that there is still more learning to be uncovered here.

The retrospective implementation of demand side response at a residential level is costly, relative to the demand reduction achieved. Introduction of standards requiring the deployment of the technology as part of the manufacturing process, for example, incorporating the ability for control of EV charging into items like charging points should be considered. This has been recommended by the My Electric Avenue Project and there is live work in this area to explore what such a standard might look like. Similar activity should be considered in advance of Australian uptake of electric vehicles accelerating.

The potentially competing nature of demand side response as it is used by retailers for hedging and by network and system operators for balancing and constraint management (respectively) should also be considered. There is a potential role for DSR arbitrage and work being undertaken in Ireland by ESV networks looking at their ‘SERVO’ system seeks to address this issue by ensuring that no DSR actions are taken that compromise the safety or performance of the network. Similar arbitrage arrangements should be considered for Australia.

Technical enablers

Challenges with data transmission remains a constant issue throughout all projects requiring reasonable levels of communication and is an essential component of any future smart grid. However, it is unlikely to be financially viable for the DSOs to extend their existing communication methods to the LV network. Similarly, the telecommunications market will not deploy mobile communication masts, increasing reliability of coverage in remote and rural areas, as it is not financially viable to do so. There is a need to consider how best to meet the communications requirements, particularly in rural areas, and this requires the engagement of a range of stakeholders including policymakers and government around how various methods could be trialled and what sort of commercial terms could be used to ensure that communications are provided in a manner that delivers value for money and enables customers to realise the benefits of the smarter grid.

4. Conclusions

The mapping exercise undertaken above has indicated some of the key priorities for innovation. Opportunities should be sought to explore these subjects and trial the various techniques in real-world environments. Where this is building on existing learning, any opportunities to trial the approaches as part of a holistic system should be maximised. For example, if there is a new area of network being constructed to serve a housing development, the opportunity could be taken to install, at marginal cost in comparison to retrofit, some of the technologies described here. This would allow greater learning to emerge around how the various techniques interact with each other and how they could be managed and controlled in the most efficient manner.

Key areas of priority to investigate for innovation projects are therefore:

- Voltage management on local networks
- Frequency control and replacements for RoCoF
- Use of decentralised control techniques through distributed intelligence
- Management of local constraints through active network management and dynamic asset rating
- Demand side response use cases, including arbitrage between them

Innovation in these areas will address some of the key challenges identified in other Network Transformation Roadmap activity and needs to be started in the immediate term such that the learning is ready to be encapsulated in business as usual in advance of the innovations being required on a day-to-day basis and to avoid the networks being overtaken by the pace of change.

This is particularly true for potential interactions with customer-side technologies (such as electric vehicles or storage units) where there may be significant benefits to be realised through standardising the way these devices can communicate with the network and/or other actors, but such benefits can only be realised if this is implemented before wide-scale take-up of the technologies occurs.

The identified areas also rely on some enabling technologies to allow them to function, which should be trialled as part of any innovative schemes to ensure they are holistic and take a systems engineering approach. This includes the use of more advanced, adaptive protection schemes and any associated communications requirements.

Network related innovation activity has significantly increased across the globe in recent years as networks seek to flex to accommodate new sources of load and generation. This provides a rich source of trials, to avoid ‘reinventing the wheel’, shortcutting potential dead-ends, and signposting areas for deployment, based on proven benefits. However, whilst the physics of the power system are consistent wherever an engineer may look, the business case and economics for deployment are often highly specific for each markets. Local factors such as customer use patterns, network topologies, communications infrastructures and Regulatory models can all have an impact on precisely which solution should be used in a given situation. Specific economic modelling must therefore be carried out alongside technical assessments in order to ensure the right solutions are used in the right circumstances.

Appendix I Overview of Australian Innovation

Virtual Power Station

Project Title	Virtual Power Station
Company	CSIRO
Funding	ARENA
Project Driver	The increasing amount of electricity generated using PV panels has the potential to affect the stability of the local electricity supply. A high density of PV can result in unacceptably high and fluctuating voltages, an unstable power supply, and an inability to export electricity to the grid. This could result in restrictions being placed on the amount of PV-based electricity connected to the grid. Power generation from PV is dependent on light, a sudden change can result in a dramatic change in generation. This can cause the voltage to fluctuate, not only for the PV owner, but for other users on the electricity network. Other renewable energy sources, such as wind power, have similar issues with voltages fluctuating with the weather conditions.
Project Objectives	The Virtual Power Station (VPS) is designed to link dispersed renewable energy generators – like rooftop solar PV panels – with energy storage and load control systems in a web-based network, to create a single reliable energy supply, much like a power station .
Key Processes	**Modelling and simulation:** Develop suitable network simulation models to assess the performance of different control strategies, meaning Australia-wide impacts and benefits of proposed solar management solutions can be assessed. **Control system design:** Develop a coordinated control system for managing loads, energy storage and reactive power at individual sites. Managing power quality and avoiding energy wastage will provide an immediate financial benefit to consumers in constrained network areas. **Aggregator system design (multi-site):** Develop an interface and coordination algorithms, suitable for use by energy service providers, allowing aggregation of multiple individual sites to provide reliable and location specific network services. Thus giving DNOs a viable alternative to PV restrictions or distribution network upgrades. **Pilot deployment:** The VPS will be deployed at pilot scale (50-100 individual sites) in a residential development. The pilot will be maintained for at least a year, with high-resolution data on the network power quality and solar PV hosting capacity made publicly available and promoted in a series of technical and academic publications, plus industry forums.
Outputs	Information learned during the project will be made available to Australian distribution network operators to help in the development of prototype distribution feeder models that will allow assessment of how VPS and other control schemes can increase the amount of PV-based electricity within the grid. The results of this testing will help to address the challenges that arise from increasing levels of PV-based electricity in distribution networks while improving power quality.
Source	http://www.csiro.au/en/Research/EF/Areas/Electricity-grids-and-systems/Intelligent-systems/Virtual-power-station

Eddy Home Energy App

Project Title	**Eddy Home Energy App**
Company	CSIRO
Project Driver	Australia has seen rising power bills over recent years due to the increasing cost of generating and delivering 'poles and wires' electricity. Increasing customer costs have been driven by network reinforcement which could be abated if peak demand reduces.
Project Objectives	● Develop a tool which allows householders to keep track of their electricity consumption and remotely switch on and off appliances using their devices. ● Allow users to remotely control major appliances that drive peak demand, such as air conditioners, hot water systems and pool pumps. ● Reduce overall electricity consumption and peak demand, allowing for reduced reinforcement and cost savings.
Key Processes Trialled	● ● An online interface – on a computer, smartphone or tablet – Eddy keeps track of electricity use, collects and analyses the data, and makes recommendations to help users save money. ● The system uses cloud-based software and mini smart meters. The smart meters connect to the cloud via a small internet communication device in the house. Once connected, the appliances linked to the meters can be remotely controlled.
Outputs	● Eddy has been commercialised by Australian company HabiDapt and is currently being trialled in Perth in conjunction with Ergon Energy in regional Queensland. ● To reduce demand on the grid during peak periods, users can also take part in demand management programs offered by their energy company and receive rewards in return, such as discounts on their energy bill. ● By viewing when their home is exporting excess energy to the grid, households with solar PV systems can save additional money by programming their system to run certain appliances when the sun is shining.
Source	http://habidapt.com/index.html http://www.csiro.au/en/Research/EF/Areas/Electricity-grids-and-systems/Intelligent-systems/Eddy-home-energy-tool

Smart Grid Smart City

Project Title	Smart Grid Smart City
Company	Ausgrid
Funding	Australian Government $100m
Project Driver	The aim of the *Smart Grid, Smart City* Program was to gather robust information about the costs and benefits of smart grids to help inform future decisions about smart grid technologies by government, electricity providers, technology suppliers and consumers across Australia.
Project Objectives	● Investigate the feasibility of high speed, reliable and secure data communications networks and associated IT systems to integrate with distribution network ● Investigated the ability of grid-side monitoring and control technologies to reduce network operating costs and support the future planning and implementation of lower cost networks. ● Focused on residential electricity consumption, reliability, customer behaviour and responses to feedback technologies and pricing models. ● Investigated the feasibility and potential benefits of distributed generation and distributed storage within electricity grids. ● Investigated the potential impact of wide-scale uptake of electric vehicles in Australia on the electricity distribution network.
Key Processes Trialled	● **Active Volt-VAr Control** Automated voltage regulating and reactive power controls to measure and maintain acceptable voltages and high power factor at all points in the distribution network under varying load conditions. ● **Fault Detection** Automation technologies used to quickly and precisely detect fault conditions, isolate faulty equipment and restore power to customers by operating remotely controlled switches. ● **Substation and Feeder Monitoring** A collection of technologies which monitor the network state (voltage, current and frequency) and condition of assets within the electrical distribution network utilising a common ICT platform. ● **Wide Area Measurement** Measurement devices capable of providing high speed, time-synchronised samples of network data, including voltage, current and frequency, called synchrophasors.
Outputs	● Smart grid technologies should be evaluated on a location specific basis before deployment. ● Rooftop solar **should** be managed to avoid harming the network. ● Fault detection technology can provide significant network benefits and should be appropriately incentivised. ● Fault detection may be more appropriate than LV monitoring in some cases. ● Active volt control should be considered in all cases where power factor, voltage or capacity constraints exist. Economic analysis of the outcomes of the SGSC project suggest that adoption of smart grid technologies across the National Electricity Market would result in an economy wide benefit of $9.5-$28.5 billion over 20 years, and lower network prices. Results also suggest that all customers would benefit from the introduction of a smart grid, with even those customers who didn't actively engage with the smart grid benefiting by between $156 and $2000 per year.
Source	http://www.industry.gov.au/Energy/Programmes/SmartGridSmartCity/Documents/SGSC-Executive-Report.pdf

Power Factor Correction (PFC) Pilot

Project Title	**Power Factor Correction (PFC) Pilot**
Company	Ergon Energy
Funding	Department of Employment, Economic Development and Innovation
Project Driver	● The Power Factor (PF) of power delivered is an indicator of the efficient use of an asset. A low PF means the asset is drawing more power from the grid than it actually uses. ● A PF of 0.9 or above means that at least 90% of the power being transferred is being consumed by the asset, the remaining percentage is lost in the system as 'Wattless' power due to the reactive element of the AC system. ● The aim of this Pilot is to improve the power factor at large customer premises to reduce the amount of 'Wattless' power transferred by the system. This reduces the total electricity that must be generated and distributed by the system, lowering costs and infrastructure. ●
Project Objectives	The aim was to reduce peak demand by 4.7 MVA. The project aimed to take strain off the electricity grid by developing a repeatable, non-traditional demand management process that would reduce: ● Customer electricity demand, and maintenance bills ● Greenhouse gases (network and customer) ● Electricity impacts on neighbors in large commercial or industrial areas ● Government expenditure on infrastructure.
Key Processes	The PFC pilot reduced load at large customer premises by improving the asset PF to 0.9 or better through the introduction of new technology, primarily capacitor banks.
Outputs	● The Toowoomba PFC pilot delivered demand savings above forecast and exceeded expectations for customer engagement. The program metrics prove the value of this demand management initiative with demand reduction of 6.27 MVA against a target of 4.7 MVA. ● It has been used as proof, by Ergon, of the economics of using PFC as an energy-saving method and a new approach to network management in Queensland.
Source	https://www.ergon.com.au/network/network-management/demand-management/previous-pilots-and-trials/power-factor-correction-pilot-project https://www.ergon.com.au/network/manage-your-energy/business-resources/understanding-power-factor

Electric Vehicles: Driving EVolution

Project Title	**Electric Vehicles: Driving EVolution**
Company	Ergon Energy
Project Driver	Electric Vehicles (EVs) have the potential to provide a significant benefit to consumers and utilities, however as demonstrated in Ergon Energy's trials, if EVs are not charged in a grid friendly manner they have the potential to increase peak demand, drive the need for increased infrastructure and put increased pressure on electricity prices.
Project Objectives	● The trial sought to gain real world understanding of customer EV driving and charging behaviour. ● Identify barriers to EV uptake and methods to remover the barriers. ● Investigate what an 'EV friendly Network' looks like.
Key Processes	Over a period of 18 months between 2012 and 2013, Ergon Energy ran trials in Townsville to understand customer acceptance of EVs, and the eco system that supports them, including chargers, electricity tariffs, and the EVs themselves. ● 10 households at two different locations - Townsville inner city (Mysterton) and Townsville city fringe (Mt Low) ● Four charging regimes / electricity tariffs – uncontrolled (T11), controlled (T33), Time of Use (ToU), and modified ToU ● Mitsubishi i-Miev BEVs.
Outputs	● The further out from the CBD the higher the energy consumption with most customers charging happening at night. ● Customers did not charge every day, but charged when they thought they needed to, triggered at about 60% state of charge. ● As the distance from the city increased so too did the likely impact on peak-demand. ● Customers generally preferred the TOU trial as it gave them flexibility over charging and enabled the customers to get a top up if needed during peak time. ● EVs were well accepted by the customers with most of the customers stating they would own one if the price was appropriate. ● Generally customers have substantial capacity in the EV at the start of network peak time and that most of the EVs are at home. This presents an opportunity to unlock this potential to support the network and their own energy needs through developing technologies such as Vehicle-to-Grid (V2G) or Vehicle-to-Building (V2B).
Source	https://www.ergon.com.au/__data/assets/pdf_file/0019/231247/Electric-Vehicles-Driving-Evolution.pdf https://www.ergon.com.au/network/network-management/innovation

Newington Grid Battery Trial

Project Title	Newington Grid Battery Trial
Company	Ausgrid
Project Driver	Varying network load due to connected renewables, storage can be used to level load. The project will investigate the potential of using grid-connected battery storage systems to reduce peak demand as an alternative solution to reinforcement for addressing a network need. Also to investigate power quality benefits and impacts and customer benefits from installing a battery storage system of this size.
Project Objectives	1. Summer peak reduction network benefits: To trial the control and scheduling methodology of a grid battery during the hotter summer months to reduce summer peak demand in a local area. 2. Summer battery performance and reliability: To test the grid battery performance during the hotter summer months when battery performance and reliability of operation may be more adversely affected by temperature. 3. Solar PV smoothing: Using the battery to store energy generation from local solar power systems to decrease potential impacts on the network or customers of intermittent solar generation. 4. Power quality issues: To test the power quality benefits and impacts of installing a grid battery in an urban network. 5. Customer benefits: To test the potential customer benefits of installing a larger battery system to reduce customer energy bills for a non-residential customer.
Key Processes	120kWh of Lithium Ion batteries and three 20kW inverters (one per phase) giving a total power output capacity of 60kW. Connected the HV network and customer connected storage solutions. Trialling: ● Network Peak Reduction ● Battery Performance and Reliability ● Solar Smoothing and Power Quality Impacts ● Customer Benefits
Outputs	**Grid Connected:** ● It is possible to use a grid-connected battery storage system to reduce the load on a network asset on peak demand days. ● A solution which provides a short term reduction in the peak demand on a network asset should ideally have the potential to provide 4-6 hours of demand reduction. ● For battery storage systems to be used to achieve peak reduction, the ability to locate the battery in a specific geographic area that enables deferral of a network need is critical. ● No power quality issues were caused by intermittent PV generation during the trial, this was due to the robust nature of the urban network. **Customer Connected:** ● Solar smoothing and storage can be effective, with annual savings of about \$2,000 to \$2,500 from the energy component of the bill ● When operated to maximise customer benefit, there was a modest network benefit but one that was much lower than when the battery was operated to maximise network benefit.
Source	https://www.ausgrid.com.au/Common/Industry/Demand-management/Energy-use-research-and-reports/~/media/Files/Industry/Demand%20Management/Ausgrid_Newington_Grid_Battery_Report_Final.pdf

Lower South East 275kv Line Uprating

Project Title	**Lower South East 275kV Line Uprating**
Company	Electranet (Transmission)
Project Driver	Avoiding reinforcement works by uprating existing equipment.
Project Objectives	This project will increase the power transfer capability of the Tailem Bend to South East double circuit 275 kV transmission line. By increasing the relevant conductor clearances, the operating temperature of these lines will be increased from 100˚C to 120˚C rating.
Key Processes	Aerial Laser Surveys have allowed the development of as-built asset models to more accurately determine the spatial location of conductors. Applied transmission line ratings are based on these ALS models, which confirm what actual conductor to ground clearances are against those legislated to allow remedial action as required.
Outputs	● The majority of benefits of the project in the short term will be realised through increasing the capability of the Heywood interconnector to import power from Victoria. In the longer term, this project will facilitate increased exports of wind power from South Australia. ● Project scope has been completed and testing of conductor joints is under way prior to detailed design and construction.
Source	https://www.electranet.com.au/projects/lower-south-east-275-kv-line-uprating/ http://www.eesa.asn.au/images/2014/SA/Dynamic_Rating_of_Overhead_Lines_J_Smith.pdf

Hot Water Load Control Trials

Project Title	Hot Water Load Control Trials
Company	Ausgrid
Project Driver	● Controlled load tariffs apply to an appliance that is metered separately to the rest of a households supply and is controlled to run outside peak times. The vast majority of the appliances connected to these tariffs are domestic hot water systems. Ausgrid has two controlled load network tariffs (Controlled Load 1 and Controlled Load 2). ● Three demand management innovation projects were developed and implemented by Ausgrid between 2011 and 2015 with the aim of exploring innovative approaches to reducing the impact of peak demand from residential hot water systems using load control solutions. Project one, to control small hot water systems is of relevance to this analysis.
Project Objectives	● Aimed to explore the technical and practical considerations for controlling small hot systems (less than 100 litres) directly at the appliance rather than through a controlled load tariff. ● Test customer response issues for limiting the electricity supply to small hot cylinders on an occasional basis to determine whether customers were still satisfied with hot water system performance ● Determine control times to limit customer disruption ● Evaluate customer response to marketing offers.
Key Processes	1: Installing a time switch with a bypass button on the hot water electrical circuit at the homes of 44 Ausgrid customers set to switch the supply to the hot water system for four hours (5pm-9pm) on one weekday a week for 18 months.
Outputs	● The results suggest that customers will tolerate the occasional control of their small hot water system for several hours on peak days for a modest financial incentive. ● Customers reported no complaints due to insufficient hot water when the electricity supply to their small to medium hot water cylinders was switched off for 4 hours on the occasional day. ● Although override was available, customers rarely used the option during load control events. ● A simple directly addressed letter with follow-up phone call offered the highest customer take-up rate. ● The higher incentive level of $100 offered only a modest improvement in customer take-up rate over the $50 incentive offer. ● The average peak demand reductions achieved was about 270 Watts per system in summer and about 400 Watts per system in winter. ● Total program costs including customer engagement and acquisition costs (e.g. marketing materials or customer contact) and the cost of supply and installation of the load control devices were **high per kilowatt of demand reduction.**
Source	https://www.ausgrid.com.au/Common/Industry/Demand-management/Energy-use-research-and-reports/~/media/Files/Industry/Demand%20Management/Ausgrid%20Hot%20Water%20DMIA%20Projects%20Final%20Report.pdf http://www.ausgrid.com.au/Common/Industry/Demand-management/What-is-demand-management.aspx#.V87uUP9THVg

Appendix II Low Carbon Network Fund – Tier 1 Innovation Projects

33kV Superconducting Fault Current Limiter

Project Title	**33kV Superconducting Fault Current Limiter**
Company	NPg
Project Funding	£2,880,000 – LCNF Tier 1
Project Driver	To facilitate the connection of distributed generation (DG) from renewable sources at the distribution level, the network needs to be capable of withstanding the consequential increase in fault level associated with such connections.
Project Objectives	This project trialled a specific piece of new equipment that has a direct impact on the operation and management of the distribution system. The first phase was to identify suitable locations for the installation and undertake a feasibility and systems readiness study to analyse the network, outlining the optimum application and specification, and confirm the business and carbon cases. The second phase was to design, build, install and commission a three-phase 33kV superconducting fault current limiter (SFCL) on the Northern Powergrid distribution network.
Key tech/process trialled	33kV Superconducting Fault Current Limiter placed at the boundary of the transmission and distribution networks at a substation jointly owned by National Grid and Northern Powergrid.
Timescales	01/2010 - 06/2013
Outputs/ Implementation/ Impact (as reported by DNO)	'With the experience from this activity, and a previous trial at 11kV, there is now sufficient confidence to specify fault current limiters as a standard network solution at 11kV for deployment during ED1. It is recommended that appropriate standards and policies are now generated to facilitate this within Northern Powergrid. These are planned for review and update during 2015.'[11] However, the 33kV SFCL was not found to be capable of meeting the required performance specification at the time.

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

The Bidoying 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	January 2012 – December 2014
Outputs/ Implementation/ Impact (as reported by DNO)	Formed the basis of ENWLs internal policy and code of practice documentation and installation instructions and procedures. The Smart Fuse now provides a means to manage low voltage transient faults by eliminating 80% of fuse operations once faulty feeders are identified. The Smart Fuse has provided over 2GB of high resolution data that has been used to analyse the performance of selected low voltage underground feeders. Electricity North West's current average short duration interruption is approximately 60 minutes therefore when a Smart Fuse restores supplies in under the IIS target of 3 minutes it effectively eliminates 'Customer Interruptions' (based on an average number of customers connected to low voltage feeders) and 60 minutes of 'Customer Minutes Lost' penalties, it is estimated that an average penalty of £500 is avoided with every Smart Fuse low voltage feeder supply restoration. In addition to the financial benefits from an enhanced performance under the IIS incentive, the benefits of being able to better manage transient faults whilst keeping customers connected cannot be underestimated.

Clyde Gateway

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

Digital Substation Platform

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

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

Project Title	Distribution Network Visibility
	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.

Hook Norton Low Carbon Community Smart Grid

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

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

Implementation of Real-Time Thermal Ratings

<table>
<tr><th>Project Title</th><th>Implementation of Real-Time Thermal Ratings</th></tr>
<tr><td>Company</td><td>SPEN with University of Durham, Areva, Imass and Parsons Brinckerhoff</td></tr>
<tr><td>Project Funding:</td><td>£450,000</td></tr>
<tr><td>Project Driver</td><td>Enable more flexibility in new generation</td></tr>
<tr><td>Project Objectives</td><td>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.</td></tr>
<tr><td>Key tech/process trialled</td><td>RTTR including installation of meteorological stations</td></tr>
<tr><td>Project Business Case (as reported by DNO)</td><td>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.
<table>
<tr><td>IT</td><td>£77,952</td></tr>
<tr><td>Materials</td><td>£1,306</td></tr>
<tr><td>TOTAL</td><td>£79,258</td></tr>
</table>
</td></tr>
<tr><td>Timescales</td><td>July 2010 – June 2013</td></tr>
</table>

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

Interconnection of WPD and NGC SCADA System

Project Title	Interconnection of WPD and NGC SCADA Systems
Company	WPD
Project Funding	£79,000 – LCNF Tier 1
Project Driver	Establish a real time link between the SCADA systems operated by NGC and WPD using the ICCP protocol such that data on either system can be viewed on the other in real time
Project Objectives	· Establish the link · Establish access to the data and methods of viewing the data · Establish the security measures required to ensure the security of the link to both of the systems against Cyber attack
Key tech/process trialled	The IT infrastructure required to achieve the above objectives.
Timescales	12/2011 - 12/2012
Outputs/ Implementation/ Impact (as reported by DNO)	This trial has been a success with data from the WPD POWERON system being visible with the XA/21 control system at NGC. It is therefore envisaged that the link will be used to allow further real-time data to be collated and transferred, potentially from multiple sources. For WPD to make this live, addition configuration would be required in POWERON to transfer the aggregation and trace process from a test function to a live application. Additional configuration works would also be required to create the aggregation points, allowing the process to collate data prior to transfer through the ICCP link. For NGC to take this forward with additional links, further configuration works will be required on a specific case by case basis. This will include the development of a separate Front End Processer (FEP) for each link to ensure security can be maintained. At initiation of this trail, the ICCP link functionality was at TRL 7. As further work is required to assess the use of the link with multiple connections, it is considered that the TRL is unchanged.

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. Exploring: ● How to measure and capture voltage, current, harmonic, real and reactive power data on a range of distribution assets in suburban areas. ● How to install equipment safely with minimal or no interruption of supply ● How often the network characteristics need to be monitored (for example 1min, 5min, 15min) ● How we can interrogate the large amounts of data generated to highlight significant network issues created by the installation of PV panels ● What the effect is of installing large numbers of PV panels on the LV network
Key tech/process trialled	How to measure and capture voltage, current, harmonic, real and reactive power data on a range of distribution assets in suburban areas. How to install equipment safely with minimal or no interruption of supply How often the network characteristics need to be monitored What the effect is of installing large numbers of PV panels on the LV network
Timescales	Ends November 2013
Outputs/ Implementation/ Impact (as reported by the DNO)	The magnitude of power flows from the HV network, through the distribution transformer into the LV network is significantly reduced during periods of high solar irradiance due to the export from the installed micro generation. 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.

Temperature Monitoring Wind Farm Cable Circuits 1

<table>
<tr><th>Project Title</th><th>Temperature Monitoring Wind Farm Cable Circuits</th></tr>
<tr><td>Company</td><td>SPEN</td></tr>
<tr><td>Project Funding</td><td>£710,500 – LCNF Tier 1</td></tr>
<tr><td>Project Driver</td><td>Enable further network capacity being available without the need for network reinforcement to allow increasing number of DG connections.</td></tr>
<tr><td>Project Objectives</td><td>Determine dynamic cable ratings for three cable circuits and assess the impact the renewable generation from the three wind farms will have on these circuits.</td></tr>
<tr><td>Key tech/process trialled</td><td>Temperature monitoring of cables;
Determination of dynamic cable ratings associated with wind generation output; and
Determination of available head room capacity.</td></tr>
<tr><td>Project Business Case (as reported by DNO)</td><td>Needs further work to quantify, but potential for increased headroom and increased capacity of connection of, in particular, wind farms.
<table>
<tr><th>Expenditure Area</th><th>Value (£)</th></tr>
<tr><td>IT</td><td>£31,623</td></tr>
<tr><td>Labour</td><td>£161,263</td></tr>
<tr><td>Optical fibre installation</td><td>£321,315</td></tr>
<tr><td>Distributed Temperature Sensing (DTS) and Dynamic Cable Rating (DCR) equipment</td><td>£181,000</td></tr>
<tr><td>TOTAL</td><td>£695,200</td></tr>
</table>
</td></tr>
<tr><td>Timescales</td><td>October 2012 – March 2015</td></tr>
<tr><td>Outputs/ Implementation/
Impact</td><td>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
Policy documents and technical specifications for future DTS and DCR systems for BAU application.</td></tr>
</table>

Temperature Monitoring Wind Farm Cable Circuits 2

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

Validation of 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	January 2012 – November 2014
Outputs/ Implementation/ Impact (as reported by the DNO)	A validated and pragmatic connection assessment approach, comprising a formal design procedure and an improved tool, that UK Power Networks will adopt into business as usual and share with other GB DNOs during 2015: The formal design procedure includes recommended design assumptions, based on real-life data. The improved tool calculates voltage rise in three steps: the first step provides a worst-case result using minimal inputs, and if required, subsequent steps provide more-accurate results, using more-detailed inputs. A rich dataset, available for GB DNOs and academic institutions to use, comprising: Measurements from 20 distribution substations and 10 customers' PV installations; 25,775 days of valid data, spanning 16 months; Over 171 million individual observations; and Nearly three months of high-resolution (one-minute) measurements over summer 2014. A review of voltage control solutions that could be trialled or adopted in GB, including recommendations of which solutions best suit likely constraint scenarios.

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.

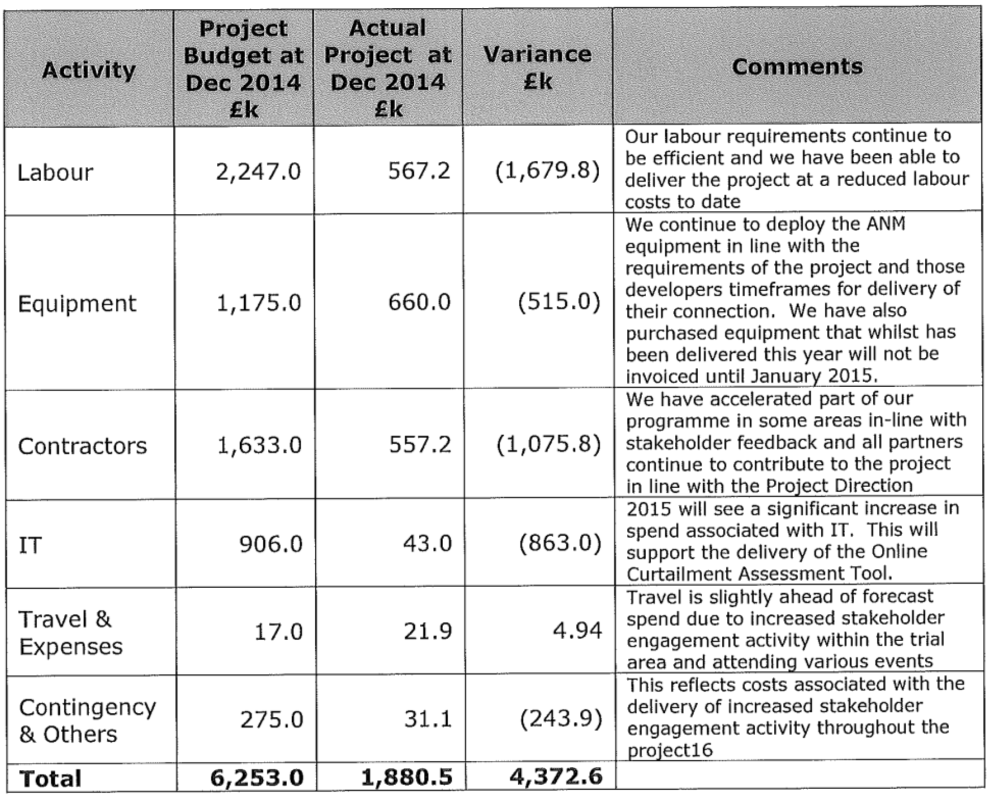
Voltage Control System Demonstration Project

Project Title	Voltage Control System Demonstration Project
Company	WPD
Project Funding	£525,000 – LCNF Tier 1
Project Driver	This project aimed to address the issue of fluctuations seen in long distribution lines in a rural area with Distributed Generation (DG) in the form of wind turbines.
Project Objectives	The objective was to determine the effectiveness of D-SVCs (Static VAr Compensator for Distribution Networks) as a system to control voltage on 11kV rural networks.
Key tech/process trialled	The intention was to trial a single installation of Hitachi's D-SVC on the 11kV network. Once the impact of a single device was established then a second phase would investigate the impact of multiple devices. The first phase's initial deployment has produced a number of outcomes that mean Phase 2 will be better investigated through a wider project scope. The output from Phase 1 has highlighted important learning from operating a single device. In light of this learning, Phase 1 was suspended and the new scope for Phase 2 will be extended and run as a new project.
Timescales	03/2014 - 03/2015
Outputs/ Implementation/ Impact (as reported by DNO)	This project established that the D-SVC could help control the voltage on the 11kV rural network by marginally reducing the absolute voltage and significantly helping to smooth the voltage profile. The project also highlighted the need of closer integration between the Hitachi systems and WPD's control systems along with the need to consider an innovative, reliable and high band width communication solution. The integration of the D-SVC with DNO's systems was more complex than envisioned. The D-SVC was originally designed to be almost entirely stand alone. In addition to this, the absolute effect of the D-SVC on the HV voltage was less than expected. It was thought this was predominantly due to the use of a standard transformer and the output of the D-SVC not being optimal for the size of the windfarm. The D-SVC did demonstrate a good ability to smooth the voltage profile. It was possible to assess the wider impact of reactive power on the system too. Additionally, the suitability of the eMS sub.net monitors for monitoring various parameters was explored. This highlighted inconsistencies of harmonic measurements from the sub.net alongside other 'Class A' devices.

Appendix III Low Carbon Network Fund – Tier 2 Innovation Projects

Accelerating Renewable Connections (ARC)

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 Commercial arrangements
Project Business Case (as reported by DNO)	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.



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**	

Project Title	Accelerating Renewable Connections (ARC)
	The above table is from an ARC 6 monthly report published in December 2014.
Timescales	January 2013 – December 2016
Current status	Underway
Outputs/ Implementation/ Impacts (as reported by DNO)	The ARC project team have enabled the connection of: An additional generation unit (1.6 MW Wind Farm) by the end of Q1 of 2015 that would otherwise, under National Grid Electricity Transmission's existing contractual and connection policy arrangements, have been delayed in connecting until 2021 at the earliest; and An 80kW PV array on 11kV network connected on a non-firm Actively Managed basis delivered at a fraction of the original cost estimate. According to SPEN's December 2014 Progress Report ANM was being accelerated through to BAU 18 months ahead of schedule.

Capacity to Customers (C_2C)

Project Title	Capacity to Customers (C_2C)
Company	Lead: ENWL, Partners: IGE UK Ltd/Parsons Brinckerhoff Ltd, Flexitricity/ENerNoc/npower, NGET, University of Strathclyde/University of Manchester, Tyndall Centre for Climate Change and Association of Greater Manchester Authorities
Project Funding	£9.597m - LCNF Tier 2 inc. partner contribution
Project Driver	Unlocking capacity for generation and demand
Project Objectives	Adaptive network control functionality: The trial will develop advanced network control functionality that will through productisation be available to all GB DNOs; Demand response commercial templates: The trial will produce a series of model commercial contracts that can be used by all DNOs to extend the C2C method and its benefits to all DNO customers; Customer segmentation template: The trial will produce a customer segmentation template, describing how a DNO's customer base can be segmented and hence better approached for the introduction of demand response contracts; New connections process: The trial will produce a new connections process detailing those technical and commercial steps required to extend the benefits to future C2C customers; Network data: Detailed analysis of the benefits of the C2C method on network losses and power quality in the form of a full set of network performance data; and New design and planning standard: to inform the amendment or replacement of Engineering Recommendation P2/6.
Key tech/process trialled	HV network automation – closing the Normal Open Point (NOP) between two adjacent HV circuits; and PowerOn Fusion.
Project Business Case (as reported by DNO)	ENWL's analysis shows that if the technical and commercial elements of the C_2C solution were adopted across the ENWL's network, then it would **release 2.4 GW of existing capacity on the HV networks, without reinforcement**. This is around 35% of the existing firm HV network capacity or around 50% of simultaneous HV demand. Analysis of electrical energy scenarios to 2050 suggests the C_2C method could thus replace much of the traditional HV reinforcement activity in the period to 2035; however this is viewed as a conservative estimate and could indeed defer reinforcement in certain networks to 2050.
Timescales	January 2012 – December 2014
Current status	Complete
Outputs/ Implementation/ Impacts (as reported by DNO)	ENWL's analysis shows that if the technical and commercial elements of the C_2C solution were adopted across the ENWL's network, then it would **release 3.1 GW of existing capacity on the HV networks**, without reinforcement. This is around 65% of the existing firm HV network capacity. Analysis of electrical energy scenarios to 2050 suggests the C_2C method could thus replace much of the traditional HV reinforcement activity in the period to 2035; however this is viewed as a conservative estimate and could indeed defer reinforcement in certain networks to 2050.

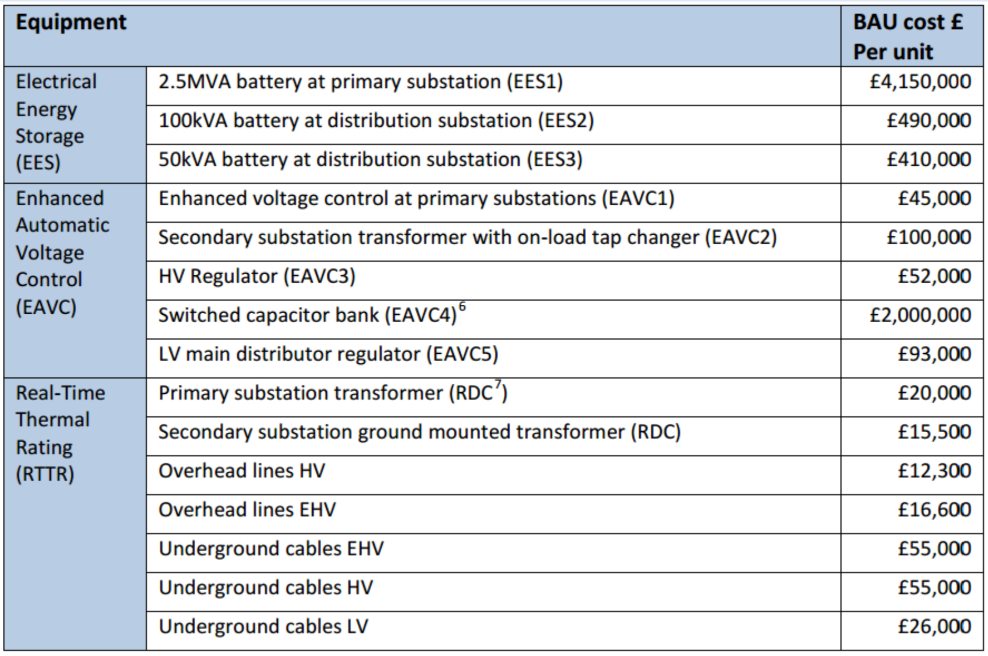
Project Title	**Capacity to Customers (C_2C)**
	under high demand expectancy that the deployment of the C_2C Solution in conjunction with traditional reinforcement to form an economically optimised strategy has the potential to **reduce total future HV network reinforcement costs (i.e. both customer and DNO funded) by approximately £50m**. However, the avoidance of future expenditure under a lower demand requirement can be met with the C_2C Solution delivering £60m of benefits. Should the C_2C Solution be scaled up and rolled out across suitable GB networks, the customer savings are even more significant. Based on advancing connections by around six months, the C_2C Method could directly claim to **facilitate 39-67 thousand tCO_2e of emissions reductions in Electricity North West network area** (depending on how the capacity is used). On the scale of Great Britain, this **carbon saving would be of the order of 0.5-0.9 million tCO_2e to 2035**. The Tyndall Centre indicates that C_2C Solution deployment in conjunction with strategic traditional reinforcement on Electricity North West's HV network in the period 2015 - 2035 would give a **net network wide reduction of 237-328 tCO2e**. This is based on saving some 58-89 thousand tCO2e network wide from reduced deployment of assets, but decreasing carbon associated with losses by 179-239 thousand tCO2e relative to traditional reinforcement techniques. For the ten new connections customers, the total customer contributions for a traditional solution would have been £7.84m versus the contributions required for the C2C Solution which totalled £0.37m, i.e. a saving of £7.47m for customers due to savings from the associated reinforcement. The customer types covered both demand and generation managed contracts and ranged in capacity from 500kVA to 10 500kVA. The following objectives were met or proven: The C2C Method will release significant capacity to customers from existing infrastructure The C2C Method will enable **improved utilisation of network assets** through greater diversity of customers on a closed network ring The C2C Method will **reduce like-for-like power losses** initially but this benefit will gradually erode as newly released capacity is utilised The C2C Method will improve power quality resulting from stronger electrical networks. The C2C Method will **facilitate lower reinforcement costs** for customers for the connection of new loads and generation The C2C Method will **facilitate a reduction in the carbon costs of network reinforcement** The C2C Method will **effectively engage customers in a new form of demand and/ or generation side response** thereby stimulating the market and promoting the future use of commercial solutions Interconnected C2C operation generally releases more demand capacity than radial C2C operation Use of post-fault demand response in security of supply requirements.

Customer Led Network Revolution (CLNR)

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

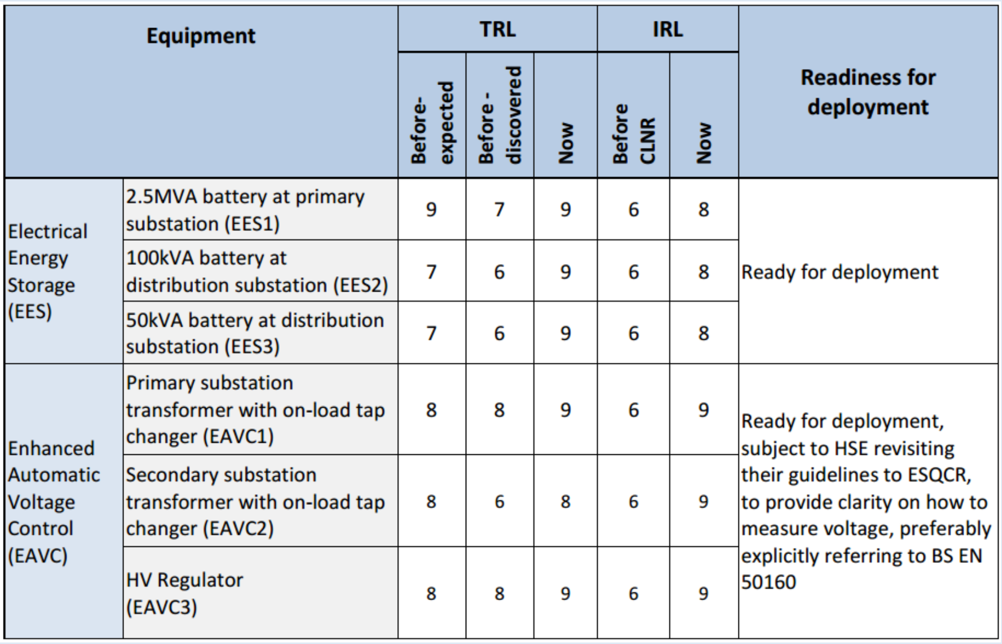
In addition to the above, the project had the following learning outcomes:
To understand current, emerging and possible future customer (load and generation) characteristics.
To what extent are customers flexible in their load and generation, and what is the cost of this flexibility?
To what extent is the network flexible and what is the cost of this flexibility?
What is the optimum solution to resolve network constraints driven by the transition to a low carbon economy?
What are the most effective means to deliver optimal solutions between customer, supplier and distributor?</td></tr>
<tr><td>Key Tech/Process Trialled</td><td>Electrical Energy Storage (EES)
Enhanced Automatic Voltage Control (EAVC)
Real Time Thermal Rating (RTTR)
Demand Side Management (DSM)</td></tr>
<tr><td>Project Business Case (as reported by DNO)</td><td>Adopting project learning nationally, £5-26 billion net financial benefit between 2020 and 2050 and 10.8-32.5 Mt CO_2 emissions savings corresponding to low and high uptake scenarios from DECC.
<table>
<tr><th rowspan="2">NPV net financial benefits over period 2020-2050
£billion in 2014 money</th><th rowspan="2">Original business case</th><th colspan="2">Revised business case</th></tr>
<tr><th>Low</th><th>High</th></tr>
<tr><td>Network capital cost savings</td><td>£2.33</td><td>£3.25</td><td>£17.70</td></tr>
<tr><td>Direct customer benefit</td><td>£0.36</td><td>£1.30</td><td>£7.00</td></tr>
<tr><td>Carbon emission savings</td><td>£2.64</td><td>£0.32</td><td>£0.94</td></tr>
<tr><td>Generation capital cost savings</td><td>£0.96</td><td></td><td></td></tr>
<tr><td>Total</td><td>£6.30</td><td>£4.87</td><td>£25.64</td></tr>
</table></td></tr>
<tr><td>Timescales</td><td>January 2011 - December 2014</td></tr>
<tr><td>Current status</td><td>Complete</td></tr>
<tr><td>Outputs/ Implementation/ Impact (as</td><td>Adopting project learning nationally, £5-26 billion net financial benefit between 2020 and 2050 and 10.8-32.5 Mt CO_2 emissions savings corresponding to low and high uptake scenarios from DECC.</td></tr>
</table>

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



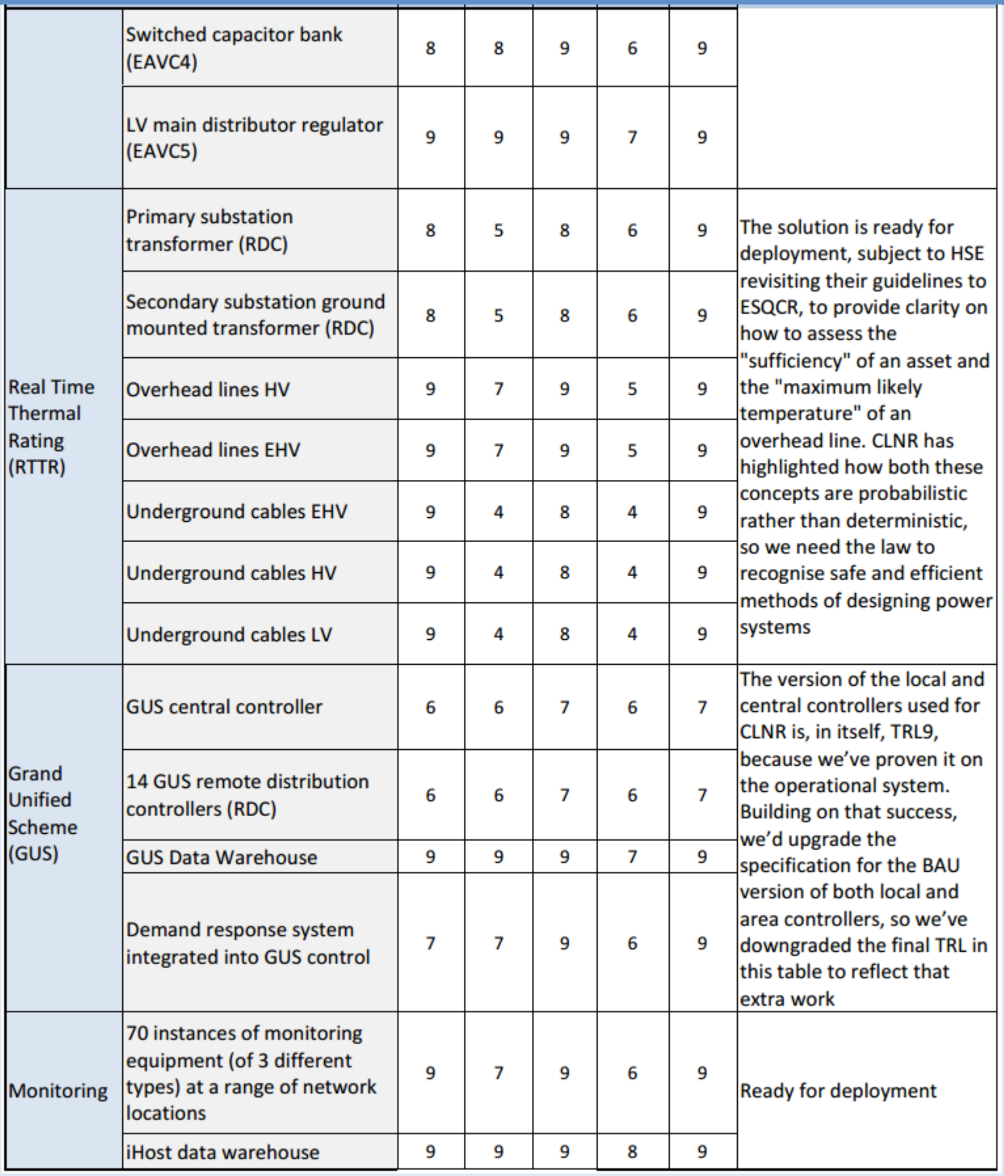
Equipment		**BAU cost £ Per unit**
Electrical Energy Storage (EES)	2.5MVA battery at primary substation (EES1)	£4,150,000
	100kVA battery at distribution substation (EES2)	£490,000
	50kVA battery at distribution substation (EES3)	£410,000
Enhanced Automatic Voltage Control (EAVC)	Enhanced voltage control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

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



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	

Project Title	**Customer-Led Network Revolution**

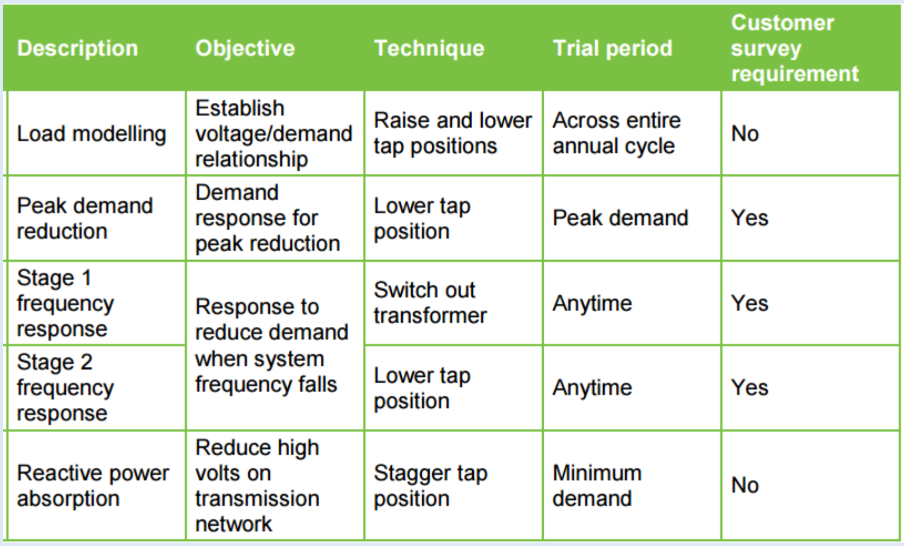


	Switched capacitor bank (EAVC4)	8	8	9	6	9	
	LV main distributor regulator (EAVC5)	9	9	9	7	9	
Real Time Thermal Rating (RTTR)	Primary substation transformer (RDC)	8	5	8	6	9	The solution is ready for deployment, subject to HSE revisiting their guidelines to ESQCR, to provide clarity on how to assess the "sufficiency" of an asset and the "maximum likely temperature" of an overhead line. CLNR has highlighted how both these concepts are probabilistic rather than deterministic, so we need the law to recognise safe and efficient methods of designing power systems
	Secondary substation ground mounted transformer (RDC)	8	5	8	6	9	
	Overhead lines HV	9	7	9	5	9	
	Overhead lines EHV	9	7	9	5	9	
	Underground cables EHV	9	4	8	4	9	
	Underground cables HV	9	4	8	4	9	
	Underground cables LV	9	4	8	4	9	
Grand Unified Scheme (GUS)	GUS central controller	6	6	7	6	7	The version of the local and central controllers used for CLNR is, in itself, TRL9, because we've proven it on the operational system. Building on that success, we'd upgrade the specification for the BAU version of both local and area controllers, so we've downgraded the final TRL in this table to reflect that extra work
	14 GUS remote distribution controllers (RDC)	6	6	7	6	7	
	GUS Data Warehouse	9	9	9	7	9	
	Demand response system integrated into GUS control	7	7	9	6	9	
Monitoring	70 instances of monitoring equipment (of 3 different types) at a range of network locations	9	7	9	6	9	Ready for deployment
	iHost data warehouse	9	9	9	8	9	

Customer Load Active System Services (CLASS)

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.

Key tech/process trialled



Description	Objective	Technique	Trial period	Customer survey requirement
Load modelling	Establish voltage/demand relationship	Raise and lower tap positions	Across entire annual cycle	No
Peak demand reduction	Demand response for peak reduction	Lower tap position	Peak demand	Yes
Stage 1 frequency response	Response to reduce demand when system frequency falls	Switch out transformer	Anytime	Yes
Stage 2 frequency response		Lower tap position	Anytime	Yes
Reactive power absorption	Reduce high volts on transmission network	Stagger tap position	Minimum demand	No

Figure 4: Summary of CLASS trials.

Project Business Case (as reported by DNO)	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.**

Project Title	**Customer Load Active System Services (CLASS)**
	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.
Timescales	January 2013 – September 2015
Current status	Complete
Outputs/ Implementation/ Impacts (as reported by DNO)	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; Although it is clear that the CLASS Method will defer network reinforcement, it is very difficult to predict the exact time period due to load growth uncertainties. It is estimated that CLASS could defer an assessment replacement scheme by up to three years. The CLASS technique can provide National Grid with a demand response for frequency reserve services. The results from the trials have shown that demand response can be achieved in less than 0.5 seconds; The trials for reactive power absorption indicated a significant benefit. It is estimated that across the ENWL's network, a maximum of 167 MVAr could be absorbed during winter peak periods and 133 MVAr during the summer minimum. It is estimated that in GB a maximum of 1.84 GVAr could be absorbed during winter peak periods and 1.67 VAr during summer. These results indicate there is an opportunity to provide National Grid with reactive power services; and The total **carbon impact benefit to National Grid** from the **combined demand response and reactive power ancillary services** could be as much as **116,000 tCO2e per annum**. Notably, there were no statistically significant variations in the proportion of customers who observed a change to their power quality in any of the customer segments consulted, demonstrating that CLASS was indiscernible to all types of customers. The level of overall satisfaction with service/supply quality amongst the survey population was either maintained or improved during the CLASS trials.

Fault Level Active Response (FLARE) - ENWL

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

Fault Level Active Response (FLARE) - UKPN

Project Title	Fault Level Active Response (FLARE)
Company	UKPN with ABB, Parsons Brinckerhoff, Energ-G, Impact Research, Combined Heat and Power Association, Schneider Electric, United Utilities and The University of Manchester School of Electrical & Electronic Engineering, Tyndall Manchester Centre for Climate Change, Greater Manchester Combined Authority
Project Funding	£5.49m LCNF Tier 2 inc. external funding
Project Driver	To help distribution network operators to quickly connect customers' low carbon demand and generation and at a lower cost than traditional reinforcement.
Project Objectives	1. To trial the Fault Level Assessment Tool software; 2. To trial two technical and one commercial techniques which, when deployed on existing network infrastructure, will provide effective and efficient fault level control; 3. To deliver novel and highly transferable solutions that can be applied to the HV and EHV networks by any GB DNO; 4. To demonstrate release of network capacity allowing quick and lower cost connection for customers' demand and generation, enabling DNOs to support the UK's decarbonisation strategy.
Key tech/process trialled	1. Adaptive Protection – also known as sequential tripping. This technique re-sequences the operation of CBs and is retrofitted into existing substation equipment. 2. Fault Current Limiting service (FCL service) – Industrial, commercial and generation customers can operate their equipment so they can offer fault level management services to DNOs using new technology trialled under FLARE. This commercial solution will enable customers to earn rewards and will benefit all distribution customers through reduced reinforcement. 3. IS-limiters – an existing technology used on private networks in the UK and extensively on public networks in Europe, USA and Australia as a fault current mitigation technique. This will be the first installation of an IS-limiter on a GB DNO network. A 2004 report written by Parsons Brinckerhoff Development of a safety case for the use of current limiting devices... 4 suggested that installation of IS-limiters would lead to difficulties in complying with a number of Electricity Safety, Quality and Continuity Regulations (ESQCR) and Electricity at Work regulations. PB Power is the technical support Partner for this Project. Together we aim to demonstrate how these devices can be deployed safely and legally and unlock the benefits this technology can provide for customers.
Project Business Case (as reported by DNO)	The FLARE Method releases the same capacity as traditional reinforcement but up to 18 times faster and at much lower cost – up to 80% cheaper – potentially saving GB £2.3 billion by 2050.
Timescales	January 2015 – October 2018
Current status	Begun

Project Title	Fault Level Active Response (FLARE)
Outputs/ Implementation/ Impacts (as reported by DNO)	The FLARE Method will reduce overall costs of the distribution network, avoid fault level reinforcement and enable much quicker connection of low carbon demand and generation. FLARE could deliver savings for DUoS customers of around £2.3 billion by 2050 and reduce costs for connections customers. It could also be used to enhance other fault level mitigation techniques such as those being trialled as part of FlexDGrid, a Second Tier LCN Fund project run by Western Power Distribution (WPD). FLARE could release 127 275MVA of capacity for the connection of customers' new low carbon generation and demand.

FlexDGrid – Advanced Fault Level Management in Birmingham

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

Flexible Approaches for Low Carbon Optimised Networks (FALCON)

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

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

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

Flexible Networks for a Low Carbon Future

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

Project Title

Flexible Networks for a Low Carbon Future

Project Business Case (as reported by DNO)

Site	Lowest cost traditional method	Year to complete traditional reinforcement	Future method cost	Additional capacity
St Andrews	£6,200k	3	£646k	4.2MVA
Whitchurch	£3,100k	2	£612k	3.8MVA
Ruabon	£1,200k	1-2	£337k	514W per customer

Cost comparison between traditional and innovative solutions for network capacity expansion.

Timescales

January 2012 – December 2014

Current status

Complete

Outputs/ Implementation/ Impact (as reported by DNO)

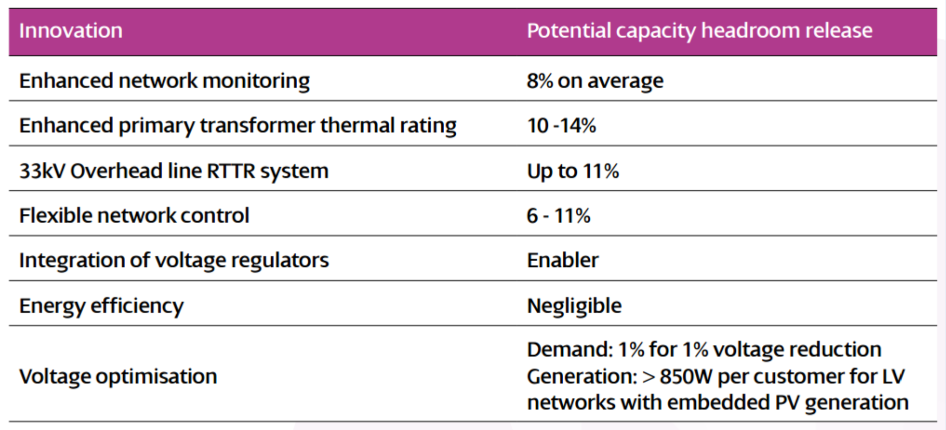
A 20% increase in network capacity through a number of innovative measures.

Learning outcomes from Flexible Networks indicate that net benefits may be greater than the initially reported saving of £8.1m against traditional network solutions.

A reduction in reinforcement costs of between 70% and 90% was achieved for the three trial sites.

The total project cost was £5.2M. Updated analysis indicates that the future method cost for these same three sites will be approximately £1.6M in total. Compared to a base case cost of £10.5M, this provides a net benefit of £8.9M.

Whilst energy efficiency measures were not applied at St Andrews or Ruabon as part of the future method, adequate capacity gain was achieved through other measures.



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

Capacity headroom release for Flexible Networks methods trialled.

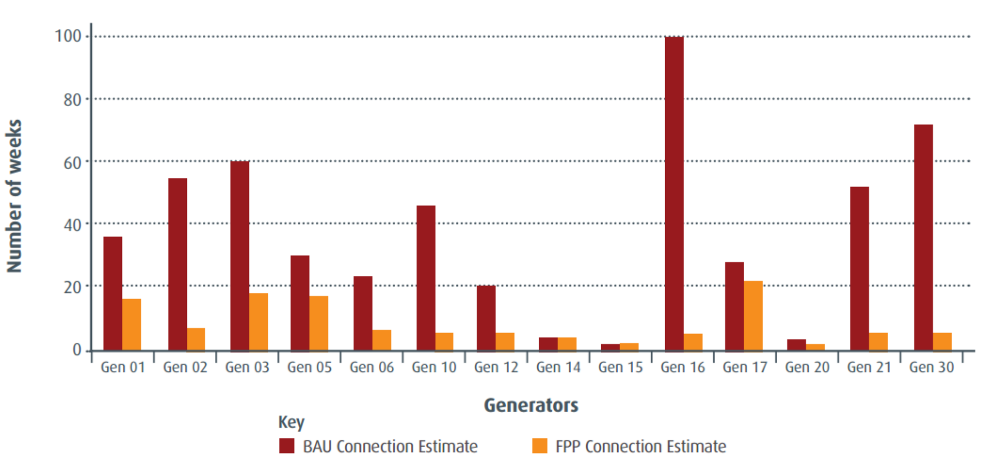
Flexible Plug and Play (FPP)

Project Title	Flexible Plug and Play (FPP)
Company	Lead: UKPN, Partners: Cable & Wireless Worldwide, Silver Spring Networks, Smarter Grid Solutions, Alstom Grid, Converteam, Fundamentals, S&C Electric, GL Garrad Hassan, Imperial College London, University of Cambridge and the IET.
Project Funding	£9.7m - LCNF Tier 2 inc. partner funding
Project Driver	Connecting distributed generation to the distribution network
Project Objectives	Develop a Strategic Investment Model which will allow DNOs to quantify, for different demand and generation scenarios, the integrated value and benefits of different smart technologies, smart commercial arrangements and smart applications. This model will also determine from both an economic and carbon perspective whether it is better to reinforce the network or use smart alternatives.
Key tech/process trialled	ANM/telecommunications – technical parameters DNOs need to consider when designing and operating such systems. Identifying critical constraint points in the network and actively managing them with ANM and smart devices. First DNO to explore the use of RF mesh technology for ANM applications. Commercial Arrangements – alternative methods of allocating curtailment, pro-rata and Last-In-First-Off, performance and practicality. Connection offers and connection agreements which form legal contract between customer and DNO and new T&Cs. Smart device – EAVC systems, dynamic line rating systems, optical sensors, a quadrature-booster and associated control system, novel protection systems. – support the delivery of the flexible connections by reducing the levels of generation curtailment whilst maintaining network security.
Project Business Case (as reported by DNO)	The technical innovation focuses on the development of an open standards platform to enable end-to-end communication between distributed smart network technologies and generation. FPP allows for decentralised monitoring, control and overall operational management of both network and generation by active network management applications. This concept and technical architecture has not been tested in a production environment in the UK before and will be a leap forward in the evolution of the DG-enabled network. Commercial innovation will be delivered in the form of investment modelling and new commercial contracts to provide flexibility and customer choice to generation customers. FPP will address the need for a more responsible, cost efficient and flexible approach to generation customer connections.
Timescales	January 2012 - December 2014
Current status	Completed
Outputs/ Implementation/ Impact (as reported by DNO)	The **flexible connections quotations** issued to DG customers in the trial area since March 2013 have proven to be a cheaper alternative than the business-as-usual alternative, **saving a minimum of 45% compared to the traditional business-as-usual offer**, with **over half of the flexible connection offers providing a saving over 90%**. Across all of the projects the **average saving is of approximately 87%, which equates to a reduction of approximately £6.5m per project**. Taking into consideration all the ANM and communication equipment costs and curtailment, over a 20 year period, all but two of the flexible connection

Project Title	Flexible Plug and Play (FPP)

offers were still more financially viable than the business-as-usual offers with an average saving of ~65% or £5.4m per project. This further reinforces that flexible connections do not only provide a short-term benefit, but **even after 20 years of curtailment they provide a long-term viable alternative**.

The **average connection time saving is approximately 29 weeks.**



Time to connect a generation customer, comparing BAU with FPP offers.

UKPN will integrate Flexible Plug and Play connection offers (as per UKPN's Low Carbon Network Fund Project) into BAU by Q2 2015.

Flexible Urban Networks (FUN-LV)

Project Title	Flexible Urban Networks (FUN-LV)
Company	Lead: UKPN, Partners: GE Digital Energy, IC Consultants Ltd, PPA Energy and CGI UK Ltd
Project Funding	£8.86m – LCNF Tier 2 inc. partner contributions
Project Driver	Government policy / low carbon targets driving the connection of LCTs in areas of network constraint
Project Objectives	**Optimise capacity on the low voltage network closest to customers** to accommodate the forecasted growth in electric vehicle charging, heat pumps and microgeneration on existing connections by making the network more flexible and resilient through capacity sharing between substations; **Improve connection offers (time & cost) in urban areas** by knowing where best to connect, and by managing voltage, power flows and fault current through the use of power electronics; and **Advance the future network architecture debate for the sector** through the evaluation and dissemination of financial learning, benefits and architecture of the power electronics applications on different network architectures and by providing network configuration control in combination with remote switching.
Key tech/process trialled	Three types of power electronic device (PED) connected to 36 trial sites in London and Brighton, across radial and interconnected networks. The trials will explore the following: Suitability of PEDs to release capacity and defer network reinforcement; PED control algorithms required for autonomous control; Connection of PEDs to network control systems; and Modelling of PEDs in planning tools to demonstrate power flow Enhanced Network Assets (LV automation and soft open points) Communications, System Integration and Data Management
Project Business Case (as reported by DNO)	There are important non-financial, and presently unquantified benefits expected from FUN-LV. For some benefits (and costs) it will only be possible to meaningfully quantify these during the course of the project. Work stream 4 is dedicated to conducting a cost benefit analysis of FUN-LV. The overall business case for carrying out the project remains strong. At a GB scale, the benefits have fallen slightly from £112.8m to £90.2m but are significant. This will be validated further during the workstream 4 cost benefit analysis activities.
Timescales	January 2014 – December 2016
Current status	Underway
Outputs/ Implementation (as reported by DNO)	Network Awareness and Process Improvements Cost Benefit Analysis of using PEDs against traditional network reinforcement methods.

Innovation Squared (I^2EV) – My Electric Avenue

Project Title	Innovation Squared (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	Commercial innovation: third party delivery of an innovation project Technical innovation: Decarbonising the transport sector; Assess and mitigate the impact of clustering of EVs on electricity networks (mainly LV)
Project Objectives	To test the delivery of an innovation project by a third party, and to develop a commercial blueprint for future roll out of innovation projects Learn customer driving and EV charging habits; Trial Smart equipment to mitigate the impact of EV charging on the network; and Explore the network benefits of such technology.
Key Tech/Process Trialled	Commercial blueprint ‘Esprit’ a DSM technology which curtails EV charging at peak demand.
Project Business Case (as reported by DNO)	Based on Transform model simulations, with the DECC scenario for High Uptake of EVs, 32% of GB networks would need intervention and using Esprit could save £2 billion on the cost of network reinforcement by the end of 2050.
Timescales	January 2013 - December 2015
Current status	Completed
Outputs/ Implementation/ Impact (as reported by DNO)	Across Great Britain 32% (312,000) of low voltage feeders will require intervention when 40%-70% of customers have EVs based on 3.5kW (16A) charging; **Esprit** is a solution that **could save GB DNOs £2.2 billion by 2050** as compared to traditional reinforcement methods; Esprit mitigates all thermal problems on the network accommodating up to an extra 46% of customers and can also raise voltage headroom by 10%; Curtailing EV charging had no significant effect on customer satisfaction; 41% of customers strongly agreed with the sentiment that they would continue to lease and 6% said the same to buying an EV after the trial; Over 18 months 213 participants made journeys totalling 3,081,328 km in their Nissan Leaf EVs representing a saving in direct emissions of around 105 tonnes of CO_2e as compared to the next best alternative, a new diesel vehicle; By deferring or avoiding reinforcement the implementation of Esprit is projected to save between 11.4 and 19.4 tons CO_2e emissions by the end of 2030. By 2050 the carbon emissions savings are expected to be between 814 and 1,390 tons CO_2e; ‘Top 10 Tips’ series of flyers disseminate the project findings on the following topics: Customer Engagement, Customer Recruitment, Novel Commercial Arrangements, Procuring Partners, Trial Installations, Data

Project Title	Innovation Squared (I^2EV) – My Electric Avenue
	Monitoring, Database Management, Managing EV Uptake (http://myelectricavenue.info/top-10-tips).

Kent Area System Management (KASM)

Project Title	Kent Area System Management (KASM)
Company	UKPN with National Grid, Navigant Consulting (Europe) Ltd. Bigwood Systems Inc.
Project Funding	£3.90m – LCNF Tier 2 inc. external funding
Project Driver	Enabling renewable energy connections Building a stronger and smarter grid
Project Objectives	Operate the network closer to its limit and hence as an alternative to traditional reinforcement; Reduce constraints placed on generators during maintenance and other planned outages; Improve operational processes to reduce time-constraints on outage planners and reduce the overall risk on the network.
Key tech/process trialled	Innovative application of a software tool, real-time contingency analysis, in a DNO control room. Transmission system operators currently use a variant of this tool to actively manage the reliability of complex transmission networks. The method brings together a number of technical and commercial components: 1. The development of the business processes and functional requirements to enable enhanced sharing of real-time operational data between DNOs and TNOs; 2. The implementation of a sophisticated suite of software tools that enables analysis of power flows for the current (intact) and post-fault (N-1, N-X) network states in operational timeframes and automatically quantifies operating shortfalls; and 3. The development of sophisticated near term unit-specific and bus-specific load and generation forecasting capabilities to enable accurate modelling of corrective and preventative control actions.
Project Business Case (as reported by DNO)	Estimated **net benefit of £0.6 million in present (2014) terms** over the business as usual approach according to quantification of: the projected costs of the base case, or business as usual; the projected costs of the KASM method; the benefits which are unlocked through its deployment; the net benefit.
Timescales	January 2015 – December 2017
Current status	Underway
Outputs/ Implementation/ Impacts (as reported by DNO)	1. Development of the strategy for inter-control room communication protocol for the purposes of KASM 2. Completion of the system integration of Contingency Analysis (CA) software into UK Power Networks systems, excluding a real-time link to National Grid 3. Completion of installation of forecasting modules that will link the DNO control room with other data sources 4. Demonstration of use of real-time contingency analysis in the control room 5. Completion of trials and implementation of reliability management, outage management and network capacity management

Project Title	Kent Area System Management (KASM)
	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.

Low Carbon Hub (LCH)

Project Title:	**Low Carbon Hub (LCH)**
Company:	WPD
Project Funding:	£3.527m – LCNF Tier 2
Project Driver	Conventional design solutions to the resulting changes in fault level, voltage control and capacity are often substantial cost. This can mean that in areas which have abundant renewable energy resources the connection of DG is uneconomical. Lincolnshire is one such area. It has a rich wind resource which may be underutilised for distributed generation due in part to electricity distribution network connection costs.
Project Objectives	Dissemination to the other GB DNO's and IDNOs of design recommendations for connecting optical fibre and wireless links to new and existing wood pole overhead power lines; Dissemination of a new set of commercial agreements jointly created between generators and the DNO; Completion and demonstration of the dynamic voltage control capability implemented within GE POWERON (Network control system widely used by UK DNOs); Completion of the nominated 10.5km of OHLs that have already been included in the DPCR5 submission to the new LCH standard; Installation and commissioning of the Flexible Alternating Current Transmission system (FACTS) device; and Operation of the 33kV active network ring connecting Alford, Trusthorpe, Chapel St Leonards and Skegness. Creating a network suitable for demonstrating the high penetration of DG.
Key tech/process trialled	The LCH has six project components and these will be trialled together as outlined below: **Network enhancements** – Sections of existing overhead lines will be upgraded within the demonstration area with higher rated conductors to increase the network's capacity to connect DG. This work is in addition to investment already funded through the DPCR5 settlement. **New commercial agreements** – Innovative agreements will be negotiated with DG customers to optimise their output and mitigate network issues (e.g. to deliver reactive power service) using real time network measurements. Potential limitations of the current regulatory framework will be identified. **Dynamic voltage control** – Building on the principles of an existing IFI project, the 33kV target voltage will be actively varied. This will be done dynamically based on real time measurements of demand and generation. Dynamic voltage control should increase network utilisation whilst maintaining the system voltage within the statutory limits. **33kV active network ring** – The active ring allows increased control of the 33kV system and network reconfiguration based on real time power flows. Construction of the ring will involve the installation of an additional circuit breaker, a new interconnector and smart grid protection and control. **Flexible AC Transmission System (FACT) Device** – A Flexible AC Transmission system device will enable WPD to control both network voltage and system harmonics of the active ring. This equipment is not normally deployed on Distribution networks for this purpose. Shunt compensation will be used to generate or absorb reactive power. These highly technical

Project Title:	Low Carbon Hub (LCH)
	solutions will be designed to increase the amount of DG that can be connected. **Dynamic system ratings** – The Skegness Registered Power Zone delivered lines. This component will further develop the solution and test new techniques to calculate the network capacity and operating limits based on real time asset data.
Project Business Case	**Ring Method** - The costs associated with the ring method are high, and the capacity released is relatively modest. As a result of the ring method, an additional 10MVA. Alternative Connection has accepted due to the reduction in constraints. **Network enhancements** – The additional costs have been estimated as £8,000 per km, whilst capacity released is approximately 12MVA of additional headroom. The method has also reduced voltage rise by 24%. **Dynamic Line Ratings** – This is less appropriate at 33kV due to the increased risk of sheltering. This is a significant barrier to DLR being used at 33kV to unlock additional generation capacity so the effective business case for this approach is very poor **Dynamic Voltage Control** - Dynamic Voltage Control did not demonstrate a cost benefit during this project. However, it shouldn't be written off as an approach because there is much potential for it in the future. **FACT Device** - The D-STATCOM has proven to be very effective at controlling network voltage and reducing losses by balancing reactive power flows. The device could also be used to manage reactive power flows between the distribution network and transmission networks.
Timescales	January 2011 – May 2015
Current status	Complete
Outputs/ Implementation/ Impact (as reported by DNO)	As of February 2015 34 Alternative Connections (a new commercial agreement) offers had been made in East Lincolnshire and have **facilitated 48.75MVA of additional generation connections.** As part of the internal implementation, ANM policies and Standard Techniques have been written for offering alternative connections as a BAU process, WPD's 200+ planners have been trained how to offer alternative connection offers, and we have changed its core database to facilitate the alternative connections. The Ring Method arrangement increases power flow route diversity, with the associated **benefits to system availability and losses reduction.** The project showed that an existing radial network could be modified, rather than rebuilt, to enhance capacity. It is now understood that the use of 33kV switchboards at a number of sites would have been an economically advantageous alternative to an Air Insulated Switchgear (AIS) or hybrid AIS solution since it offers a reduced network risk during an offline build, a quicker construction phase, and a simpler network to operate. The learning from the project also showed that, having suitable current and voltage transformers in the right locations is often a limitation to smarter solutions which often require a greater number of measurement points. The Network Enhancements (reconductoring a circuit with a larger conductor) have **increased the summer capacity of the circuits from 16MVA to 41MVA** and it has been modelled to **reduce voltage rise by 24%** compared to the existing circuit during maximum reverse power flows. At the end of the project the estimated TRL is 9.

Project Title:	**Low Carbon Hub (LCH)**
	Dynamic Line Ratings - The method has showed that using wind farm electrical data can cost effectively calculate an enhanced theoretical rating of the OHL based on using the calculated wind speed data. Dynamic Voltage Control has shown there are substantial opportunities to optimise target voltage settings. VVT is a lower cost, quicker and simpler solution to installing new VTs and associated equipment into an existing primary substation for steady state measurements. The cost of retrofitting VVT into an existing standard SuperTAPP® n+ scheme has been estimated at £4k, whilst the associated cost of installing a fixed outdoor VT is approximately £40k, although this is site dependent. Development of a UK technical recommendations for: Installing optical fibre on existing and new wood pole OHL; Installing microwave or radio links for networks. Development and dissemination of a future financial model detailing how future Low Carbon Hub could be created in other suitable network locations without LCN Funding. Development of the FACTS device to control voltage changes, determining if the voltage can be controlled by installing and operating the FACTs device. Development of a stronger relationship with distributed generators.

Low Carbon London (LCL)

<table>
<tr><th>Project Title</th><th>Low Carbon London (LCL)</th></tr>
<tr><td>Company</td><td>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</td></tr>
<tr><td>Project Funding</td><td>£34.5m – LCNF Tier 2 inc. partner contributions</td></tr>
<tr><td>Project Driver</td><td>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.</td></tr>
<tr><td>Project Objectives</td><td>• Using smart meters and substation sensors to facilitate smart grids;
• Enabling and integrating Distributed Generation; and
• Enabling the electrification of heat and transport.</td></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 (as reported by DNO)</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/ Impacts (as reported by DNO)</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.
• By recognising that reinforcement could be deferred in 10 LPN substations out of the 88 with potential additional capacity under ANM, the CBA</td></tr>
</table>

Project Title	**Low Carbon London (LCL)**
	concludes that the NPV of gross network benefits could be £2.6m for a passive approach that connects more DG and uses more monitoring, or £8.7m for an active approach that uses ANM. • Case study analysis suggests that £25/customer of benefits might be available through deferring reinforcement using dToU price signals at some substations, before the full costs of implementing such a tariff are taken into account • The experience and findings from LCL have allowed UK Power Networks to adopt DSR as a business as usual activity. This has culminated in **savings within the 2015 RIIO-ED1** business plan submission of £12m across the LPN licence and a **total of £43.5m** across all three of UK Power Networks' licensees during the period. • Financially the project met its in-project benefits case, delivering **£1.5m of network reinforcement savings through the successful application of I&C DSR** at Ebury Bridge substation. • Finally, LCL completed all its objectives under budget, enabling a further £4.8m to be returned to LPN customers • Carbon emissions from today's electricity system are around 450g/kWh. If only one of the initiatives demonstrated in Low Carbon London was fully adopted across the country, an additional contribution of 5g/kWh towards this reduction would be achieved, with the potential for far more. • The project estimates that the GB will gain in the order of £9.5bn of gross **benefits, of** which **£1.0-2.0bn** might be expected to accrue **to DNOs** from their **making use of flexible demand** and the remaining **£7.5 - £8.5bn might accrue to the electricity system more broadly as a result of avoided carbon emissions and carbon penalties**. The estimated cost of accessing these benefits has reduced from £3.5bn to £2.3bn.

Low Energy Automated Networks

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 (as reported by DNO)	The project's loss savings estimations are based on the same methodology used in the recent RIIO-ED1 submission. In this process, the value of lost energy was identified as £48.42 per MWh. If the typical figure of 90 MWh per annum is assumed, then the energy saved each year has an approximate annual value of £4,500 and, based on an unchanged load factor, the discounted present value over 45 years would be approximately £126,000 per site. This project will investigate the opportunity to de-energise transformers by a variety of means including manual operation, remote control via existing switchgear and automatic control using high-performance switchgear. The estimated method cost is described below: Option 1: De-energise transformers via remote control of existing switchgear with additional 11kV network automation if appropriate. Option 2: De-energise transformers using remote control including advanced local control equipment to ameliorate any switching surges, or inrush currents.

Project Title	Low Energy Automated Networks
	Option 3: De-energise transformers using remote control with high-performance switchgear to reduce inrush currents repeatedly.
Timescales	January 2015 - March 2019
Current status	Begun
Outputs/ Implementation/ Impact (as reported by DNO)	Continue current, successful asset replacement programme to deploy lower loss equipment, and with optimal configuration of the network. Continue with programme of implementing a range of technologies designed to reduce losses as part of normal business processes on the lower voltage networks (11kV and below). Use innovation to increase the range of technologies available for standard implementation. Improve understanding of the energy use of customers and work with customers to reduce their overall energy use, especially at peak times, taking advantage of smart metering as part of this process. Use new sources of data to create better models that allow analysis and losses tracking, and target loss reduction. Work with Electricity Supply Licensees to detect and prevent fraudulent energy use.

LV Network Templates

Project Title	LV Network Templates
Company	WPD with RWE Npower, University of Bath
Project Funding	£9.02m– LCNF Tier 2
Project Driver	To complicate matters, the LV network is also the part of the network about which we have the least information about, or knowledge of the 'headroom' available to accommodate a low carbon future. We do not accurately understand the impact of low-carbon initiatives on the LV network, and have little insight into the supply performance of the LV network against the European power quality standard EN50160. Therefore, we do not have a clear picture of how best to design or manage the network to meet these challenges. Nor can we tell National Grid (NG) how much UK LV microgeneration is running – having knowledge of this microgeneration will optimise the UK's spinning reserve.
Project Objectives	The project will give WPD a view of the power flows and voltages of the LV network in South Wales, together with visibility of impacts arising from Welsh Assembly Government (WAG) low-carbon initiatives covering some 3,000 homes, and including 1,000 PVs installations
Key tech/process trialled	Development of LV templates that can with an 82.2% level of accuracy estimate the load and voltage flows at a given LV substation without the need for costly monitoring.
Timescales	April 2011 – July 2013
Outputs/ Implementation/ Impact (as reported by DNO)	The reduction in HV in target voltage will **reduce maximum demand by 15.7MW.** The reduction in HV and LV system voltage will **reduce Customer bills by a calculated £9.4M each year**, based on DECCs current valuation of domestic and I&C rates. - The reduction in HV and LV system voltage will **reduce CO_2 emissions by some 41,000 Tonnes each year**, based on DECC 2011 data. DECC provisional 2012 data would give a figure 10% higher than this. The transmission entry capacity of major generators for the same period was 81.742 giving a margin of 24,252MW, and thus a saving of 618MW would (coincidentally) also represent **an increase of 2.5% in current capacity margin**, though that figure would increase with impending station closures. - At that rate, the value to domestic customers alone of such a reduction in energy would be some £315M per annum based on DECCs current valuation of marginal domestic and I&C rates. - Taking that voltage reduction applied at primary substation level would also apply to HV connect customers, the annual carbon reduction figure of an annual **1.98 Million Tonnes of CO_2** is conservative for the current generation mix.

Network Equilibrium

Project Title	Network Equilibrium
Company	Lead: WPD, Partners: National Grid, SPEN, Newcastle University and Parsons Brinckerhoff
Project Funding:	£13m - LCNF Tier 2 inc. partner contribution
Project Driver	Development of smart grids and ensuring network stability
Project Objectives	**Increase the granularity of voltage and power flow assessments,** exploring potential amendments to ENA Engineering Recommendations and statutory voltage limits, in 33kV and 11kV networks, to unlock capacity for increased levels of low carbon technologies, such as DG; Demonstrate how **better planning for outage conditions** can keep more customers (generation and demand) connected to the network when, for example, faults occur. This is particularly important as networks become more complex, with intermittent generation and less predictable demand profiles, and there is an increased dependence on communication and control systems; **Develop policies, guidelines and tools,** which will be ready for adoption by other GB DNOs, to optimise voltage profiles across multiple circuits and wide areas of the network; **Improve the resilience of electricity networks** through flexible power link (FPL) technologies, which can control 33kV voltage profiles and allow power to be transferred between two, previously distinct, distribution systems; and **Increase the firm capacity of substations,** which means that the security of supply to distribution customers can be improved during outage conditions, leading to a reduction in customer interruptions (CIs) and customer minutes lost (CMLs).
Key tech/process trialled	Advanced planning tool System voltage optimisation Flexible power link
Project Business Case (as reported by DNO)	By 2050, WPD conservatively estimates that Network Equilibrium will release 11.3 GW of capacity for LCTs across GB, with a cost saving of £1.5 bn when compared to the most efficient traditional solutions, such as network reinforcement, presently in use.
Timescales	March 2015 - June 2019
Current status	Begun
Outputs/ Implementation/ Impact (as reported by DNO)	The expected benefits are: The **Carbon Benefit** (expressed in terms of DG capacity released); There will be **lower Distribution Use of System (DUoS) charges for distribution customers**, due to lowering the socialised part of DG connections. This will result in lower bills for electricity consumers, when Equilibrium's solution is installed instead of conventional (network reinforcement) solutions; The additional resilience of the electricity network and **increased security of supply to distribution customers** can be measured through reductions in customer interruptions (CIs) and customer minutes lost (CMLs); The **avoidance / deferral of network reinforcement** (particularly the new build of overhead line infrastructure) will result in benefits to the GB

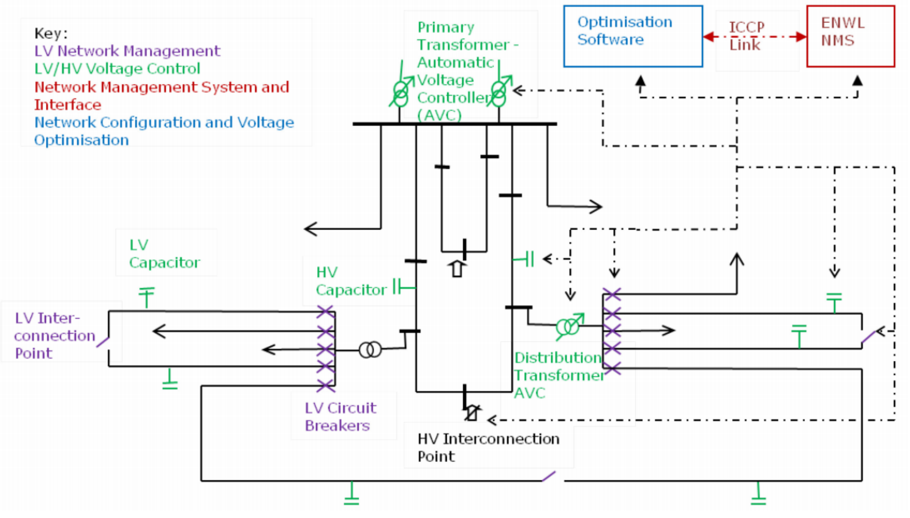
Project Title	Network Equilibrium
	Environment, such as in Areas of Outstanding Natural Beauty and financial benefits for the National Grid and other transmission system operators. GB DNOs will benefit from: the amendment and/or creation of new standards for voltage control and power flow management within electricity networks; design specifications, procurement specifications and other policy documents through the associated resource savings; Existing DG customers will benefit from reduced downtime, due to electricity network outages; Future **DG customers** will receive improved connection offers, they will be able to **connect to the network more quickly and more cost-effectively** than by conventional solutions; and The Equilibrium Solution will be equally as applicable to existing and/or future demand customers, particularly those looking to integrate LCTs into electricity networks, creating a fair system.

New Thames Valley Vision (NTVV)

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	Understand the different customer types connected to the distribution network, and their effect on network demand; Understand how the behaviour of different customer types allows informed network investment decisions to be made; Demonstrate mitigation strategies, both technical and commercial, in a live environment, to understand: The extent to which DSR can contribute to network flexibility, and identifying which customers are most likely to be early and effective adopters of DSR; Where and how power electronics (with and without energy storage) can be used to manage power factor, thermal constraints and voltage to facilitate the connection of renewables on the LV network; Link network reinforcement to a better understanding of SSE's electricity consumers; Undertaking dissemination and scaling activity to ensure validity and relevance to the GB, with learning and understanding provided at two levels: Provide front line training courses for the industry to embed real practical knowledge and skills; and Keeping the public informed so the intentions and benefits of the smart grid are clear and opinions informed.
Key tech/process trialled	The project will demonstrate that common mathematical and statistical techniques used in other areas, such as consumer retail, can be applied to electricity consumers and fed into network planning processes. Such analysis will help to: Target investment and the strategic placement of 'distributed LV solutions'; Facilitate scenario planning; Minimise errors in network design; and Reduce risk to connected customers. This sophisticated analysis will be complemented by credible alternatives to conventional network reinforcement.
Project Business Case (as reported by DNO)	Using the methodology developed and scaling it for two SSEPD licences yields net benefits of over £600m from 2020 - 2050: Southern Electric Distribution Ltd - £482m (based on the difference between £936m of novel deployment costs to £1,400m of conventional reinforcement); and Scottish Hydro Electric Distribution Ltd - £143m (based on the difference between £302m of novel deployment costs to £440m of conventional reinforcement).

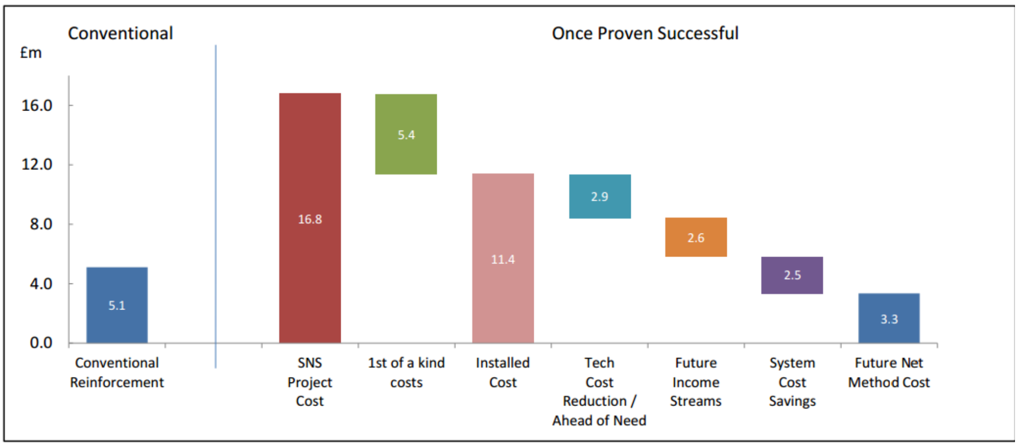
Project Title	**New Thames Valley Vision (NTVV)**
	Further to this SSE anticipates that NTVV will yield more immediate benefits including: Accelerated low carbon technology connection for customer; Avoidance of supply failure resulting from unanticipated demand peaks; Reduction of network losses as a 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/ Impact (as reported by DNO)	The Learning Objectives (LO) are as follows: 1. An understanding of what SSEPD needs to know about customer behaviour in order to optimise network investment. 2. Anticipation of how SSEPD can improve modelling to enhance network operational, planning and investment management systems. 3. Understanding to what extent modelling can reduce the need for monitoring and enhance the information provided by monitoring. 4. Understanding of how might a DNO implement technologies to support the transition to a Low Carbon Economy? 5. Understanding which commercial models attract which customers and how will they be delivered?

Smart Street

Project Title	Smart Street eta
Company	Lead: ENWL, Partners: Kelvatek, Siemens UK Ltd and Impact Research
Project Funding:	£11.476m – LCNF Tier 2 inc. partner contribution
Project Driver	Making effective use of interconnection combined with voltage control to facilitate increased use of LCTs and low carbon generation, and to reduce customers' energy consumption.
Project Objectives	To test the following hypotheses: The 'eta' method will deliver a **reduction in customers' energy consumption** (Research Workstream); Customers within the 'eta' trial area will not perceive any changes in their electricity supply (Customer Workstream); The 'eta' method will have no adverse effects on customers' internal installation or appliances (Research Workstream); The 'eta' method is **faster to apply than traditional reinforcement**, supports accelerated LCT connection and reduces network reinforcement costs (Research Workstream); The 'eta' method facilitates the prioritisation of the range of solutions across differing LCT adoption scenarios based on a cost benefit analysis to accommodate customers' uptake of LCTs (Research Workstream); The 'eta' method will deliver a **reduction in overall losses** through network configuration and voltage optimisation (Research Workstream); and The 'eta' method facilitates real time control of a portfolio of LV network solutions, using retrofit technologies with application combined or in isolation (Technology Workstream).
Key Tech/Process Trialled	Integration of several technologies developed and separately tested under existing IFI or Tier 1 LCNF projects into a common operating regime, co-ordinated and managed through optimisation software. *Figure 2.2 eta Method intervention on stylised HV and LV networks* 
Project Business Case (as reported by DNO)	The 'eta' method releases capacity up to four times faster and is 40% cheaper than traditional reinforcement techniques for LCT clusters. The eta **solution is transferable to 64% of the ENWL network and 72% of GB networks**; releasing capacity up to 2,985 MW and 39,630 MW for ENWL

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

Smarter Network Storage (SNS)

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

Project Title	Smarter Network Storage (SNS)
Timescales	January 2013 – December 2016
Current status	Underway
Outputs/ Implementation/ Impact (as reported by DNO)	Overall this project should help to inform the means in which storage can be incorporated more cost effectively into future business plans of DNOs. The specific findings from the June 2015, 6 monthly report are: The provision of TRIAD avoidance service is likely to form an important part of the portfolio of services for a commercial operator, which in some scenarios could cause conflicts with services to a DNO; EMC compatibility testing and factory acceptance should be thoroughly carried out using representative layouts, connections and scales of equipment as close as possible to the 'as-installed' system; Earthing systems appropriate for high frequency currents should be specified for future installations of building housed storage to avoid unwanted circulating currents; Consideration needs to be given to appropriate validation test methods for frequency response behaviour; Control systems that have no synchronisation in the architecture at the system level may cause small fluctuations in power output, if they choose to optimise power delivery amongst inverters; and Relatively simple parts of the overall solution can become single points of failure that could have a significant effect on network support operations or commercial services. Redundancy and resilience should be considered at all sub-system and IT levels. Learning reports are available for the following deliverables: **SDRC 9.1** - practical issues and consideration in the design and planning of large-scale distribution-connected storage. **SDRC 9.2** - overall design of the Smart Optimisation & Control System incorporating a description of the business processes to be implemented across participants to facilitate the SNS solution. **SDRC 9.3** - contract templates for commercial arrangements that can also be tailored for other forms of flexibility and leveraged system wide by DNOs. **SDRC 9.4** - commissioning and operation of energy storage device.

SoLa Bristol

Project Title	SoLa Bristol
Company	WPD with Siemens, University of Bath (with RWE npower) and Bristol City Council. Moixa Energy
Project Funding	£2.48m – LCNF Tier 2 inc. external funding
Project Driver	Reduce need for network reinforcement Facilitate connection of low carbon devices at reduced cost
Project Objectives	The project will test the following Hypotheses: Should new Low Carbon Technologies (LCTs) increase distribution network peaks and cause thermal overloads, then battery storage, demand response and DC networks could be an efficient solution, conventional network reinforcement for short thermal overloads may not the most efficient use of customers' money If DC networks in properties could be used to reduce network harmonics, phase distortion and improve voltage control then their use may be vital in the connection of LCTs. Because the safe, efficient operation of distribution networks is reliant on the power quality and voltage being within statutory limits If DNOs and customers could share battery storage on DC networks with a variable tariff, then the mutual benefits may make battery storage financially viable, as battery storage could be a shared asset or sold to customers as a service
Key tech/process trialled	Home energy storage with demand response New variable tariffs DC networks
Project Business Case (as reported by DNO)	By 2030 the total carbon savings associated with BRISTOL is expected to be 1,452.3 thousand tonnes of CO_2 corresponding with a saving of £36.8m from deferred network reinforcement.
Timescales	December 2011 – January 2015
Outputs/ Implementation/ Impact (as reported by DNO)	Benefits for domestic customer came from the demand reduction brought by PV and demand shift brought by battery storage, both of which were triggered by Time-of-Use tariff. The **average bill saving of the 11 houses on the trial were £52.10 in the seven months of the trial**, a saving of almost 25% on their original bills. With the penetration levels of battery and PV being relatively low in the trial network the corresponding network investment deferral was found to be less than £300. However, when the penetration and network utilisation increases, the network investment deferral is increased to thousands of pounds. Battery and DC circuit helped keep the lights on during power outage even when on prepayment key meter.

Solent Achieving Value from Efficiency (SAVE)

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

Project Title	Solent Achieving Value from Efficiency (SAVE)
	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/ Impact (as reported by DNO)	Following the consultation from Ofgem dated 7th December 2012 entitled 'Low Carbon Networks Fund- Electricity Demand', SEPD became interested in potentially trialling such demand reduction. At present this is untested and therefore cannot be used in BAU. Through these trials, SEPD hopes to quantify the most cost effective approach to having a measurable change in the operation of the distribution system and develop means of controlling the demand reduction in order to be able to rely on the demand reduction and defer or avoid network reinforcement.

Vulnerable Customers and Energy Efficiency (VCEE)

Project Title	Solent Achieving Value from Efficiency (SAVE)
Company	UKPN with British Gas, CAG Consultants, University College London (Energy Institute), Tower Hamlets Homes, Poplar HARCA, Bromley-by-Bow Community Centre and the Institute for Sustainability, National Energy Action, British Red Cross (Critical Friend) and Consumer Futures (Critical Friend).
Project Funding:	£5.49m LCNF Tier 2 inc. external funding
Project Driver	The government's Low Carbon Transition Plan necessarily has an impact on customers' energy bills. Those with the potential to be hardest hit include the 4.5 million fuel poor in the UK (2011, DECC), of which a significant number are also vulnerable in some way. Separately, the Distribution Network Operators (DNOs) are forecasting increasing and more uncertain demands on their networks as the result of the electrification of heat and transport and the increased reliance on micro-generation and distributed generation (DG). The more customers that participate in providing time-shifting or Demand Side Response (DSR) and the more customers that can achieve sustained energy savings, the more it will help to mitigate this substantial challenge.
Project Objectives	How to identify and use existing trusted social resources to effectively engage fuel poor customers in the adoption and use of smart metering technologies; The amount of energy savings (in energy and monetary terms) arising from a set of intervention measures tailored to the specific resources and needs of the trial area community; The amount of energy shifting arising from a package of intervention measures tailored to the specific resources and needs of the trial area community The impact on network reinforcement from reduction or shift in energy consumption Improved demand profiling for these customers What engagement material and communications channels were effective in reinforcing and supporting their behaviour.
Key tech/process trialled	Demand reduction and demand shifting, by providing 550 households in 2 groups with a smart meter, simple energy saving and energy shifting devices, energy advice and Time-of-Use tariffs. The trials will research the effectiveness of techniques and capture learning on the: Level of response from fuel poor to smart meter data & price signals Energy cost savings achieved from customer interaction and network benefits Improved demand profiling for these customers What engagement material & channels were effective in supporting their behaviour.
Project Business Case (as reported by DNO)	£413k to £825k saving over 45 year asset life for 2.5MVA to 5MVA 10 year reinforcement deferral. £1.05m to £2.1m saving over 45 year asset life for 2.5MVA to 5MVA indefinite reinforcement deferral (no reinforcement over life of asset). £180k saving from a 52.4GWh reduction in energy distributed. £38 to £61 bill saving potential for households when participating in energy efficiency.

Project Title	**Solent Achieving Value from Efficiency (SAVE)**
Timescales	January 2014 - December 2017
Current status	Underway
Outputs/ Implementation/ Impact (as reported by DNO)	The project hopes to understand: the extent to which this residential customer group is able and willing to engage in energy efficiency and an 'off peak' tariff; the benefits that they can realise from their change of behaviour in household energy management; the challenges and best approaches to engaging with these groups of customers to achieve these aims; consequently, how their move and reduction in demand away from network peak periods may benefit the electricity network by deferring or avoiding network reinforcement.

Global Footprint

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