Customer-Led Network Revolution

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Progress Report 7

DOCUMENT NUMBER

CLNR-L020

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ISSUE DATE

20th June 2014

LCN Fund Low Carbon Networks | NORTHERN POWERGRID | British Gas Looking after your world | Durham University | Newcastle University | EA technology

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1. Executive summary

1.1 The Customer-Led Network Revolution (CLNR) project is assessing the potential for new network technology and flexible customer response, to facilitate speedier and more economical take-up by customers of low-carbon technologies and the connection to the distribution network of increasing amounts of low carbon or renewable energy generation. This seventh formal progress report sets out the progress on delivering the learning outcomes relating to understanding existing and future load, customer flexibility, network flexibility, the optimum mix of solutions and the most effective delivery routes to implement those solutions.

1.2 In the September 2010 bid, we set out what we would deliver in each learning outcome and the method to be followed. As is typical of such projects, not all the learning has taken the form originally envisaged. But the method is unchanged and the progress to date suggests that the value of the learning will be at least as good as that in the bid and quite likely better. In particular, the network models, the customer trial data and the research into customers' energy practices are already contributing to a rich socio-technical dataset that arguably exceeds the original expectations.

1.3 We are on target to deliver the project within the total cost envelope with the real prospect of being able to return around £0.4m of customers' money. We are forecasting completion of the project in December 2014, one year later than originally planned due to delays experienced in recruiting customers and delivering the innovative customer and network technology. We have submitted a formal change request that has undergone consultation with the other distribution network operators and is with Ofgem for approval.

1.4 Additional sources of funding have been obtained to provide value to the CLNR project by enhancing the quality of the outputs at no cost to the customers funding the project. Most notably, British Gas contracted with DECC and £2.2m was invested in subsidising heat pump installations in the absence of a renewable heat incentive.

1.5 Also, our academic partners have combined other grants with the LCN funded activity. Early in the project a £0.5m Durham University grant helped to establish much of the modelling simulation capability in a smart grid laboratory that has been so important to delivering both the baseline and additional outputs from the project. More recently, a £2m grant for Newcastle University from the Department for Culture, Media & Sport is creating a national centre for Big Data and Cloud Computing. This will support the hosting of the legacy data from CLNR post project closedown that we expect to be an important national resource for the next decade. Both grants are leveraging value from CLNR, were not committed at bid, and are at no cost to customers funding the project.

1.6 Notable achievements in the reporting period include:

- The customer trials are now substantially complete, with most of the data transferred to Durham Energy Institute and analysis well underway. Trial participants surveyed to date are reporting high levels of customer satisfaction with the in-trial and decommissioning process.

- Encouraging evidence of load shifting from heat pumps with thermal store. 14 calls for demand side response (DSR) achieved demand reductions of up to 3kW per heat pump for periods of up to one hour, with no evidence of any customer concern.
- DECC's Energy Innovation Team is to use our work on heat pumps as the mainstay of the UK's contribution to an International Energy Association (IEA) case study programme on domestic DSR.
- Successful execution of 15 calls for DSR to the smart washing machines of *ca.* 90 customers.
- Successful implementation of the grand unified scheme (GUS) trialling the integration of different smart grid solutions, considered to be the most sophisticated active network management (ANM) system in use in the UK, and arguably in Europe. It uses state estimation followed by optimisation as opposed to relying on pre-programmed rules, which makes it inherently more responsive, flexible and adaptable.
- Participation of 14 industrial and commercial (I&C) customers, mostly through commercial aggregators but also directly, with a total of 17MW of DSR in trials for large scale fast reserve. Over 30 events were successfully called through our GUS ANM system.
- Completion of around 150 trials of network technology solutions (different permutations of enhanced automatic voltage control and electrical energy storage) and customer flexibility solutions under the control of the GUS initiated via real-time monitoring and thermal rating inputs, deploying the interventions singly and in combination.
- Successful trials of open loop control of electrical energy storage (EES) systems on live rural and urban LV networks, using real and reactive power to maintain voltage. Further, we have demonstrated an EES unit controlling the voltage to well within statutory limits on a solar PV cluster during a period of high generation output and low load.
- Successful completion of open loop trials of enhanced automatic voltage control (EAVC) using on-load tap changers at three distribution substation locations.
- Successful completion of closed loop trials to control voltage on live LV networks using GUS, which intervened to control the on-load tap changers without the need for human involvement.
- Demonstration of how increases in the number of heat pump, electric vehicle (EV) and photo-voltaic (PV) connections can be managed through an ANM system controlling either a mechanically switched capacitor or EES.
- Shared key learning from the project at industry forums and conferences including DECC's benefit and monitoring review group and the Next Generation Utilities Summit in Berlin. We also focused on communication with our stakeholders, instigating a programme of monthly e-news bulletins, sent to our 900+ mailing list subscribers.

1.7 With the progress highlighted above we are set to deliver outputs of practical use, such as real evidence to validate the scale of demand shifting that can be achieved, the factors which affect customers' participation, and protocols for integration of smart grid solutions in industry-scale control systems. Our customer trials have now largely concluded, with good rates of customer retention and most of the equipment now decommissioned. Analysis of the consumption and generation data collected is well underway and on target for publication in August 2014, in addition the social science analysis continues to yield rich and varied results for nine academic publications. This work is delivering significant learning about how and why customers responded to the arrangements trialled, which is critical to developing and scaling up such interventions in the future.

1.8 Network trials of the EES, EAVC and DSR interventions and of the GUS ANM system are more than halfway through the programme. The data is being analysed as the trials progress, yielding both substantive results and an opportunity to refine the remaining trials. We have rectified the failure of the inverter unit of the largest of the energy storage device which was reported in the previous period. The device has since undergone full commissioning tests and is performing safely during our network trials.

1.9 We continue to make good progress in the development of the prototype NPADDS (Network Planning and Design Decision Support) tool and have demonstrated to a range of interested audiences its ability to assess the voltage and thermal impact of rising LCT uptakes on medium and low voltage networks. We continue to develop a suite of guidance documentation for distribution network operators (DNOs) including policy recommendations, equipment specifications, equipment application guides and lessons learnt reports.

1.10 With the network equipment trials fully operational and the customer facing activities now substantially complete, the risk profile is naturally decreasing as we approach the end of the project. Although their current risk rating is lower than previously, the risks with the highest current risk rating are:

Risk	**Current risk assessment**	**Impact**	**Mitigating actions**	**Contingency plan**
Installation risk: 25. The GUS central control system may not function as required.	Impact: low Probability: low Rating: blue Owner: Northern Powergrid	It may not be possible to conduct all of the network trials under the control of GUS, if any of the GUS functionality should fail.	We have used testing and commissioning to ensure all required functionality is included and working.	Run the autonomous trials and as many of the collaborative trials as is possible using workarounds, dependent upon the extent of the problem. Using the results of the autonomous trials, model the predicted results of the collaborative trials.
Other risk: 48. Loss of academic personnel	Impact: high Probability: negligible Rating: amber Owner: Durham University	Loss of key knowledge and skills will prevent or delay the work of the project, or adversely affect the quality of the learning outcomes delivered.	Contracts have been extended to the end of the project ensuring coverage of the crucial analysis and conclusions stage.	Replacement staff to be recruited. This would limit but not entirely mitigate the impact.

1.11 We continue to disseminate the learning from the project within Northern Powergrid, and to external audiences via our CLNR website, e-news bulletins, project newsletters, PR and social media campaigns, speaking engagements and participation in industry forums and conferences. A number of peer reviewed academic papers have also been published in the period.

1.12 Our approach to learning capture includes a review and write-up on completion of key stages of the project. Dissemination of learning, both externally and within Northern Powergrid, is underpinned by two main principles; communicating in a way appropriate to the target audience and maximising reach and impact by using multiple channels.

2. Project manager's report

2.1 With the network equipment and the GUS active network management system operational, and the customer facing activities now substantially complete, our focus is on completing the network trials, analysing all customer and network trials data, and developing the outputs and tools needed to integrate the solutions into business as usual.

Learning outcome 1 (existing and future load) & Learning outcome 2 (customer flexibility)

2.2 The trials with domestic, SME and I&C customers are substantially complete. Together these trials cover conventional load, heat pumps, EVs, PV, micro CHP, and merchant generation. We are monitoring the patterns of customers' load and generation, and also the effect of a range of flexibility seeking interventions: time of use and restricted hours tariffs, DSR with domestic customers ('direct control') and with I&C and DG customers, and PV balancing. The full range of test cells are listed in appendix 3, and of these 20 test cells, just two are still to complete: domestic customers with electric hot water heating and storage heating (subsets of test cell 2a, due to complete end June 2014), and responsive generation for voltage support (test cell 19).

2.3 The majority of the data has been transferred to Durham University for quality control and analysis. The analysis reports are being reviewed by Northern Powergrid designers and planners to ensure that they are relevant to decision making by the wider DNO community. The final outputs from the customer trials will be completed by the end of August 2014.

Concluding engagement with trial participants

2.4 We now have completed over 90% of our trials with domestic and SME customers, with the two remaining trials (2a hot water and 2a hot water plus storage heating) due to be completed by the of June 2014. The trial participants surveyed to date reported high levels of customer satisfaction with the in-trial and decommissioning process.

2.5 Robust procedures have been put in place at British Gas and with all equipment and service providers, to ensure customers are informed in advance about when the test cell they are participating closes; this is in line with their terms and conditions of participation. Customers were also advised of the arrangements for removal of any control / monitoring equipment, or in the case of Time of Use trial participants, offered a suitable replacement tariff by British Gas.

2.6 Monitoring equipment has been removed from circa 900 (75%) of trial participants' premises. Customer satisfaction rates for both the service provided and the quality of the works carried out are very high, there have been no requests for remedial visits, customer complaints or claims for damages or compensation following our decommissioning activities.

2.7 As part of the customer trials close down, we carried out a check of how customers on the Time of Use tariff trial have fared financially. We promised customers a safety net, and that they would be compensated in the event that they were financially worse off with the Time of Use tariff. We found that the majority of customers (60%) did save money, but that the significant minority who did not will be compensated accordingly. Further information on this and the trial combinations of time of use tariff with either smart washing machines or heat pumps is available in Appendix 6.

2.8 We have carried out qualitative research for the demand side response trials through home visits to customers with heat pumps and smart washing machines and who are taking part in trials of restricted hours or direct control interventions.

2.9 We are organising the final interviews with industrial and commercial customers, which will support the CDCM[1] analysis and also the conclusions regarding distributed generation profiles (TC8). The interviews will take place, and the results disseminated later this year.

Data management

2.10 British Gas has transferred to Durham University data from all the domestic customer trials, with a final upload for the small number with electric hot water and storage heating (test cell 2a) to follow when that test cell completes at the end of June. Similarly, the bulk of the SME data has also been transferred and the remainder will, after quality control checks, be transferred by the end of June 2014.

2.11 Durham University are working through all the data sets, carrying out a final data cleanse to provide a sound basis for analysis. This involves removing redundant data, detecting and correcting missing values, detecting and correcting incorrectly or ambiguously labelled data (e.g. monitored equipment or units) and correcting erroneous source data formatting. This exercise follows, and is in addition to, the initial data cleanse done by British Gas and given the size of the source data (the files range in size from a few hundred megabytes to tens of gigabytes), this is no small task. Information on the completeness, number of recorded customers and time span of each of these test cells will accompany the final results.

2.12 A reduced EV dataset from Charge your Car will be transferred to Durham University for inclusion in the project's outputs in 2014. The meters have been reconfigured for remote data transfer and from 1 July 2014 we will start collecting data for a further nine-month period so that this data can be made available to other researchers as part of the project's data legacy.

2.13 All the power quality monitoring data has been extracted and this will be analysed by EA Technology. We will also install additional monitoring at locations with clusters of EVs which have been identified by the My Electric Avenue project, thus extending the data available for analysis by the project and by other researchers post project.

2.14 We will shortly complete data cleansing activity for all the test cells, and we will conclude our analysis and publish our final results for the customer trials by the end of August 2014. This will comprise qualitative socio-technical learning and quantitative load and generation profiles, and associated reports.

Smart washing machine demand side response trials

2.15 We have conducted DSR trials using smart washing machines to assess the potential for load reduction from domestic customers. Customers signed up for either restricted hours or direct control interventions; the purpose of the trial is explained further in the video CLNR smart appliance trials with domestic customers.

[1] Common distribution charging methodology

Figure 1: Installation and demonstration of smart washing machine

2.16 We had previously reported that in about one third of smart washing machine installations, the distance between the gateway and appliance was causing problems with communications, and that we were experiencing compatibility problems between the repeater plug used to solve the problem, the smart appliances and the gateway. We had developed four options to resolve the issue and were therefore confident that good communications between the gateway and the appliance could be established for all trial participants.

2.17 We have successfully solved the issue using powerline communications (PLC) plugs. We revisited the *ca.* 60 affected trial participants, relocating the communication gateway nearer to the smart washing machine and making the network connection back to the router via the PLC plugs. Once the communication equipment and PLC plugs had been reconfigured, connection rates proved more stable and consistent. However, connection rates during the trials still fluctuated due to customer broadband issues or customers occasionally simply unplugging equipment, and such situations were resolved via a phone call and, where appropriate, a service visit.

2.18 We have now successfully made 15 calls for demand side response from the smart washing machines of *ca.* 90 customers, with the signal being successfully received by the gateway in 76% of cases. This is a largely positive outcome. There were a number of reasons for the signal not being received and acknowledged by the gateway in all cases, including the broadband being down, the equipment being unplugged and teething problems with the technology platform. Progress was made to resolve these issues over the course of the DSR events. Later this year we will publish reports on the technical issues experienced and on customers' response to the calls for DSR under the smart washing machine trials.

Heat pump demand side response trials

2.19 As with the smart washing machine trials described above, the purpose of the heat pump DSR trials is to assess potential for load reduction from domestic customers. In the last reporting period we completed the installation of our smart heat pumps with thermal store technology, and we have now completed the majority of the demand side response trial events with these customers. We executed 14 DSR calls with circa 20 customers and achieved reductions of up to 3kW per heat pump for up to one hour, with no evidence of customer concern. The trial is explained further in the video entitled [CLNR heat pump trials with domestic customers.]

Figure 2: Heat pump with thermal store

2.20 Although we have seen encouraging evidence of load shifting, a relatively high number of the DSR calls were cancelled by users. It's possible that minor adjustments made to the unit's temperature settings by customers have caused an automatic override (to prevent excessive loss of temperature in the hot water cylinder). We will conduct face-to-face interviews with the trial participants to gain some insight into consumer acceptance and reasons for participants cancelling the response.

2.21 We have experienced some connection and operational challenges with the heat pumps, requiring a number of re-visits to rectify. A second wave of heat pump DSR events is currently underway with the six units that experienced connection issues which meant that that they were not available to participate in the main programme.

2.22 The main connection-related issues encountered have been;

- IP port restrictions/closed gates on customer routers preventing access from the Greencom Platform load-control messages;
- Firmware changes for the operating system for the heat pump;
- Customer internet connection stability and shifting IP addresses; and
- Many of the units also requiring a parts upgrade after the heat pump manufacturer identified a potential systemic fault with the PCB in some units.

2.23 To support the programme, a test system was installed and tested extensively at British Gas's micro-generation/Smart Home "iLab" in Leicester. It enabled us to run the heat pump unit for longer periods than would have been possible in real customers' homes (i.e. until significant radiator-temperature drops were observed), and to test a broad range of fault conditions and potential responses.

2.24 Despite the challenges discussed above, the initial results on load-shifting potential are encouraging, with shutdown periods of up to one hour on some of the later tests. Further, there were no customer complaints about temperature fluctuations or reports of inconvenience during the events. Our initial results indicate that even on the longer-duration events, the impact on hot water cylinder temperatures was unlikely to have been sufficient to cause any noticeable customer discomfort when the overall system inertia is taken into account.

2.25 It is important to note however that the trial ran throughout winter 2014, a period characterised by relative mild weather, and so the system's draw on the hot water cylinder would have been less sustained than during a harsh winter, where only shorter-duration events would likely to have been practicable.

2.26 In March 2014, we shared the initial results from the trials and demonstrated the iLab heat pump unit at a workshop with DECC's Energy Innovation Team (heat pump programme funders) and representatives from the Energy Technologies Institute (ETI). They recognised the significant achievement of the project in bringing such a complex and innovative system to live field trials and intend to use the work as the mainstay of the UK's contribution to an International Energy Association (IEA) case study programme on domestic DSR.

Large-scale demand side response

2.27 We have signed further agreements for the provision of large-scale DSR; two with commercial aggregators Kiwi Power and ESP, and one direct with an I&C (industrial and commercial) customer, bringing to 14 the number of customers participating in DSR trials and a total of 17MW of DSR.

2.28 The contract with Kiwi Power is for five I&C customers to provide a total of 3MW of demand side response. All five customers signed onto the pricing structure used in the first round of trials which is based on the short-term operating reserve (STOR) methodology, and uses an availability and utilisation component. The contract with ESP is for three I&C customers to provide a total of 2MW of DSR. This contract uses a daily price concept with a floor methodology, which requires the site to drop consumption below a threshold level. The direct I&C contract is for 5MW of DSR and also uses this same methodology.

2.29 All of our I&C DSR trials were successfully completed in this reporting period and were initiated automatically through the GUS ANM system. A total of 31 DSR events were called with only one failure to respond which was due to a standby generator starter motor fault.

2.30 Further, discussions are progressing well with a merchant generator regarding the provision of voltage support through the utilisation of reactive power (TC19). We have identified a wind farm site on the 66kV network at Middlemoor (electrically close to the rural test cell based out of the Denwick primary) which has the potential to prove the concept of actively managing reactive power. We also confirmed an alternative route to secure the voltage support service, without any requirement for a new commercial contract or cost to the customer, as current Grid Codes allow Northern Powergrid to define settings for the generator's existing equipment to actively manage the voltage.

Learning outcome 3 (network flexibility)

2.31 Learning outcome 3 seeks to understand to what extent the network is flexible and the likely cost of this flexibility. It involves trialling network technologies and the grand unified scheme (GUS) control system through a series of large-scale field trials. Although the technologies trialled have previously been deployed individually at high voltages, this project is delivering new learning on the deployment of technologies in combination, in conjunction with demand side response and at lower voltage levels.

In this reporting period, we completed the commissioning of all the network equipment, closed out the final functionality issues with the GUS control system, and made good progress in conducting over half of the extensive programme of network trials.

Network equipment

2.32 All of our six electrical energy storage (EES) batteries, including the 2.5MVA unit connected at high voltage on the Rise Carr urban network, have been commissioned, made operational and fully charged for use in the trials. To date, we successfully completed both real and reactive powerflow and voltage control trials.

2.33 In the last period we reported an inverter unit failure during commissioning of the 2.5MVA unit. The failure had caused some damage to the power capacitor and secondary wiring on the inverter unit. However, there was no impact on the battery cells and most importantly no injuries were sustained. We completed a thorough investigation into the cause of the failure prior to the repair and re-energisation of the unit. It identified a manufacturing defect which has been fixed.

Figure 3: 2.5MVA EES unit at Rise Carr

2.34 All the enhanced automatic voltage control (EAVC) equipment installed on transformers, regulators and switch capacitors is operational and has proved itself in both autonomous and local coordinated tests. Each responded to the settings applied to tighten the controlled bandwidth and to assess the value of headroom released within the network trials.

2.35 All the thermal rating equipment on overhead, underground, primary and secondary transformers has been operational and has been coordinated by the GUS, calculating and informing the system of available headroom gains based on environmental conditions and enabling the trials of the DSR functionality of the system.

2.36 We have completed all of the operational guidance and training related to GUS and published the following documents in Northern Powergrid's controlled document system:

- OPS/007/001 – Operational guidance and training requirements associated with the trial of secondary transformers equipped with an integral on load tap changer
- OPS/007/002 – Operational guidance and training requirements associated with the trial of battery electrical energy storage systems
- OPS/007/003 – Operational guidance and training requirements associated with network trials using the Grand Unified Scheme (GUS)

GUS active network management system

2.37 Our GUS ANM system comprises the central controller, the remote distribution controllers (RDCs) and the interfaces between the central GUS and the RDCs. The RDCs interact with the energy storage, monitoring, thermal rating equipment and voltage control devices (collectively referred to as 'Enhanced Network Devices' or ENDs). The simplified diagram below illustrates how these components interact and the relationship between the central and the remote elements.

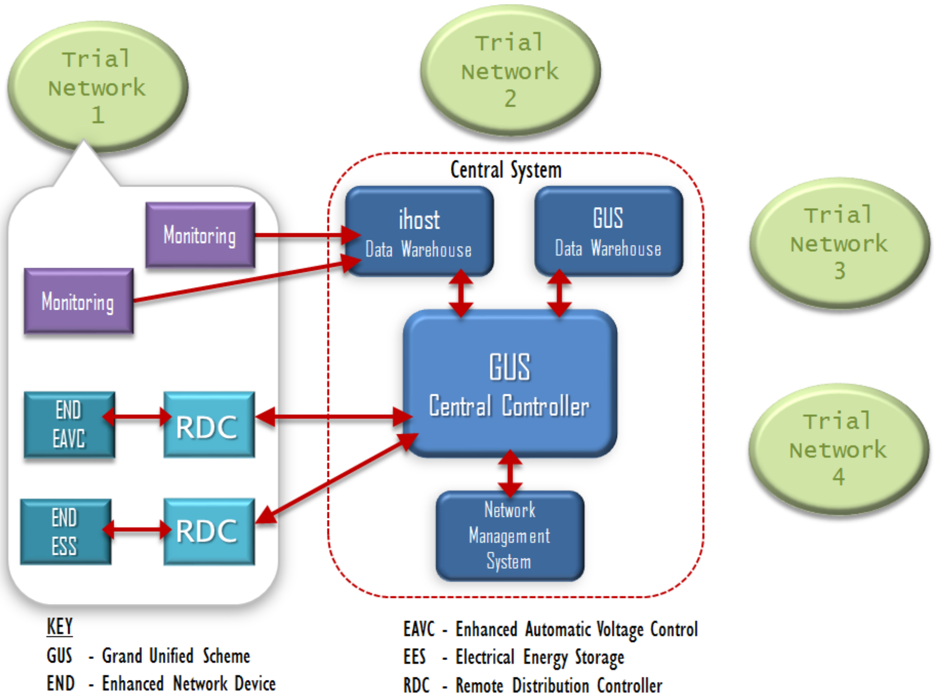

Figure 4: simplified schematic of GUS and trial networks

2.38 The remote elements are located within the four trial networks and at various other points of interest on the Northern Powergrid distribution network. The GUS control system provides the capability to remotely control ENDs, thus managing power-flows and voltage and thermal constraints. It runs alongside the existing network management system which manages safety and network configuration.

2.39 In this reporting period, we have established visibility for Newcastle University of all network data points. We have proven the communications resilience of the mirroring between Northern Powergrid's operational control system and the mirrored data warehouse at Newcastle.

2.40 We have fully commissioned the integrated system and the network components for all of the network test cells, including the primary networks of Rise Carr and Denwick. This involved concurrently proving GUS and the network technologies, to ensure GUS can perform all of its roles regarding the state estimator settings and set points for running trials in different environments.

2.41 We have completed the testing of equipment settings at the interfaces between the RDC and the ENDs at all locations.

2.42 At the heart of the GUS system is a complex state estimator and volt var controller, which has proved difficult to commission across our range of network test cells. During the implementation of GUS, we have made giant strides in improving the system and we continue to learn throughout the trial phase about the systems operation, configuration and the capture of its control decisions. These lessons learned will be documented and shared with other DNOs.

2.43 We have enhanced the resilience of the configured alarms on the storage and EAVC equipment to feedback via existing SCADA systems and configured the alarm points onto the Northern Powergrid control system.

2.44 We have successfully implemented and tested the "SAFE" function into the existing network management control system, driven by our network control engineers. This function enables the entire system, test cell or individual location and apparatus to be put in a predefined safe condition in the event of a network or system failure event. Further, we were able to prove this function during recent lightning storms affecting our region.

2.45 We built, tested and commissioned the network control system interface function that informs the network switch status between our network management system and the GUS platform.

2.46 We have successfully proven the system's ability to consider network power-flow limits and coordinate them with the GUS platform in a series of DSR calls with our contracted domestic and I&C customers.

2.47 We migrated the overhead line RTTR system from an externally hosted server to a dedicated server within Northern Powergrid's corporate IT infrastructure and integrated it into GUS. We completed the integration of the iHost database of monitoring data into the GUS system (i.e. with the RDC and the central controller).

Network trials

2.48 The main objective of the network trials is to evaluate the capability of the network interventions and control systems to mitigate voltage and power-flow issues arising from the large scale deployment of low carbon technologies load and generation. To enable this, voltage and power-flows are controlled on a live electrical network within more stringent upper and lower voltage and thermal limits so that observations can be made as to how the various pieces of active equipment will react in isolation or in tandem with others. This data is being collected and evaluated. The trials are split among four network flexibility test cells which enable investigation of specific future scenarios. The test cells are split between the following network areas:

- Heat pump cluster at Sidgate Lane distribution substation, Hexham
- PV cluster at Mortimer Road distribution substation, Maltby
- Urban network fed off the Rise Carr primary substation electrical network, Darlington
- Rural network fed off the Denwick primary substation electrical network to Wooler

2.49 Trials of overhead line real-time thermal rating (RTTR); we have collected in excess of a year's worth of monitoring data for overhead EHV and HV conductors.

2.50 Trials of EAVC on-load tap changers for distribution transformers; autonomous open loop trials have been completed at three urban and rural locations, and closed loop GUS-controlled voltage trials have successfully controlled the network voltage between two predetermined voltage set points.

2.51 Demand side response trials; we have successfully completed all the trials with domestic and I&C customers, including complex multi-intervention trials. The GUS control system called for customers to either generate power or shed load on the network by automatically sending an instruction to I&C and domestic customers with agreed response contracts.

2.52 EES trials; we successfully ran autonomous open loop voltage control trials on live LV networks at five urban and rural locations, using real and reactive power to maintain network voltage between two set points. The battery system has been proven to absorb power from the network to charge the batteries when the network voltage set point is high. The best example of this is at our Mortimer Road site which has a cluster of solar PV users. When the sun shines the solar panels generate power onto the LV network increasing the LV network volts, and the battery systems have been deployed and proven to resolve this issue by controlling the network voltage.

2.53 Trials of combinations of EAVC and EES; autonomous closed loop voltage control trials have been carried out on LV networks with on-load tap changer distribution transformers in combination with EES. At Mortimer Road the PV cluster was observed and appropriate interventions suggested and made to control the voltage on the network with embedded PV generation.

Learning outcome 4 (optimum solutions)

2.54 Learning outcome 4 seeks to develop the optimum solutions to resolve future network constraints which could result from the transition to a low carbon economy. We are considering optimum solutions for representative customer groupings and networks, and these solutions are informing network design and are being encapsulated in the prototype tool for network designers, NPADDS.

2.55 We are combining data and analysis from learning outcomes 1, 2 and 3, with desktop modelling, simulation and emulation. This approach allows us to model combinations and future scenarios and those which are unfeasible or not economically viable to pilot in the field.

2.56 We have continued to update and validate our trial network models, as further data from network monitoring became available. We are using the data and models to predict the outcomes of network field trials. This work has also enabled us to evaluate which trials will provide the most learning and therefore to optimise the trial programme.

2.57 Later this year, we will publish an optimum solutions paper which will outline a merit order of solutions to network constraints, taking academic learning and placing it firmly in an industrial context. Non-CLNR solutions are also being considered, to create a comprehensive merit order of solutions and forge a coherent, wide-ranging view of how to design future networks. It will consider opportunities and solutions and explain why in practice, DNOs might take a certain policy stance. The conclusions will be structured so that they can be easily incorporated into relevant policy documents, and they will also inform the coding of the NPADDS design tool to ensure that it is consistent with policy.

2.58 In summary, the optimum solutions paper will therefore bring together:

- learning from customer and network trials within the CLNR programme;
- learning from a selection of other relevant projects, using techniques not trialled in CLNR validation from other like projects elsewhere, which is part of the "V" for validation in the VEEEG methodology[2];
- modelling of a wide range of scenarios of LCT load and generation
- compare and contrast with unlike solutions from other projects and with conventional solutions;
- the DNOs' appetite (on behalf of their customers) for risk; and
- consideration of practical implementation issues such as tolerable levels of risk, failure, degradation, back-up, upgrade paths and future-proofing.

Learning outcome 5 (most effective delivery)

2.59 The objective of learning outcome 5 is to provide a framework for transition of the technologies and interventions trialled by CLNR into business as usual (BAU). For DNOs, this will include:

- the provision of prototype design software tools;
- material for training courses;
- new operational procedures to define safe working practices for new technologies;
- design policy guidance;
- equipment specifications and equipment application documents; and
- recommendations to update national design standards.

For the wider industry, this includes possible new commercial models and policy recommendations as well as an assessment of the value of these solutions to the customer.

Network planning and design decision support tool (NPADDS)

2.60 The core framework and functionality of NPADDS is complete. In this reporting period we have concentrated on integrating models of the trial network areas into NPADDS and have demonstrated the assessment of these medium and low voltage networks at both internal and external events. Through the integration of DECC uptake scenarios, the NPADDS tool allows the user to understand the effect of low carbon technology penetrations on individual networks in terms of voltage and thermal issues.

[2] VEEEG – Validation, Extension, Extrapolation, Enhancement, Generalisation – see appendix 5 for more information

2.61 We have developed new NPADDS functionality, integrating solution templates that enable the assessment of which solutions are likely to work for any given network constraint. This will provide network designers, who are faced with multiple options, a guide to the solutions which will most cost-effectively release headroom. We implemented the solution template set derived from the Smart Grid Forum Workstream 3. The tool can now suggest solutions for issues due to a new connection, low carbon technology uptake or general load growth.

2.62 We have implemented a thermal modelling tool for transformers in NPADDS which will allow the user to assess thermal constraints on the network. The inputs to the model are the load profiles generated by the network assessment part of NPADDS, alongside a set of key parameters for the transformer (e.g. rating and time constants). The engine is an implementation of the IEC standard (IEC60076). The output is a graph of winding temperature over time (see figure 5).

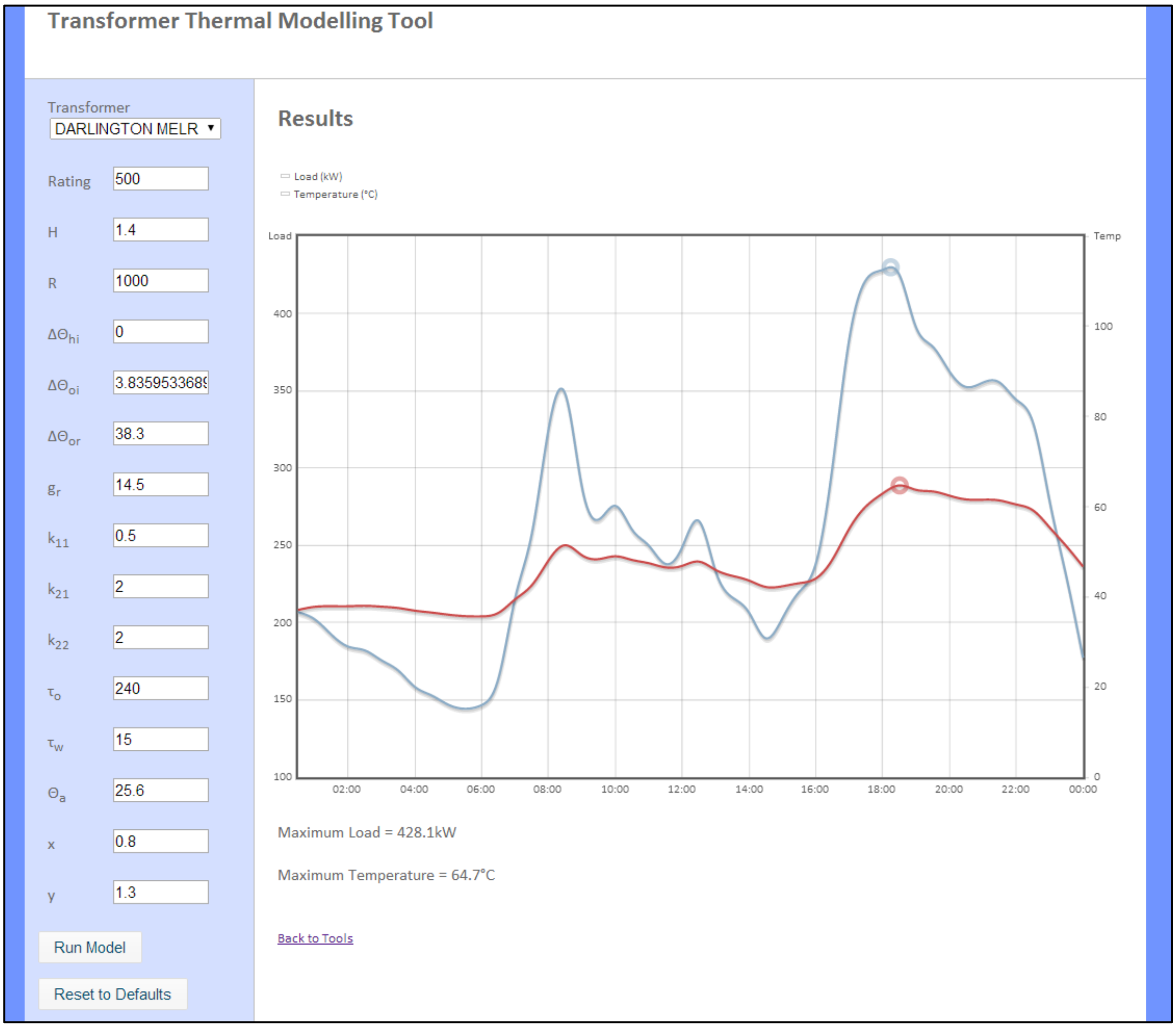

Figure 5: Thermal modelling output from NPADDS

Key: Blue = load, red = temperature

Winding temperature hotspots denoted by circular markers.

2.63 An important and unique aspect of the NPADDS tool is its ability to link policies to design and planning activity. We have uploaded existing Northern Powergrid policy and guidance documentation into the core NPADDS database and developed a tool to allow searches of documentation clauses. A search produces information sets which can span multiple documents and ranks them in order of relevance. The ranking uses an algorithm set similar to internet search engines.

2.64 Later this year we will complete the detailed solution assessment functions, including methods to model the effect of EES, DSR and control techniques. We will implement additional functionality for network planning, including methods to assess multiple network areas and build up reinforcement requirements (smart and conventional) over time. Further work will be completed on the cost benefit assessment functions, so that the estimated cost of a number of solutions and the expected benefits of each can be directly compared. Furthermore, we will create a specification of the full version of NPADDS, enabling development as a commercial product post project.

Training

2.65 We are developing training packages covering each of the individual network technologies, and additional packages focusing on DSR, active network management and an overview of the low carbon technologies trialled.

2.66 We have held workshops with Northern Powergrid operational staff to allow us to capture the knowledge gained during the trials and incorporate it into the training packages and other outputs. The training packages will be delivered in the next reporting period and will provide a solid grounding in the understanding of new network technologies, as well as information on their expected performance.

2.67 Further workshops have been arranged for autumn 2014 to allow Northern Powergrid's leads in asset management and field operations an opportunity to review the training packages, provide any final input and ensure the training packages are suitable for dissemination to all DNO audiences.

Policy guidance documents

2.68 We have commenced a review of Electricity Network Association Engineering Recommendations P15[3], P17[4], and P27[5]. In the remaining months of the project, we will draft recommendations for modifications to these recommendations, alongside reviews of how G59[6], ACE49[7] and ETR130[8] should be influenced by the knowledge gained from the project.

[3] P15: Transform loading guide: a guide to the loading of double wound transformers having nominal ratings of 120MVA and below, supplying systems at 66kV and below from the Supergrid and 132kV systems, 1971
[4] P17: Current rating guide for distribution cables, 1976; solid type cables for 33kV, 1976; ratings for 11kV and 33kV cables having extruded insulation, 2004
[5] P27: Current rating guide for high voltage overhead lines operating in the UK distribution system, 1986
[6] G59: Recommendations for the connection of generating plant to the distribution systems of licensed distribution network operators, 2013
[7] ACE49: Statistical methods for calculating demand and voltage regulation on LV radial distribution systems, 1981
[8] ETR130: Application guide for assessing the capacity of networks containing Distributed Generation, 2006

Impacts on power quality

2.69 In addition to the power quality monitoring in customer premises, we are collecting power quality data from 70 network locations, including substations and smart link boxes. We will collate, analyse and share the customer and network power quality data with interested parties later this year.

Network design standards – ACE49

2.70 We have begun analysing data from the customer trials, and by the end of 2014 we will complete the following key tasks:

- estimating P and Q values for general domestic customers based on the annual peak day data obtained from the smart meter dataset;
- deriving an outline set of industrial and commercial load profiles;
- deriving an outline set of base LCT load/output profiles; and
- describing likely sources of error within the DEBUT LV design tool (such as emergent properties generated by compound net low carbon technology outputs from independent properties) and developing a pragmatic, representative approach for handling them using applied statistical experience of the project team.

Future asset specifications

2.71 The specifications for procuring EES have been reviewed and, except for one suggested modification for noise limits, accepted. These will be published by the end of 2014. Similarly, the specifications for real-time thermal rating are well advanced and a draft of the document has already been shared with UKPN. Work is underway on the specifications for GUS and EAVC, and these too will be finalised in 2014.

2.72 We have held a series of workshops with Northern Powergrid operational and non-operational staff involved in the design, specification, procurement, installation and commissioning of the network equipment. The purpose of the workshops was to document the lessons learned during these stages and to capture learning on the choice of sites, pre-planning, communications, installation experience, testing and commissioning. To date, we have completed workshops on RTTR, EAVC and EES and we will shortly hold workshops covering GUS and the iHost data warehouse. We also intend to hold workshops with Newcastle University to capture the academic learning from each of the network technology trials.

3. Consistency with full submission

3.1. The high level solution being demonstrated and the high level method being trialled in the project remain the same as set out in the full submission. In that document we set out what we would deliver in each of five learning outcomes and this has not changed. However, we have submitted to Ofgem a change request for an additional 12 months to complete the project and a restructuring of the budget. If this change request is approved we are confident that, by using the additional external funding, some of the contingency budget and the efficiencies generated from the project to date, it will be possible to deliver the learning outcomes at the required level of quality within the original funding.

3.2. As is typical of such projects, not all the learning has taken the form originally envisaged, but the method is unchanged and the progress to date suggests that the value of the learning will be at least as good as that in the bid and quite likely better. In particular, the network models, the customer trial data and the research into customers' energy practices are already contributing to a rich socio-technical dataset that arguably exceeds the original expectations. Additional value will be provided through amalgamation of our project findings with other trials and through hosting of our dataset in an ambitious accessible format.

4. Risk management

4.1 This section provides an update on the key risks which affect, or might affect the delivery of the learning outcomes as described in the full submission. The key issues which have affected progress in the reporting period or which may present a challenge in the remainder of the project are discussed in section 2.

4.2 We have encountered a number of issues and risks which have resulted in delays to the project, and we have submitted a change request to Ofgem requesting a one-year extension to the project which we consider to necessary to deliver the learning outcomes, and which reflects the additional time that was needed to successfully mitigate the issues and risks encountered. For this reason, we have not highlighted in this section issues and risks causing delay if these can be mitigated such that the whole project can still be delivered within this extra year.

4.3 The risk profile of the project has naturally diminished as we approach the end of the project. The table below summarises the current most significant risks and also the status of the risks identified at the bid stage in box 26 of the full submission proforma. These are summarised in the following table and then discussed in more detail below. The full risk register is included in Appendix 2. The project has no procurement risks since all customer and network equipment and installation services have been procured.

Ref	Risk category	Risk	Risk Owner	Unmitigated risk			CURRENT Risk			Contingency Plan
				I	P	R	I	P	R	
1	Installation	Network Equipment may not operate as specified	Northern Powergrid	H	L	Red	L	N	Green	For equipment that does not function during the trials, use simulation or modelling by Newcastle University.
2	Installation	Possible failure to deliver the integrated demand response system	Northern Powergrid	M	M	Amber	Risk closed.			

Ref	Risk category	Risk	Risk Owner	Unmitigated risk			CURRENT Risk			Contingency Plan
3	Customer recruitment	Insufficient Customers Recruited for Test Cells	British Gas	H	H	**Red**	Risk closed			
4	Other	British Gas withdraws from the project	Northern Powergrid	H	L	**Red**	Risk closed			
5	Other	Emerging findings indicate a major change of project scope is required	Northern Powergrid	M	M	**Amber**	Risk closed			
25	Installation	GUS Control System not function as designed.	Northern Powergrid	H	M	**Red**	L	L	Blue	Run the autonomous trials and as many of the collaborative trials as is possible using workarounds (would depend upon the extent of the problem). However, this would slow the rate at which we can work through those trials. Using the results of the autonomous trials, model the predicted results of the collaborative trials.
43	Installation	DSR I&C test cell customers are located in un-monitored Network areas	Northern Powergrid	L	M	**Amber**	Risk has materialised. With the contingency measures, impact is low			Use simulation from Newcastle University to match signals for DSR to customers and network monitoring.
44	Installation	Network Technology & GUS integration	Northern Powergrid	M	M	**Red**	Risk closed			
45	Installation	Major Incident affecting trials equipment	Northern Powergrid	H	N	**Amber**	M	N	**Blue**	Reschedule and / or reduce numbers of physical trials, filling any gaps with simulation.
48	Other	Loss of academic personnel	DEI	H	H	**Red**	H	N	**Amber**	In the event that the project is extended but that staff / students leave before then, seek to replace personnel.

H = high, M = medium, L = low, N = negligible

Risk rating from high to low is red – amber – blue – green (see appendix 2)

Risk 1: Network equipment (EAVC, RTTR and storage) fails to operate as specified

4.4 Over the course of the project, our knowledge of the network equipment has increased and we have progressed through successful bench and witness tests of the individual devices, installation, commissioning and operation in the field trials. We consider the probability of this risk occurring to be negligible and so we have reduced the overall risk rating to green.

Risk 2: Failure to deliver the integrated demand response system

4.5 This risk was identified at the time of the bid. The demand side response platform successfully trialled the link between the control system and the aggregators who called the demand response from I&C/DG customers (test cells 18 &19). In addition the British Gas demand response host (Greencom) called demand response from domestic customers on the direct control trials (test cells 11a and 14). Accordingly, we have closed this risk.

Risk 3: Insufficient numbers of customers are recruited

4.6 This risk was identified at the time of the bid. Although there were a number of external factors which made recruitment of large numbers of customers more difficult than we had envisaged, we took a number of actions to successfully overcome these, and so we closed this risk. Our change request discusses in more detail the issues encountered and our mitigating actions. The 'change request supporting addendum' discusses the quality of the learning and explains that for those test cells where we have much lower numbers than originally planned, we are able in the majority of these cases to deliver meaningful results due to the modelling which extrapolates data from the field trials.

Risk 4: British Gas withdraws from the project

4.7 This risk was identified at the time of the bid. With the collaborative working relationship with British Gas and the evident continuing high level of commitment to the project, we have closed this risk.

Risk 5: Emerging findings indicate a major change of scope is required

4.8 This risk was identified at the time of the bid. This risk has been closed since its probability is low and naturally diminishes with time. Indeed, with equipment designed, purchased and installed and customers recruited, should this risk materialise making any major changes of scope would not deliver benefits from the investment already made. Furthermore, giving due consideration to the findings from other studies would only serve to enhance the learning delivered from CLNR.

Risk 25: GUS system not functioning as designed

4.9 The GUS ANM system with its blend of central and distributed control forms an important technical component in the coordination of individual network components and in facilitating network-to-customer communications. If some of the GUS functionality does not operate as designed, it may not be possible to conduct the full suite of the network trials under GUS supervision. However the customer intervention trials have already been completed and the network trials using GUS are well underway, so we consider the probability of this risk materialising to be reduced from 'medium' to 'low'.

4.10 Our contingency plan, in the event that this risk materialises before we complete the full suite of trials, is to run the autonomous trials and as many of the collaborative trials as is possible using workarounds, dependent upon the extent of the problem. However, workarounds would slow the rate at which we can work through the trials. Using the results of the autonomous trials, we would model the predicted results of the collaborative trials.

4.11 With the contingency plan described above, we have reduced the risk rating to blue.

Risk 43: trial participants for large scale demand response trials are located in un-monitored areas

4.12 I&C and DG customers are contracted to provide large scale DSR (test cells 18 and 19). The risk that recruitment would not be successful in our monitored network areas did indeed materialise. The impact of this is that DSR is not called from a customer who was located on the same network as where the GUS control system is signalling an artificial network constraint.

4.13 To mitigate this, we have executed our contingency plan, which is to use data from the already monitored network locations to generate the signals required to call DSR and to demonstrate the end-to-end DSR processes via this signal, and to monitor the response delivered by a customers in different geographic locations. Modelling will be used to combine the need and the response as if they are on the same area of network in order to evaluate its success.

Risk 44: Network technology & GUS integration

4.14 We had identified a risk that certain elements of the installed network equipment might not communicate or integrate correctly in every instance with the GUS control system & data warehouse, and this would affect the field trials. All the interfaces between the GUS system and END devices have been commissioned, and the field trials are well underway. Many difficulties were encountered but these were successfully resolved. Accordingly, we have closed this risk.

Risk 45: Major incident affecting trials equipment

4.15 There is a risk that a major incident such as an extreme weather event could affect one or more of the trial networks and adversely affect the lead up to or execution of the network trials, causing delay to the project. In the unlikely event that this occurs, our contingency plan is to develop an alternative strategy to deliver the network trials by switching resources to other unaffected network areas, and/or reduce the physical trials, filling any gaps with simulation.

Risk 48: Loss of academic project personnel

4.16 Some of the academic staff working on the project were on fixed term contracts of employment which were aligned with the original project end date so there was a risk that some might have left before the revised end date for the project. A similar situation also applied to PhD students working on the project. We have significantly reduced the likelihood of premature loss of key academic personnel by extending contracts to ensure coverage of the crucial analysis and conclusions stage where much of the learning benefit will be realised.

5. Successful delivery reward criteria (SDRC)

5.1. We are set to achieve all the deliverables and activities referred to by the SDRC, although some of these will be later than the original SDRC dates due to the material changes in external circumstances, as set out in our change request. We have proposed revised SDRC dates, subject to approval by Ofgem, and our progress against each SDRC is set out in the table below:

SDRC type	SDRC description	SDRC original	SDRC revised	Status
Dissemination activities	1st Regional stakeholder panel meeting held	31-Mar-11		Completed on time
Dissemination activities	Project website up and running and updated in line with project developments	31-May-11		Completed on time
Dissemination activities	1st Industry stakeholder forum held	31-May-11		Completed on time
Project milestone	Commence installation and commissioning of network equipment relating to learning outcome 3	30-Sep-11		Completed on time
Dissemination activities	2nd Regional stakeholder panel meeting held	31-Mar-12		Completed on time
Dissemination activities	2nd Industry stakeholder forum held	31-May-12		Completed on time
Dissemination activities	1st Distributor project review meeting held	31-Jul-12		Completed on time
Project milestone	Complete installation and commissioning of network equipment relating to learning outcome 3	31-Dec-12	31-Dec-13	Completed on time
Data sets	Demand profiles grouped by customer type	31-Dec-12	31-Aug-14	Interim results published in line with original SDRC. On track to complete final results on time.
Data sets	Demand profiles grouped by low-carbon technology type	31-Dec-12	31-Aug-14	
Data sets	Output profiles of existing generation types	31-Dec-12	31-Aug-14	
Data sets	Output/ demand profiles before and after a range of interventions	30-Apr-13	31-Aug-14	
Data sets	Network data showing performance of selected network technologies	30-Sep-13	31-Oct-14	On track for completion on time
Integration of network technologies	Provide an understanding of, and disseminate to other distributors, how advanced voltage control, thermal ratings and storage may be integrated to enable more low-carbon technologies to be accepted on the network. Provide a view of the costs associated with these arrangements	30-Sep-13	31-Dec-14	

SDRC type	SDRC description	SDRC original	SDRC revised	Status
Dissemination activities	3rd Industry stakeholder forum held	31-Dec-13		Completed on time
Dissemination activities	2nd Distributor project review meeting held	31-Dec-13		Completed on time
Dissemination activities	3rd Regional stakeholder panel meeting held	31-Dec-13		Completed on time
Analysis of load profile data	Publish analysis of load profile data	31-Dec-13	31-Dec-14	On track for completion on time
Analysis of generation profile data	Publish analysis of generation profile data	31-Dec-13	31-Dec-14	
Commercial models arrangements	Undertake, and disseminate to other distributors, a critical review of how commercial models and arrangements between distributor and supplier may evolve to facilitate customer-side response	31-Dec-13	31-Dec-14	On track for completion on time
Dissemination activities	Dissemination of learning from customer trials, network trials and the project outputs		31-Dec-14	On track for completion on time
Project milestone	Project close down report produced	31-Dec-13	31-Dec-14	On track for completion on time

6. Learning outcomes

Learning outcome 1 (current and future load) & learning outcome 2 (customer flexibility)

6.1 In April 2014, we published **CLNR-L052: CLNR Social Science Report 3** and an accompanying briefing note **CLNR-L053: DEI Briefing Note 14** which summarises the key learning. This report adopts a practice-based approach to inform our understanding of how and why electricity is used in residential households and businesses. It suggests that the interaction of five core elements, described as the CCRES Framework, (Capacities, Conventions, Rhythms, Economies, Structures) shape the use of electricity and its flexibility. It also begins to integrate social and technical data analysis.

6.2 **"Smart Grid Data Cultures"** (Robin Wardle and Gareth Powells) was accepted into the RGS-IGB Annual International Conference, 27th-29th August 2014 for the session "The role of commercial data in #Census 2022". This paper will draw on the authors' experiences of working with CLNR data, to explore the types of analysis that are being performed, the data that is being collected to permit these analyses and the practical issues experienced. It draws conclusions about the operational and analytic challenges and opportunities of linking commercial, scientific and official data sets for integrated analysis in order to feed into the design and realisation of future data collection and statistical systems.

6.3 A paper on CLNR's electric vehicle (EV) research titled **"Connecting the Car: Electric Vehicles and Smart Infrastructures"** authored by Gareth Powells, has been accepted for the Behave Energy Conference 2014 (http://behaveconference.com/). This paper draws on all available data from the project's EV research to disseminate key implications for networks, policy makers and researchers.

6.4 Gareth Powells presented the paper **"Understanding evening peak electricity use in the UK: a socio-technical analysis"** (Gareth Powells, Steve Lyon, Harriet A. Bulkeley, Sandra Bell) at the Smart Grids and the Social Sciences Workshop, at the Norwegian University of Science and Technology, Trondheim, 10th-11th April 2014. This paper introduces the evening consumption multiplier (ECM) statistic as a quantitative and statistically robust device for exploring the increases in energy use during the early evening observed in all test cells. It also reveals the variability of ECM and the ways in which different socio-geographic groups of households will exhibit different degrees of evening electricity intensity, and thus contribute to the evening peak demand for electricity to different degrees. The paper also begins to draw on the qualitatively grounded CCRES framework to relate the socially shared uplift in evening demand to the ways in which they are socially reproduced through capacities, conventions, rhythms, economies and structures.

6.5 The paper **"Peak Electricity Demand and the Flexibility of Everyday Life"** (Gareth Powells, Harriet Bulkeley, Sandra Bell and Ellis P. Judson) was accepted for publication by Geoforum (http://www.journals.elsevier.com/geoforum/). This paper draws on 186 home tours conducted for the project to examine the social practices which shape electricity demand curves used by the electricity industry to understand current consumption and manage networks. Using qualitative analysis the authors consider how; in what ways, and for what purpose consumption of electricity may be or may become flexible in response to Time of Use tariffs designed to reduce consumption in the early evening. The authors find that it is practices not people which may or may not be flexible and distinguish between the most and least flexible practices. Through analysis of qualitative data about how social practices responded to Time of Use pricing the authors argue that the flexibility of practice such as laundry, cooking and so on is affected, at least, by their rhythmic characteristics. We argue that where there are socially conventional times for conducting practices, as is the case with dining, the financial incentive has not been successful in creating flexibility. By contrast, other practices such as laundry for example are less constrained in time and by social conventions and provide more opportunities for people to improvise in response to interventions.

6.6 **"The co-evolution of energy provision and everyday practice: Integrating heat pumps in social housing"** (E Judson et al) is in final review stage with the Journal of Science and Technology Studies (http://www.sciencetechnologystudies.org/). The authors find that air source heat pumps (ASHP) are taken up within existing social relations and everyday practices, such that rather being adopted in the manner by which designers intend, they are 'domesticated' – made to work within the particular socio-technical contexts in which they are located. The authors argue that a better system of provision is required if ASHPs are to be welcomed as an advancement in the provision of heating and hot water for social housing and their reputation enhanced.

6.7 **"Fostering active network management through SMEs practices"** is in submission to Energy Policy. This paper draws on analysis of the SME "energy tours" conducted as part of the project and presents a social practice-oriented theoretical perspective which enables us to a) see how and where energy is used, b) examine practice commonality across SMEs and c) pin-point which practices harbour potential flexibility. The paper concludes that for SMEs there is "no one size fits all" approach and different routes to flexibility for different activities across sectors are present. SMEs present an implacability in existing structures and systems that may counter attempts to introduce flexible practices. Potential opportunities for flexibility in electricity management could be achieved by re-shaping SMEs practices, provided that interventions are tailored to specific needs.

6.8 The paper entitled **"Household Relations and Domestic Demand Side Response"** (Sandra Bell, Ellis Judson, Harriet A. Bulkeley, Gareth Powells) has been accepted for the 13th European Association of Social Anthropologists (EASA) Biennial Conference, Tallinn University, Tallinn, Estonia, 31st July – 3rd August 2014. The paper identifies installers and intermediaries as important to the successful take-up of heat pumps and that rather than regarding users as passive adopters of new technologies, such approaches would recognise the vital work that users perform in maintaining and transforming energy systems and a basis through which to engage households in new ways of thinking about and 'doing' energy use.

6.9 **"Smart Grids and the Constitution of Solar Electricity Conduct"** (Harriet A. Bulkeley, Gareth Powells, Sandra Bell) received positive feedback from peer reviewers as part of the publication process with Environment and Planning A (http://www.envplan.com/A.html). The paper has been accepted for publication subject to some very minor revisions. In this paper, the authors draw on theories of governmentality and social practice to consider the ways in which the smart grid is serving to constitute new forms of energy conduct. We argue that in contrast to households where solar PV has been regarded primarily as a device to deliver new flows of finance, the introduction of smart grid logics through the installation of in-home displays and hot water storage has served to rearticulate what 'good' electricity conduct entails and to reconfigure the ways in which energy-intensive practices are undertaken in households. We find these new forms of 'governing the self' to be critical in shaping how, and to what effect, the smart grid is taking root.

6.10 Harriet Bulkeley and Gareth Powells contributed a chapter titled **"Smart grids and the governing of energy use: reconfiguring practices?"** to a book which will be published by Routledge entitled Beyond Behaviour Change. The chapter draws on the CLNR PV test cells and emphasises that governing smart grids is an on-going and imprecise process prone to breakdown, revision and one which requires constant repair and re-establishment, in which multiple alternative outcomes are ever present.

Learning outcome 3 (network flexibility)

6.11 Paper 0323, **"Future low carbon technologies, impacts and energy storage solutions on UK distribution networks"** (Oghenetejiri Anuta, Christian Barteczko-Hibbert, Neal Wade) is to be presented at the CIRED Workshop, 11-12 June 2014, during the poster session: 'Grid operation and congestion management'. This paper draws on CLNR project data, as well as network and asset models to assess the impacts of future demand and generation from heat pumps and solar photovoltaics, which can be evenly dispersed or locally concentrated on a medium voltage network. The paper investigates the effectiveness of using energy storage to manage the resulting issues arising from such networks.

Learning outcome 4 (optimum solution) & learning outcome 5 (effective delivery)

6.12 We have completed an internal report on trials of the LV system at Denwick entitled **"CLNR Initial Trial Analysis - Analysis of Autonomous and Single + GUS voltage control trials at Denwick"** using data from the HV/LV on-load tap changer (OLTC) equipped transformer trials. The results illustrated that when planning systems which use secondary transformers with OLTC operating autonomously, one should be cognisant of the possible measurement error of the local busbar voltage. For example, if the measurement tolerance is +/-1%, when considering high load/high generation scenarios, simulated remote end network voltages should not drop below 0.95pu and should not rise above 1.09pu to ensure that the customers do not experience voltages outside of the statutory limits. It was found that the validated models can be only be adequately modelled if the sample rate of the input data (voltage, real and reactive power) is at least 1 minute/sample. Lower sample rates are likely to underestimate the number of tap changer operations. This could be a particular characteristic of OLTC equipped secondary transformers as primary transformers are likely to observe lower normalised slew rates on the voltage, real and reactive power traces due to the diversity of the load at higher voltage levels.

6.13 We have completed an internal report on trials of mechanically switched capacitors under the control of the GUS system entitled **"CLNR Initial Trial Analysis - Mechanically Switched Capacitor Bank Autonomous and Single + GUS Voltage Control at Denwick"**. It can be seen from the studies that the application of a mechanically switched capacitor in conjunction with GUS, can increase allowable ASHP, EV and solar PV connections significantly when there are downstream clusters. It was found that if these LCTs are distributed in a uniform manner across the network, the addition of the GUS control system gives limited benefits in comparison with a conventional voltage control approach.

6.14 We have completed an internal report on trials of energy storage (EES) entitled **"CLNR Initial Trial Analysis - EES1 Autonomous and Single + GUS Powerflow Management at Rise Carr".** It can be seen from the studies that the application of EES in conjunction with GUS, can increase allowable ASHP, EV and solar PV connections significantly by alleviating issues associated with thermal constraints on the system.

6.15 We have submitted an invited paper to Applied Energy entitled "**Design and analysis of electrical energy storage demonstration projects on UK distribution networks".** This paper brings together work from the UK Power Networks Hemsby electrical energy storage project, also funded by the LCN Fund, with work from CLNR utilising the VEEEG methodology. The paper demonstrates how the VEEEG methodology can be applied to the results of network flexibility field trials from other projects to extend, extrapolate and enhance the results thus generalising the final result. The VEEEG analysis of the peak shaving trial results from Hemsby, established that the relationship between the energy capacity required of an EES unit located at a secondary substation, and the number of additional ASHP or PV installations on a downstream LV network was non-linear.

Overview of overall approach to capturing the learning and dissemination

6.16 Our approach to capturing the learning from the project includes a review and write up on completion of each of the key stages of the project. We use both workshop style sessions and learning capture in the field. For the latter, we have deployed an additional person on site to observe, discuss and note down activities and/or issues and take photographic and video evidence.

6.17 Our approach to disseminating learning, both externally and within Northern Powergrid, is underpinned by two main principles; delivering information according the type of audience and maximising the reach by using multiple channels. Our external contacts are segmented into five 'clusters' allowing us to tailor messaging and use communications channels which are appropriate to each audience.

External dissemination

6.18 Our external communication and dissemination strategy utilises a number of different channels including speaking engagements, the CLNR website and newsletters, published materials (reports, presentations, newsletters, videos) as well as press releases, email and social media campaigns. We have over 900+ opt-in subscribers to our CLNR mailing list, 363 Twitter followers and 233 members of our LinkedIn discussion group. We communicate with all our stakeholders in a regular, consistent and appropriate manner. In this reporting period we have added six new videos to the CLNR YouTube channel taking the total available to view to 28.

6.19 The following communications and dissemination activities have taken place during this reporting period. Materials marked * have been added to the CLNR website's project library for access by a wider audience.

Date	Type	Description
02/12/2014	CLNR Event	*CLNR DNO Knowledge Sharing Event, Darlington, UK
02/12/2014	PR	'North East leads the way in energy innovation'
04/12/2014	Feature Article	Article on DSR with industrial and commercial customers for the Major Energy Users Council (MEUC) magazine entitled 'What price energy flexibility?'
06/12/2014	Feature Article	Professor Harriet Bulkeley of Durham University talks to Utility Week about consumer response to smart meters and IHDs
10/12/2014	Feature Article	BDaily magazine 'Low carbon pilot from North East gets national attention'
17/12/2014	Internal	Northern Powergrid's Regulation end of year conference, York, UK
20/12/2014	Direct Publication	*CLNR Progress Report 6
22/12/2014	Stakeholder	CLNR referenced in DECC's second annual report on the roll-out of smart meters (P.24)
17/01/2014	Feature Article	CLNR article in the Financial Times 'UK's CLNR tests low carbon grids'
18/01/2014	Knowledge Sharing	Contribution to the Energy Storage Operators Forum (ESOF) best practice guide
20/01/2014	Feature Article	BDaily magazine 'North East's smart grid project stages energy industry event'
07/02/2014	Feature Article	The Telegraph – CLNR featured in Siemens smart grid article
13/02/2014	Stakeholder	Northern Powergrid annual stakeholder report - Low Carbon Outlook
27/02/2014	PR	'Putting electrical energy storage to the test' press release
27/02/2014	Knowledge Sharing	CLNR's customer engagement strategy presented at SSEPD's Solent Achieving Value from Efficiency (SAVE) knowledge sharing event.
28/02/2014	Email	First CLNR monthly e-bulletin to stakeholders
04/03/2014	Knowledge Sharing	Presentation on CLNR at the DECC benefits monitoring and review group, London, UK
04/03/2014	Feature Article	Northern Powergrid puts electrical energy storage to the test - Renewables Focus Magazine
10/03/2014	Feature Article	'UK begins largest energy storage trial' - Metering.com
24/03/2014	Stakeholder	Officials from HSE visit and tour of Darlington battery installations
28/03/2014	Stakeholder	Information sent to the Climate Change & Sustainability department of the National Audit Office with links to CLNR reports
28/03/2014	Email	Monthly e-news bulletin to stakeholders
03/04/2014	Video	CLNR 'Smarter Homes' video uploaded to YouTube

18/03/2014	Stakeholder	Northern Powergrid annual stakeholder report launch, Newcastle upon Tyne, UK
24/03/2014	Stakeholder	Northern Powergrid annual stakeholder report launch, Leeds, UK
20/03/2014	Knowledge Sharing	Lecture by Professor Phil Taylor: MicroGrids - Niche Application or Fundamental to Future Energy Systems? Institute of Mechanical Engineers, London, UK
18/04/2014	Video	New CLNR customer trials video released 'Engaging consumers in the smart grid'
18/04/2014	Video	CLNR smart appliance trials with domestic customers
18/04/2014	Video	CLNR trials with heat pump customers
18/04/2014	Video	CLNR trials with solar PV customers
18/04/2014	Video	CLNR and National Energy Action
21/04/2014	Feature Article	CLNR features in Siemens editorial for the NESCO event in the Newcastle Journal
23/04/2014	Feature Article	Feature article in the Newcastle Journal 'North east project testing effectiveness of energy storage'
24/04/2014	Direct Publication	*CLNR-L052 Social science interim report 3
24/04/2014	Direct Publication	*CLNR-L053 DEI Briefing Note: Social science interim report 3
24/04/2014	Email	Email to targeted mailing list contacts with links to social science report and briefing note
29/04/2014	Stakeholder	Northern Powergrid community energy event – Leeds, UK
30/04/2014	Stakeholder	Northern Powergrid community energy event - Newcastle upon Tyne, UK
30/04/2014	Email Campaign	Monthly e-news bulletin to stakeholders
01/05/2014	Feature Article	Energy Management Magazine on Active Network Management and the GUS platform
01/05/2014	Stakeholder	Presentation on CLNR with local authority to ETI - Newcastle upon Tyne
02/05/2014	Feature Article	Utility Week Magazine - Dave Miller, CLNR's Technical Architect on 'Putting together the pieces of the smart grid puzzle'
06/05/2014	Stakeholder	Presentation on CLNR with local authority to ETI - Hull
14/05/2014	Email	Monthly e-news bulletin to stakeholders
07/05/2014	Stakeholder	NECC - The Energy Debate, Balancing the Energy Mix
08/05/2014	Stakeholder	Energy Live Event - Drax Power Station, North Yorkshire
13/05/2014	Stakeholder	PRASEG Reception: Electricity Storage in the Future Vision for a Lower Cost Sustainable Electricity System
19/05/2014	Stakeholder	Presentation on CLNR with local authority to ETI - Sheffield
20/05/2014	Industry Conference	Presentation by British Gas on CLNR and Smart Metering at the Next Generation Utilities Summit - Berlin, Germany
22/05/2014	Press Release	UK's largest study of consumer electricity practices sheds light on customer flexibility
23/05/2014	Knowledge Sharing	Presenting on electrical energy storage at a global Webinar together with Siemens

Internal dissemination

6.25 As with external dissemination, our internal communication and dissemination strategy utilises a variety of appropriate channels and formats. This includes briefings with staff from key functions involved in delivering the project, and those who are involved in the development and approval of key deliverables.

6.26 We run workshops with staff in the functions who will lead the transition into business as usual, and topics covered to date include EES, EAVC, RTTR and NPADDS. We will cover off GUS and commercial arrangements in the next reporting period. We will also begin a programme of high level 'lunchtime' project briefings open to all interested Northern Powergrid employees, regardless of their role in the business.

6.27 We hold user forums to ensure that the outputs of the project including policies, equipment specifications, commercial propositions, training materials and design tools will be fit for purpose. We attend Northern Powergrid operational and safety seminars and have produced special materials for control and field operations staff that will allow them to recognise, understand and safely operate the any new network equipment they encounter. Members of the CLNR team have also participated in or led events with the management team and with specific business functions (such as call centre, network trading, design etc.). Some of these events will cover the whole breadth of the project, helping us to raise awareness, whilst others focus on specific topics which could affect their day to day roles, e.g. with design staff we focused on potential changes to policy and on the development of NPADDS.

7. Business case update

7.1. The business case presented in the full submission proposal was based on delivering an estimated £14.3bn of net financial benefits, including 43.5MtCO_2 benefits, to GB consumers over the period 2020 – 2050. This was based on the solutions being delivered by the project being applicable to 80% of GB networks and being adopted such that the uptake of low carbon technologies can be accelerated by one year.

7.2. The change request which we have submitted does not result in a change to the estimate of this benefits case. This is because the proposed project changes are expected to deliver the originally intended learning and customer benefits, as described in the original proposal. The only difference
is that they will be delivered 12 months later than had been anticipated under the original timetable. However, given the methodology used to assess the original business case, a delay of this length would not impact on the estimate of benefits. This is because no benefits were assumed to flow until 2020, given the conservative assumptions that were used about the speed of roll-out of low carbon technologies. Since the learning from CLNR will be complete by the end of 2014 we consider there is sufficient time to ensure the learning could be implemented in advance of 2020. Consequently, if we were to rerun the analysis with the same inputs there would be no change in the benefits reported.

7.3. We recognise that it will also be important to update the business case to reflect more recent forecasts of input data and to utilise the more sophisticated tools now available to evaluate the benefits that we expect to be delivered by this project (such as the EA Technology's Transform™ model). We plan to undertake this exercise and include the results as part of the project closedown report.

8. Progress against budget

8.1. We are on target to deliver the project within the total cost envelope with the real prospect of being able to return to customers *ca.* £0.4m of the contingency budget which is currently unallocated.

8.2. Additional sources of funding have been obtained to provide value to the CLNR project by enhancing the quality of the outputs at no cost to the customers funding the project. Most notably, British Gas contracted with DECC and £2.2m was invested in subsidising heat pump installations in the absence of a renewable heat incentive.

8.3. Also, our academic partners have combined other grants with the LCN funded activity. Early in the project a £0.5m Durham University grant helped to establish much of the modelling simulation capability in a smart grid laboratory that has been so important to delivering both the baseline and additional outputs from the project. More recently, a £2m grant for Newcastle University from the Department for Culture, Media & Sport is creating a national centre for Big Data and Cloud Computing. This will support the hosting of the legacy data from CLNR post project closedown that we expect to be an important national resource for the next decade. Both grants are leveraging value from CLNR, were not committed at bid, and are at no cost to customers funding the project.

Cost Category	**Costs to Date** (May-14)	**Project Direction Plus agreed £1.1m transfer**	**Current Forecast**	**Variance of revised budget against project direction plus agreed £1.1m**[9]		**Forecast variance** (relative to Nov 2013 progress report)		
						Nov-13	**Variance**	
	£m	**£m**	**£m**	**£m**	**%**	**£m**	**£m**	**%**
Box 6 (Employment costs)	3.449	3.480	4.376	0.896	26%	4.584	(0.209)	-5%
Box 7 (Equipment costs)	12.664	12.124	12.664	0.541	4%	12.583	0.081	1%
Box 8 (Contractor costs)	10.435	10.297	12.194	1.897	18%	11.929	0.265	2%
Box 9 (Customer and user payments)	0.358	0.769	0.499	(0.270)	-35%	0.442	0.057	13%
Box 10 (Other costs)[10]	0.647	4.364	1.301	(3.063)	-70%	1.495	(0.194)	-13%
Total costs	**27.553**	**31.034**	**31.034**	**0.000**	**0%**	**31.034**	**0.000**	**0%**

[9] A £1.1m transfer of costs from box 8 to box 7 has been agreed by Ofgem since the project direction.

[10] Most of the reduction in 'other costs' is due to the reallocation of £2.7m of contingency from 'other costs' to costs in other budget categories. These cost variations are explained in the CLNR change request

9. Bank account

9.1. Deloitte conducted a review of the transactions on the memorandum account for the reporting period. The outcome of this review was successful and no significant issues were noted. The report received from Deloitte can be viewed in Appendix 1.

9.2. Confidential Appendix A: Memorandum Account Transactions lists the transactions between 1 December 2013 and 31 May 2014.

10. Intellectual Property Rights (IPR)

10.1. No IPR have been registered or royalties earned in this reporting period. In the remaining months of the project we will establish IPR arrangements appropriate to the commercial value of the outputs.

11. Other

11.1. Further supporting information has been included within the report as appendices, which are as follows:

- Appendix 1: Deloitte audit statement – memorandum account transactions
- Appendix 2: Project risk register
- Appendix 3: Customer trials – a guide to the test cells
- Appendix 4: Network equipment
- Appendix 5: VEEEG methodology
- Appendix 6: Time of use tariff savings & compensation

12. Accuracy assurance statement

12.1 The approach taken to ensuring the accuracy of the information contained in this report is based on building in quality to the whole process/lifecycle of the progress report and the data and information contained therein. This quality assurance is provided by the following processes and controls:

- The integrity of the underlying systems and professional competence of the staff involved.
- Referencing existing 'within project' reports, records and materials to avoid errors or omissions.
- Independent checking of the financial aspects of the report, by Northern Powergrid staff where appropriate and by external auditors where mandated (i.e. the Project Bank Account transactions).
- Regular scheduled review of the project financial data with the senior Northern Powergrid financial staff including the Finance Director.
- Review by project board members who represent a wide range of interests and competencies and include representatives from all four project partners.

- Approval by the executive board, providing senior management endorsement by all four project partners in addition to the Accuracy Assurance Statement from a Northern Powergrid board director

12.2 The key steps in this approach are:

Step	**Rationale**
Content has been contributed by project personnel according to their areas of responsibility and expertise.	This provides confidence in the capability of the responsible staff to produce a meaningful and accurate report.
External auditors have certified Northern Powergrid's accounting arrangements for the project as being satisfactory, and revisit this on an annual basis (i.e. the provision of the annual report to Ofgem to confirm compliance with the requirements set out in the Bank Accounts section of the Project Direction). The most recent annual audit was undertaken in December 2013.	This provides confidence that sources of data for the financial aspects of the report are indeed reliable.
Responsibility for preparing the financial sections of the report has been allocated to the project accountant who is an accounting professional.	This provides confidence that the financial aspects of the report are professionally prepared.
The schedule of memorandum account transactions is audited by Northern Powergrid's external auditors.	Required by the Project Direction, this provides confidence in this aspect of the report.
As part of our quality assurance process, we will check that the actual expenditure figures in 'Progress Against Budget' reconcile with records in Northern Powergrid financial systems and this check will be carried out by a person other than the person who has prepared this information for inclusion in the report.	This reduces the possibility of human error.
The report is reviewed by all members of the project board and approved by the executive board. Both the project board and the executive board include representatives from each project partner including Northern Powergrid. Members of the Executive Board are at director level in their respective organisations.	This ensures that the report is comprehensive and balanced.

12.3 Sign off: I confirm that the processes in place and steps taken to prepare this report are sufficiently robust and that the information provided is accurate and complete.

John Barnett
Commercial Director, Northern Powergrid
20 June 2014

Appendix 1: Deloitte audit statement – memorandum account transactions

Deloitte.

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13th June 2014

Dear Sirs

Northern Powergrid (Northeast) Limited ("the Company") – Customer-led Network Revolution Project ("the Project"): Memorandum Account Transactions Report of Factual Findings

We have performed the following procedures as agreed by Northern Powergrid (Northeast) Limited ("the Company") and OFGEM on the schedule of information provided by the Directors of the Company ("the Schedule") in accordance with our engagement letter dated 9th May 2014, a copy of which is attached. The procedures were performed solely for the purpose of assisting the Company with their compliance with Clause 3.82 of the LCN Fund Governance Document.

Scope of our work and factual findings

The procedures performed and the results were as follows:

Procedures	Results
Obtain a schedule of all the memorandum account transactions for the Project for the six month period ended 31st May 2014.	We obtained the Company's schedule for the 6 month period ended 31st May 2014.
Ensure that the schedule includes interest and confirm that this has been calculated according to the rate project funds would earn on the open market (i.e. in a separate bank account).	As the funds related to the project are held within the Company's current account, the schedule shows interest which has been calculated on a daily basis by reference to the closing balance of funds related to the Project, and the interest rate applying to the main current account. We obtained confirmation of the interest rates from the Company's treasury function, and we have gained confirmation that the transactions are related to the Project by the testing below.

Deloitte.

Procedures	Results
Select a sample of 25 transactions from the schedule and perform the following:	
1. Agree the details of the transaction to supporting documentation;	All transactions have been agreed to relevant documentation.
2. Agree the transaction to the bank account of the Company; and	All transactions have been agreed to bank statement.
3. Confirm that the transaction relates to the Project.	All transactions have been confirmed as relating to the project.

The scope of our work in preparing this report ("Report") was limited solely to those procedures set out above. Accordingly we do not express any opinion or overall conclusion on the procedures we have performed. You are responsible for determining whether the scope of our work specified is sufficient for your purposes and we make no representation regarding the sufficiency of these procedures for your purposes. If we were to perform additional procedures, other matters might come to our attention that would be reported to you.

Our Report should not be taken to supplant any other enquiries and procedures that may be necessary to satisfy the requirements of the recipients of the Report.

The procedures we performed did not constitute a review or an audit of any kind. We did not subject the information contained in our Report or given to us by the Directors to checking or verification procedures except to the extent expressly stated above. This is normal practice when carrying out such limited scope procedures, but contrasts significantly with, for example, an audit. The procedures we performed were not designed to and are not likely to reveal fraud.

The audit work of Deloitte LLP on the financial statements of the Company was carried out in order to report to the Company's members as a body in accordance with the statutory obligations under Chapter 3 of Part 16 of the Companies Act 2006 and is subject to a separate engagement letter. The audit work was undertaken to state to the Company's members those matters required to be stated in an auditor's report and for no other purpose. The audits of the Company's financial statements were not planned or conducted to address or reflect matters in which anyone other than such members as a body may be interested.

In particular, the scope of the audit work was set and judgements made by reference to the assessment of materiality in the context of the audited accounts taken as a whole, rather than in the context of the Report contemplated in this letter. Deloitte LLP have not expressed an opinion or other form of assurance on individual account balances, financial amounts, financial information or the adequacy of financial, accounting or management systems.

Deloitte LLP do not accept or assume responsibility to anyone other than the Company and the Company's members as a body, for their audit work, for their audit report or for the opinions they have formed. To the fullest extent permitted by law, Deloitte LLP do not accept or assume responsibility or liability to anyone by virtue of this engagement or our Report in relation to our audits of the Company's financial statements.

Deloitte.

Use of Report

Our Report has been prepared solely for your exclusive use and solely for the purpose of assisting the Company with their compliance with Clause 3.82 of the LCN Fund Governance Document. Our Report is not to be used for any other purpose, recited or referred to in any document, copied or made available (in whole or in part) to any other person without our prior written express consent. We accept no duty, responsibility or liability to any other party in connection with the Report or this engagement.

Yours faithfully

Deloitte LLP

Deloitte LLP
Chartered Accountants
Newcastle Upon Tyne, United Kingdom

Appendix 2: Project risk register

Risk rating system

The following matrix illustrates the risk rating system used, i.e. the probability and impact of a risk combine to give a risk rating of red, amber, blue and green.

Probability					
It is judged to be **near certain** that the risk will occur (70% < probability <100%)	High	NH	LH	MH	HH
It is judged to be **probable** that the risk will occur (40% < probability < 70%)	Medium	NM	LM	MM	HM
It is judged to be **possible** that the risk will occur (1% < probability < 40%)	Low	NL	LL	ML	HL
It is judged to be **improbable** that the risk will occur (probability <1%)	Negligible	NN	LN	MN	HN
		Negligible	Low	Medium	High
		Should the risk occur it is judged that the impact on the programme would be **negligible**	Should the risk occur it is judged that the impact on the programme would be **marginal**	Should the risk occur it is judged that the impact on the programme would be **critical** **(or opportunity would be significant)**	Should the risk occur it is judged that the impact on the programme would be **catastrophic** **(or opportunity would be tremendous)**

Impact

The following pages are an extract of the project risk register for all active risks.

Ref	Ofgem category	Risk Definition & Summary Description	Risk Owner	Unmitigated risk			Risk Mitigation Response	CURRENT Risk			Contingency Plan
				I	P	R		I	P	R	
1	Installation	**Title: Network Equipment may not operate as specified** **Impact:** If items of network equipment (EAVC, RTTR and storage) fail to operate as specified, this would affect our ability to conduct the field trials with said equipment. This would prevent the operation of or invalidate the results of certain test cells.	Northern Powergrid	H	L	**Red**	Preference for market ready products, multiple suppliers, test bed operation and phased rollout. Trials have been designed to contain different combinations of equipment and network applications in order to diversify the overall risk of single point technical failure. Investigate failures and take corrective action.	L	N	**Green**	For equipment that does not function as specified, consider simulation or modelling by Newcastle University instead of field trials.
25	Installation	**Title: GUS Control System not function as designed.** **Impact:** The control system will form an important technical component in the coordination of individual network components and in facilitating network-to-customer communications. We envisage a hybrid approach using both forms of control architecture, and have observed that there is no single vendor offering an off-the-shelf turn-key solution to integrate all elements of the control system from network component to individual customers in this manner. If the control system does not work as designed it will not be possible to conduct the full suite of network trials under the control of GUS, so the learning outcomes of LO3, and consequently the outputs in LO4 and LO5, will be compromised.	Northern Powergrid	H	M	**Red**	Working through the GUS system development and commissioning strategy to confirm the functionality of the GUS product to be installed meets the requirements of all project partners to successfully deliver the trials and the learning outputs. A new cross-party working group has been set up by NPg and closer working with Siemens has been initiated, with weekly conference calls, reports and increased senior level project visibility.	L	L	**Blue**	Run the autonomous trials and as many of the collaborative trials as is possible using workarounds (would depend upon the extent of the problem). However, this would slow the rate at which we can work through those trials. Using the results of the autonomous trials, model the predicted results of the collaborative trials.

Ref	Ofgem category	Risk Definition & Summary Description	Risk Owner	Unmitigated risk			Risk Mitigation Response	CURRENT Risk			Contingency Plan
				I	P	R		I	P	R	
43	Customer Recruitment	**DSR I&C test cell customers are located in un-monitored Network areas** I&C and DG customers will be contracted to provide DSR, but there is a risk that these may not be located in the network areas where we have installed monitoring (or may not remain contracted for sufficient time to warrant the time and cost of installing monitoring devices those areas of network).	Northern Powergrid	L	M	**Amber**	We will target recruitment at the areas where monitoring has been installed and at other areas where Northern Powergrid are planning investment plan (Claywheels, Bottisford and Goole).	Risk has materialised. With the contingency measures, the impact is low			Wherever this is not possible then use simulation from Newcastle University to match signals for DSR to customers and Network Monitoring.
45	Installation	**Major Incident or Disruptive Failure of trials equipment** A major incident other extreme event affecting the NPg trial network will adversely affect the lead up to or execution of the network trials, causing delay.	Northern Powergrid	H	N	**Amber**	Liaise with Control Operations to develop an alternative strategy to deliver the network trials by switching resources to other unaffected network areas, or reduce trials,	M	N	**Blue**	Reschedule and/or reduce numbers of physical trials, filling any gaps with simulation
48	Other	**Title: Loss of academic personnel** **Impact: P**roject is delayed and quality of learning is adversely affected.	DEI	H	H	**Red**	In parallel with agreeing the change request, enact arrangements which could enable DEI to extend fixed-term contracts for academic staff and PhD studentships which would otherwise expire prior to the end of the project.	H	N	**Amber**	In the event that the project is extended but that staff/students leave before then, seek to replace personnel.

Appendix 3: Customer trials – a guide to the test cells

	Test cell	Customer type	Load	Intervention
Learning Outcome 1: existing and future load[11]	1a	Domestic	General	None – monitoring only
	1b	SME	General	
	2a	Domestic	General	None – detailed monitoring only
	2a HW		General, with electric hot water immersion heating	
	2a HW+SH		General, with electric hot water immersion heating & storage heating	
	2b	SME	General	
	3	Domestic	Heat pump	None – monitoring only
	4	Domestic	Micro-CHP	
	5	Domestic	PV	
	6	Domestic	Electric vehicle	
	7	I&C	General (for CDCM[12] study)	
	8	DG	Various types of distributed generation	
Learning Outcome 2: customer flexibility[13]	9a	Domestic	Regular	time of use
	9b	SME	Regular	time of use
	10a	Domestic	Regular	restricted hours
	10b	SME	Regular	restricted hours
	11a	Domestic	Regular	direct control
	12	Domestic	Heat pump	time of use
	13	Domestic	Heat pump	restricted hours
	14	Domestic	Heat pump	direct control
	18a	I&C	Responsive load	DSR for ancillary services (fast reserve)
	18b	DG	Responsive generation	
	19	DG	Responsive generation	DSR for ancillary services (voltage support)
	20	Domestic	PV	automatic within premises balancing
				manual within premises balancing

[11] A small number of the domestic customers taking part in a range of trials (heat pump, PV, electric vehicle, micro-CHP and general load customers) will also have power quality monitoring equipment.
[12] Common distribution charging methodology
[13] Test cells 15-17 relate to electric vehicles, but have been cancelled due to the low uptake of EVs and other related reasons, as explained in the change request

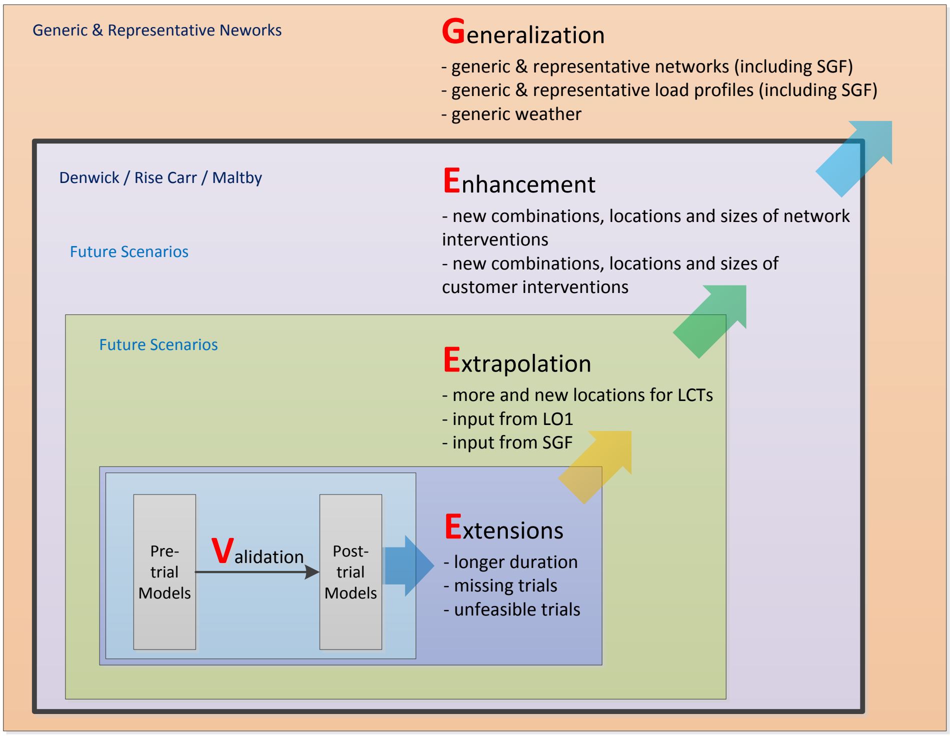
Appendix 4: Network equipment

Equipment		Urban network Rise Carr, Darlington	Rural network Denwick, Northumberland	Heat pump cluster Hexham, Northumberland	PV cluster Maltby, South Yorkshire
Electrical energy storage (EES)	2.5MVA battery at primary substation (EES1)	Rise Carr	~	~	~
	100kVA battery at distribution substation (EES2)	High Northgate	Wooler Ramsey	~	~
	50kVA battery at distribution substation (EES3)	Harrowgate Hill	Wooler St. Mary	~	Elgar Drive
Enhanced automatic voltage control (EAVC)	Primary substation transformer with on-load tap changer (EAVC1)	Rise Carr	Denwick	~	~
	Secondary substation transformer with on-load tap changer (EAVC2)	Darlington Melrose	Wooler Bridge	~	Mortimer Road
	Regulator (EAVC3)	~	Hepburn Bell AND Glanton	~	~
	Switched capacitor bank (EAVC4)	~	Hedgeley Moor	~	~
	LV main distributor regulator (EAVC5)	~	~	Sidgate Lane	~
Real-time thermal rating (RTTR)	Primary substation transformer	Rise Carr	Denwick	~	~
	Secondary substation ground mounted transformer	Darlington Melrose High Northgate	Wooler Bridge Wooler Ramsey	Sidgate Lane)	Mortimer Road
	Overhead lines	~	2 locations at 66kV 4 locations at 20kV	~	~
	Underground cables EHV	Rise Carr	~	~	~
	Underground cables HV	Rise Carr	~	~	~
	Underground cables LV	Darlington Melrose	~	~	~
Grand unified scheme (GUS)		GUS central controller			
		14 GUS remote distribution controllers (RDC)			
		GUS Data Warehouse			
		Demand response system integrated into GUS control			
Monitoring		70 instances of monitoring equipment (of 3 different types) at a range of network locations[14]			
		iHost data warehouse			

[14] Includes power quality monitoring

Appendix 5: VEEEG methodology

A conceptual representation of the VEEEG methodology:



For more information see a paper on the design and development of the trial programme methodology and the VEEEG methodology presented at CIRED 2013, “**Programmatic Smart Grid Trial Design, Development and Analysis Methodology”** by P Lyons, P C Taylor, R Hetherington, D Miller, D Hollingworth, D Roberts. The trial design methodology provides a system to rationalise the number of trials carried out as part of the programme and ensure that the trials are as comprehensive as possible within the limited timescales of the CLNR project programme. The VEEEG methodology was shown to systematically augment and expand the results from the trial programme in order to provide robust findings regarding smart grid interventions and control system architectures, in future distribution networks with large quantities of embedded LCT.

Appendix 6: Time of use tariff savings & compensation

As part of the pure Time of Use tariff trial (Test Cell 9a), the Time of Use tariff and Heat Pump trial (Test Cell 12) and the restricted Hours Smart Washing Machine trials (Test Cell 10a), we trialled a three rate static time of use tariff with a population of over 700 customers with the following pricing structure:

Rate	Time period	Per kWh adjustment
Day	0700 – 1600, M-F	- 4%
Peak	1600 – 2000, M-F	+ 99%
Night & Weekend	2000 – 0700, M-F, S,S	- 31%
	Daily Standing Charge	16p

The Terms & Conditions of trial participation promised customers that if they pay more on the trial tariff than they would have paid on British Gas's standard tariff over the period, then British Gas would refund the difference via a credit to their account.

British Gas undertook a 'shadow billing' exercise on a customer by customer basis over the course of the trial, ranging from April 2012 to March 2013 versus British Gas's standard tariff during the period. This exercise determined the savings or loss made by each customer over the period of the trial and hence any compensation required.

A summary of results is presented below:

Test Cell 9a: Time of Use Tariff Trial

Of 682 customers that had taken up the tariff, 60% of customers have saved money, with an average saving of £31 over the period and a maximum saving of £376. 40% of customers have paid more on the Time of Use tariff than they would have paid had they been on British Gas's standard tariff during the period, with an average compensation due of £25 and a maximum of £191.

Test Cell 10a: Smart Washing Machine Restricted Hours Trial

Of 52 customers that had taken up the tariff as well as a smart washing machine, 43% of customers have saved money, with an average saving of £11 over the period and a maximum saving of £45. 57% of customers have paid more on the Time of Use tariff than they would have paid had they been on British Gas's standard tariff, with an average compensation due of £11 and a maximum of £31.

Test Cell 12: Heat Pump Time of Use Tariff Trial

Of 10 customers that had taken up the tariff as well as the installation of a new Heat Pump, 60% of customers have saved money, with an average saving of £34 over the period and a maximum saving of £67. 40% of customers have paid more on the Time of Use tariff than they would have paid had they been on British Gas's standard tariff, with an average compensation due of £9 and a maximum of £19.

Reasons for having paid more for their electricity on a Time of Use tariff than they would have, had they been on British Gas's standard (flat) tariff are a mixture of customers either not having shifted consumption out of the weekday peak pricing period of 4pm to 8pm, increasing their consumption during these peak periods and/or not having reduced consumption overall. For those that have paid more than they would have on British Gas's standard tariff, British Gas is now in the process of contacting customers in order to apply their bill credits.

Although the majority of customers have benefited by saving money by participating in the trial, and no one will actually lose money as a result, It is important to note that in future this 'safety net' of a guaranteed saving against a standard or 'flat' tariff may or may not be commercially or practically viable for a time of use tariff to be launched to market and highlights that a tariff designed in this way may produce 'winners' and 'losers'.