SUCCESSFUL REWARD DELIVERY APPLICATION

CUSTOMER-LED NETWORK REVOLUTION

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1 Executive summary

The Customer-Led Network Revolution (CLNR) has successfully delivered an ambitious programme of work over a four-year period. All successful delivery reward criteria (SDRC) have been satisfied, the output from the project has more than fulfilled the commitments made and it was delivered on budget, despite an extra year required to manage the impact of a few significant externalities.

Although principally funded by the Low Carbon Networks (LCN) fund for the benefit of electricity distribution network customers, the project has produced learning that offers important insights to policy makers and the broader energy industry as we seek to address the challenges caused by the decarbonisation of society in the period to 2050. This application sets out the evidence that justifies the recovery of the remaining 10% of project costs following the delivery of the committed outputs and the achievement of the SDRC.

A significant investment of £31m has been made in trialling a range of customer and network flexibility techniques to deliver increased network capacity at least cost to customers. This has resulted in a rich body of research and learning completed at end December 2014 with net benefits estimated in the range £5bn to £26bn in the period 2020 to 2050 (range dependent on the different scenarios for take-up of low carbon technologies). However, the learning and benefit does not stop there. The insights generated on CLNR will act as a springboard for Northern Powergrid, its partners and other parties to ensure that the development of smarter grids continues to make effective progress.

While network management and demand response technologies already existed and were well documented prior to CLNR, they had not previously been deployed at distribution level in a market with the degree of vertical separation of Great Britain (GB). CLNR created a programme of integrated work to bring together the knowledge and resources necessary to bridge this gap. It did this by bringing together Northern Powergrid, the wires-only distribution network operator (DNO) for the Northeast, Yorkshire and northern Lincolnshire and the largest national unaffiliated energy supplier (British Gas), together with a multi-disciplinary academic team from Durham University and Newcastle University and network consultants EA Technology, to assess a range of customer-side solutions (innovative tariffs and load control incentives in association with different low carbon technologies (LCTs)) alone and in combination with network-side technology (including voltage control, real time thermal rating and energy storage). The project has delivered robust learning that, by design, is applicable to a high percentage of GB electricity distribution networks and demographic groups.

In headline terms, CLNR has delivered impressive results through the planned approach of learning from trials involving real customers on real networks. The headlines from this ambitious programme of work are:

- The customer trials involved ca. 11,000 domestic, 2,000 SME, industrial & commercial (I&C) and distributed generation customers;
- CLNR has been one of the most extensive network technology integration trials undertaken;
- It has delivered significant learning to benefit customers and leaves a comprehensive legacy;
- There have been a few surprises - low carbon technologies are less disruptive and domestic customers are more flexible than previously predicted;
- We have developed a route map to guide the development of smart grid technology and systems to 2050 – we will start relatively simple and increase the complexity as and when required;
- From our trials with domestic customers we consider that time of use tariffs, enabled by smart meters, could deliver value in the next 10 years, when delivered in conjunction with energy suppliers;
- In contrast, I&C demand side response (DSR) is fit for business as usual today;
- CLNR has provided improved data on the services provided to the network by distributed generators;
- Electrical energy storage has proven to be an effective form of demand side management alongside customer flexibility – assisting to alleviate upstream network constraints;

- We have validated that the existing engineering thermal ratings are not overly conservative - with 10-15% headroom on some overhead lines and conversely some cable networks requiring de-rating by around 10%;
- We have demonstrated how to control voltage better - with the optimal devices being an in-line regulator on rural high voltage networks and an on-load tap-changer (OLTC) on secondary transformers in urban networks;
- The path followed has been challenging at times but the key milestones and commitments have been achieved.

This SDRC application follows a comprehensive project closedown report[1] and over 200 other documents and resources. All are freely available on the website project library at www.networkrevolution.co.uk.

The successful delivery reward incentivises companies to deliver what they promised. When the associated criteria are satisfied, companies have the opportunity to recover the remaining 10% of project costs that were not funded up front by customers. Based on the success of the project, Northern Powergrid is seeking recovery of the full 10% in order to cover the costs incurred by the project. This application provides the justification to support this claim. It covers the areas of timeliness, quality, cost and project management for Ofgem's consideration.

In CLNR there were 16 criteria that covered measurable deliverables associated with conducting and analysing trials, making recommendations, and disseminating knowledge. This document describes how these explicit commitments were satisfied. In headline terms, there are few exceptions to note. Some of the achievement has been through different routes from the intentions specified in our original 2010 bid for funding and this was set out in our project change request that was approved in September 2014. In this application, we describe the differences and also justify why the new approach was at the least equivalent. In overall terms, the quality of the learning from the project is at least as good as (if not better than) committed at the bid stage. An extra year was required to complete and the output was more back-end loaded than envisaged. This impact was mitigated by building pre-trial estimated conclusions into industry models. Our project demonstrated that these assumptions were quite accurate. On cost, value for money was considered throughout and spend was contained within the overall project budget with partners committing extra resources and additional external funding secured. Finally, best practice project management was deployed in order to achieve these outcomes.

The key consideration on timeliness was whether or not the CLNR project would produce learning in time to inform distribution investment plans prior to need for the 2015-23 ED1 period and beyond. The industry uses the Transform model that is itself a development of the CBA model developed in preparing the 2010 CLNR bid. The first version of Transform included solution templates with parameters taken from the original estimates of CLNR solution performance. These original estimates formed the basis of the inputs into DNO business planning for ED1 and the findings from CLNR have to a large extent validated these earlier assumptions. We have now updated these templates based on findings from the field trials and these will be considered in the next round of governance for Transform scheduled for 2015. There are two of the 16 SDRC where we did not achieve full compliance on timely delivery. The exception is explained in this report and its impact is negligible.

We have delivered high-quality project outcomes that deliver on the bid commitments and the criteria specified at the start of the project. Conclusions reached have been supported with justification so that the level of confidence in the result may be recognised and factored into how the DNOs and the wider industry take the learning forward. The robustness of the learning has been underlined by the detailed reports issued by our academic partners and the independent verification that is associated with this community. The academic peer review process has ensured that other experts sense-checked the social and technical analysis and the submission of 12 papers to peer reviewed journals demonstrates the scale and significance of this work. This includes five published in the most prestigious of the international journals, confirming that this work is indeed of 'archival' quality. In this application, we describe the quality of the learning against each of the 16 SDRC.

Also relevant to the quality consideration is the value of the learning in terms of the impact on future DNO actions. The project has contributed to the smart solutions that are selected most by the Transform model when forecasting which options would be most appropriate to apply in the future. Our cost benefit modelling identifies that smart solutions trialled in CLNR provide over 70% of all the financial benefits calculated by the Transform model when it deems that a smart solution is more appropriate than a traditional reinforcement option.

On cost, we have focussed on minimising spend for customers and adding value through additional contributions from partners and external funding. All partners had to commit extra resources in order to deliver this ambitious programme of work and overcome the various delivery challenges. There is an unquantified cost to the companies that is the opportunity costs of deploying key resources on this project as opposed to other valuable organisational priorities. Spend differed significantly from original bid assumptions. We used both contingency and underspends in the customer trials to fund additional project management activity and the cost of the one-year time extension that was needed to address the externalities set out in our change request and which were associated with the availability of customers and technology. The *ca.* £11m deployment of innovative network equipment was delivered within 6% of budget – a significant achievement for such a wide area application of novel technology. More generally, value for money was obtained by tendering competitively for goods and services where appropriate. And more external funding was secured – principally for heat pump installation (£2.2m) and creation of a smart grid lab (£0.5m).

Ofgem has identified that it wishes to explore not only 'what' was delivered but also 'how' it was delivered. As such we have included evidence of our effective project management that was key to delivering a successful outcome for customers. In addition to managing time, quality and cost, we also focussed on scope and risk, all in the context of the expected benefits from the project. The programme of work involved delivering much 'first of its kind' work across multiple organisations and multiple disciplines such that effective project control was vital to deliver as we did. Our project management also delivered compliance with the various obligations associated with legislation, LCN fund governance and internal company protocols. Highly complex problems were solved with balanced outcomes delivered for customers. The changes since bid were rolled into a single change request that was formally approved by Ofgem in September 2014.

This document addresses each of the areas required by the Ofgem guidance. Accordingly, the sections that follow contain details of timeliness and quality, cost effective delivery and project management.

2 Timeliness and quality

2.1 Summary

Over the course of the project there were a number of material changes in external circumstances which meant that additional time was needed to deliver the learning outcomes. These circumstances, described in the change request approved by Ofgem, included the shortage of heat pump and EV trial participants that we resolved with a £2.2m grant from DECC and new partnerships, and the difficulties in the procurement and manufacture of some of the novel technology in what proved to be a relatively immature supply chain. In all respects, we found alternative routes to deliver the learning but we needed one more year to complete the project (in December 2014).

Despite the difficulties experienced in delivering what has been an ambitious and challenging undertaking we have managed to deliver almost all of the outputs specified in the successful delivery reward criteria to time. In the customer trial datasets, over 95% were delivered to time with the remainder delivered later than planned. We mitigated this delay by releasing draft results into the Transform DNO forecasting process at an early stage so that the effect of the delay was negligible.

The quality of the learning is evidenced by the number of published peer-reviewed academic papers and presentations at international conferences. There are 12 papers either published or going through the review loop prior to publication. These include five papers already published in *Applied Energy*, *Energy*, *Geoforum, IEEE Transactions on Smart Grids* and *IEEE Transactions on Power Systems* journals; each of which is rated as being in the upper quartile of journals in their fields in terms of impact factor. In appendix A, we detail the academic papers that have been published (or submitted for publication) in journals. Of these, over 80% of the papers are in journals that are in the top half of the quality scale - providing independent verification of the high quality of learning delivered in this project.

The SDRC set out in the project direction are listed in appendix B. The following sections of this submission describe the timeliness and quality associated with each of the following criteria:

- Criteria related to installation and commissioning of network equipment (x2)
- Criteria related to communications and engagement (x4)
- Criteria relating to customer trials datasets (x4)
- Criterion relating to network trials datasets (x1)
- Criteria relating to impact of new load and generation profiles (x2)
- Criteria relating to disseminating the implications of our findings (x3)

2.2 Criteria related to installation and commissioning of network equipment

SDRC 1: Commence installation and commissioning of network equipment relating to learning outcome 3 – Sept 2011
SDRC 2: Complete installation and commissioning of network equipment relating to learning outcome 3 – Dec 2013

The commencement and completion of the installation and commissioning of the network equipment was completed on time (see appendix C for cross references to the location of the evidence). Network equipment included monitoring, enhanced automatic voltage control (EAVC), real time thermal rating (RTTR) and electrical energy storage (EES). The final commissioning was the large EES installation at Rise Carr Primary substation in November 2013.

The installation and commissioning, together with the relevant training and authorisation of operational engineers was a significant task for the project and we involved Northern Powergrid staff with a range of responsibilities and expertise to ensure that this was achieved to a high level of quality. This included frequent progress meetings and review stages with senior stakeholders from Field Operations, Asset Management and Safety and Training.

Evidence that the installation and commissioning was achieved to a high level of quality includes:

- The successful completion of a suite of over 200 network trials which involved all the commissioned network equipment
- Successful integration of the grand unified scheme" (GUS) active network management (ANM) system with each of the commissioned pieces of network equipment Training and site visits by a large number of Northern Powergrid operational staff, including very experienced and senior personnel.
- 3rd party commendations:
  - The Energy Storage Operators' Forum (ESOF), the leading industry body on this subject, visited our site and we have contributed to the ESOF Good Practice Guide13
  - The safety process and the quality of installation were commended by other DNOs and were supported in an invited assessment session held with three senior specialist HSE inspectors who visited a range of the installed sites and the control system development.

From our experience we have developed a 'safety first' methodology for application to the design, installation, commissioning and operation of equipment, and we presented this at various national events including the LCN fund conference at Brighton in 2013, and multiple events including for both the Institution of Mechanical Engineers and the Institute of Engineering and Technology.

In addition, our experience of specifying, procuring, installing and commissioning the network equipment has been captured in the form of an extensive toolkit for other DNOs to use. This includes operational guidance, lessons learned reports, technical recommendations for purchase, training materials and a report on network monitoring, see appendix D. The network equipment installed and commissioned is listed in appendix E. For a description of the equipment and how it was used, see the closedown report[1,] pages 8-11.

2.3 Criteria related to communications and engagement

All four of the SDRC in this category were completed on time with the location of evidence identified in appendix C.

Throughout the project we employed a range of different mechanisms, channels and tactics to ensure that the learning generated was captured and shared effectively with DNOs and other interested stakeholders. In the closedown report[1], we set out in section 12 what worked well and could be replicated by future projects and in its appendix 9 we reported on the effectiveness of the various methods employed and listed the key communication and dissemination activities undertaken. This included evidence of over 300 communication and dissemination activities, including email campaigns sent to our 900+ opt-in mailing list subscribers, our suite of project videos, press coverage in trade and in mainstream media, knowledge sharing at over 50 high profile academic and industry conferences, and evidence given to select committees. We also shared our approach to with other DNOs' stakeholder managers at the DNO best practice sharing group in 2014. See appendix C for references demonstrating the high quality of the outputs for all four criteria.

SDRC 4: Project website up and running by end of May 2011 and updated in line with project developments
The CLNR project website went live on 25 May 2011 at www.networkrevolution.co.uk. It originally featured a simple navigation structure which signposted the important project library resource and clearly communicated the project's drivers, aims and outcomes. We made a number of improvements to the website throughout the course of the project (described more fully in appendix F) including using CLNR social media channels (Twitter, LinkedIn and YouTube) to increase the reach of the project and drive more traffic to the website, a major refresh and re-launch of the website to improve the visitor experience and to support the sharing of knowledge with our stakeholders, and improving the usability of the project library. Following feedback from our closedown consultation process, we further improved the usability of the project library by implementing an advanced search function which enables users to drill down and locate the specific document or range of documents they were interested in. We updated the website content to reflect the project's completion and added new pages to clearly signpost the project's findings and conclusions. Our objective has been to ensure that the website is a key part of the enduring legacy of the project and most people's first port of call for information.

SDRC 5: Industry stakeholder forum held on an annual basis by end of May 2011, May 2012 and Dec 2013
Industry forums were aimed at an audience of national stakeholders. Interest and attendance at these events increased year upon year culminating in the 2013 event in London which was attended by over 100 key industry figures.

SDRC 6: Distributor project review meetings held by end of July 2012 and Dec 2013
These events were designed to encourage two-way interaction, the content was pitched at a level applicable to the audience and the format of the day included visits to see CLNR sites and equipment. See appendix C for references demonstrating the high quality of the outputs.

SDRC 7: Regional stakeholder panel meeting held on an annual basis by the end Mar 2011, Mar 2012 and Dec 2013
At the outset our regional stakeholder panel consisted of a core group of relevant stakeholders who provided valuable feedback and input on our plans. We held all three regional stakeholder forums, culminating in the 2013 event attended by over 60 delegates.

2.4 Criteria relating to customer trials datasets

The SDRC datasets covering over 95% of trial participants were completed on time.

There were 21 final datasets produced to satisfy these four criteria. 16 were published on time: 2 covering the distributed generation and industrial & commercial customers, and 14 covering over 95% of the domestic, SME and distributed generation trial participants. The remaining 5 datasets were published by the project completion date of the end of 2014 – but were late measured relative to the SDRC dates. The delays were linked to the challenges arising from the scope and scale of the datasets where we needed additional time and resources to deliver robust learning from all of the datasets. The impact on DNOs and other stakeholders was negligible since estimates had already been entered into the industry's common scenario planning model (Transform). These early estimates were proven to be quite accurate following completion of the CLNR learning. The tasks were completed by the end of the project such that this was a minor delay that had no material detriment to stakeholders or other stakeholders.

Appendix G contains a table setting out the timing of the publication of each individual dataset within each of the four criteria relating to customer trial datasets.

The consumption datasets were designed to be readily usable by others not involved in the CLNR project and were accompanied by guides and reports giving insights into the data means. The datasets are ready to plug into the leading industry standard smart grid modelling tool Transform, and include supplemental information so that the reader understands the data provided, and guides accompanied the key datasets.

The quality of these quantitative SDRC deliverables is enhanced by the accompanying qualitative analysis and the benefits of the socio-technical approach adopted by CLNR. Through 250 interviews and 1,250 surveys as well as collection and analysis of consumption data, we have created detailed and in-depth learning as well as statistically robust learning in our analysis of the social dimensions of energy usage, low carbon technologies and novel interventions. An important fact to note is that, despite market conditions leading to the take up of LCTs being less than envisaged, we did cover all the key technology types in significant numbers (380 heat pumps, 160 EV, 470 PV).

CLNR was unique across the Ofgem funded portfolios in developing detailed understanding on the social response to smart grids, and it was the only project with an interdisciplinary social science team that worked on understanding the social meaning of technology and everyday practices, along with those who can conduct quantitative analysis of behaviour change – most stop at the latter. This part of our research has been in demand across the industry. Social science lead Professor Harriet Bulkeley has given evidence on the customer engagement implications for the national smart meter programme to the Energy and Climate Change Select Committee.

We analysed customer engagement and the processes of developing, offering and trialling the technical and commercial solutions. Where participant numbers were less than planned, this was either due to market failure (i.e. in terms of the readiness of technologies) or important barriers to participation that we have found through the research (e.g. in terms of SMEs). The challenges of recruitment have delivered qualitative learning[25] which will be important for the industry to understand if it is successfully to introduce demand response from customer segments where the CLNR project has demonstrated this is not currently possible at all or at mass market scale. Similarly our report on equipment installation[77] focuses on the successes, challenges and lessons learned from the installation process during the residential and SME trials.

Where recruitment challenges led to small samples, this required in-depth explanation of the sort that qualitative research can provide – quantitative research can provide patterns and some level of confidence in terms of the causes of those patterns (who, when, where). Qualitative research answers the 'why', 'how' and 'so what' questions and we undertook extensive research with customers to determine what initially interested them in the trial and, if they did not proceed, the reasons why. This is particularly important for the SME demand response and restricted hours trials where we contacted over 20,000 SME customers and actually signed up over 350 SME to the trials but later only three proceeded to trial after site visits revealed a range of reasons why they could not participate. We have reported on the barriers to SMEs offering greater flexibility and, in particular, their energy practices[35]36.

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 (progress report 7[11], para 2.26).

The quality of the learning produced from the customer trials is also evidenced by the number academic publications (appendix A). We signalled the release of the interim and final customer datasets to interested parties using a range of targeted communication techniques. We sent emails to selected contacts from our mailing list to alert them to the publication of the datasets (see progress report 5[9], appendix 3 and progress report 8[12], appendix 2) and promoted this to a wider audience via social media and interim and final results press releases (evidence of national and regional press coverage generated as a result is listed below.

- Financial Times 'UK's CLNR tests low-carbon power grids' (January 2014)
- Channel 4 'Power to the people' (November 2013)
- Newcastle Chronicle 'Families willing to change daily routine if it cuts bills, North East study shows' (June 2014)

We have shared our learning throughout the course of the project at industry forums and our own CLNR-led dissemination events, most notably our 2013 national stakeholder event in London which focused on interim results from our customer trials (see progress report 6[10], appendix 3) The customer datasets and subsequent analysis were also used to inform our three key learning reports[2,3,4] which are aimed at our DNO peers and other interested stakeholders and communicate the key findings from the project.

In summary, we have delivered high quality learning that is of value to all DNOs and other stakeholders, both in the consumption datasets and in an understanding of how customers' electricity use is shaped in relation to interventions designed to realise flexibility, and an examination of both the processes through which the roll-out of low carbon technologies is likely to take place in the future and how/why households are and are not changing their use of electricity in response to interventions to realise flexibility. Our qualitative research has produced some new and important insights into how electricity is used and flexibility that challenge existing assumptions across government and industry. For example, that socio-demographic analysis provides little basis for forecasting electricity use which could lead to significant new directions for the industry, and that we know a lot more now about how/why heat pumps are being taken up, where, by whom, and what this process of installation means for how they are then used, and customer responses to them.

SDRC 8: Demand profiles grouped by customer type - interim by end 2012, finalised Aug 2014

The interim profiles publication provided a first view of the domestic and SME smart meter trials with the release of robust datasets containing one year's data for over 5,000 domestic customers and 8 months' monitoring of almost 1,800 SME customers. The datasets CLNR-L011[22] were accompanied by a report CLNR-L010[14] which presented the findings.

Further to this interim publication, a comprehensive suite of 14 datasets was published in August 2014, accompanied by report CLNR-L071[15], a guide to the load and generation profiles. The demand profiles published provide detailed insight into the electricity usage of around 10,000 domestic and SME customers. The analysis of the TC1a[55] dataset, which comprises two years of half-hourly smart meter data for approximately 8,000 customers, has been presented in a detailed insight report, CLNR-L216[16]. Further analysis of this dataset was used to make recommendations to update ACE49 (see SDRC 13) and to compute ADMD curves for domestic customers by mosaic group (see CLNR-L217[17]). The TC1b[56] dataset is equally rich with a year's worth of smart meter data available for over 1,500 customers across multiple business sectors. This overall picture of UK SME electrical consumption is discussed further in the accompanying report CLNR-L261[18].

Our drive to capture robust datasets of at least a year's data resulted in the enhanced profiling trials ending later than originally planned, as agreed in the Change Request. Examples of this include test cells 2a (HW) and 2a (SH) which concluded in May 2014. In December 2014, we revisited the analysis of TC2a and associated hot water (TC2a HW) and storage heating (TC2 SH) trials, producing rich datasets giving valuable insight into disaggregated customer loads as well as insight in to the power demand of customers with electric hot water and storage heating, This is evidenced in insight report CLNR-L094[19].

Test cell 7 investigated the impact of the Common Distribution Charging Methodology (CDCM) on 2,054 Industrial and Commercial (I&C) customers across Northern Powergrid's Northeast and Yorkshire regions. The data was analysed by Durham University and published for the December 2012 SDRC milestone as an interim dataset (CLNR-L088[20]). Re-published as final version in 2014, the dataset was accompanied by report CLNR-L087[21] - April 2010 tariff reform analysis; an introduction to the Common Distribution Charging Methodology (CDCM). As summarised in report CLNR-L247[3], we reviewed the electricity consumption of half-hourly metered HV and LV customers in the year before and the year after the introduction of the 2010 tariff reform and found that the introduction of the CDCM Red/Amber/Green time bands in 2010 has not had a statistically significant effect on the number of units consumed.

SDRC 9: Demand profiles grouped by low-carbon technology type - interim by end 2012, finalised Aug 2014

The interim dataset CLNR-L011[22] and accompanying guide CLNR-L010[14] were released at a time when recruitment to the LCT trials was still ramping up although in some areas it was slower than originally anticipated, as documented in progress report 4[8] (section 4.7) and the report CLNR-L036[23]. The initial release provided an early, first glimpse at the load profiles associated with air source heat pumps, electric vehicles and solar PV customers.

These datasets were superseded in August 2014 by the final datasets CLNR-L075[24], CLNR-L076[25], CLNR-L077 [26] and CLNR-L078[27] which were accompanied by a guide CLNR-L071[15]:

Whilst being a small trial in terms of customer numbers, dataset CLNR-L076[25] provides a strong view on micro-CHP customers' electrical demand and generation. The dataset is accompanied by report CLNR-L086[28] which highlighted the potential impacts of micro-generation on the electricity network.

The TC3[24] dataset released in August 2014 encompassed heat pump demand data for up to 322 ASHP customers. In December 2014 the TC3[24] dataset was reissued after the discovery and correction of some data anomalies/contamination. This was a function of the complexities and difficulties associated with data collection and analysis. The re-released dataset was accompanied by CLNR-L091[29]: Insight Report: Domestic Heat Pumps.

A year's worth of data was collected and published in August 2014 for over 140 solar PV customers. Monitoring both load and generation the dataset established a baseline from which to assess the impact of PV generation on the network. The dataset (CLNR-L077[26]) was further investigated with findings documented in CLNR-L090[30]: Insight Report: Domestic Solar PV Customers. Building on this research, the data was further investigated to produce a technical note (CLNR-L095[31]) which addressed two areas of interest (i) investigation of the installer-declared net capacity of the PV installation versus the measured peak capacity and (ii) examination of the diversity of the Solar PV panels using the After Diversity Maximum Demand (ADMD) methodology.

The TC6[27] dataset released in August 2014 comprises data for up to 133 customers EV charging and household data. Research findings were documented in CLNR-L092[32]. The data was collected in partnership with Charge Your Car (North) Ltd. Problems with meter configuration resulted in much of the Project's early data being unavailable for analysis. The dataset is still a valuable resource with around 6 months of aligned EV charging and household demand data available. As the dataset released in 2014 covered a shorter duration than originally intended, the partnership with Charge Your Car has continued with data being collected until July 2015. As a result of this a full year's dataset will be made available as post project and will be included in the CLNR data legacy.

SDRC 10: Output profiles of existing generation types - interim by end 2012, finalised Aug 2014

We have published distributed generation profiles (CLNR-L011[22]) for wind farms, landfill gas sites, hydro plant and various cogeneration schemes accompanied by a report (CLNR-L010[14]). Half-hourly capacity factors were calculated in order to form generation profiles per site within each sector. The quality of this dataset enabled us to make the recommendation (see SDRC14) that a risk-based planning approach be developed using this data and considered in the review of ETR 130 methodology for assessing the contribution of DG to network security by the "Review of ER P2/6 Working Group" of the Distribution Code Review Panel.

SDRC 11: Output/ demand profiles before and after a range of interventions - interim by end Apr 2013, finalised Aug 2014

The ambitious CLNR intervention trials have yielded a wealthy resource of research data. Interim datasets released in December 2012 with an accompanying guide (CLNR-L012[33]) provided early insights into customers' response and acceptance of a variety of interventions. Superseded in August 2014, datasets relating to time of use, direct control and in-premised PV generation balancing have generated exceptional insights into customer behaviour on intervention trials. This was also accompanied by a guide (CLNR-L071[15]). The analysis of the datasets is supported by in-depth insight reports.

The analysis of the quantitative data from the monitoring and intervention trials was integrated social science analysis from interview and survey. The benefits of this socio-technical approach a set of papers which summarise the key messages from the trials and provide a unique view into customers' energy use behaviour and their responsiveness to interventions.

Reports to demonstrate the high quality of the learning are identified in appendix C.

2.5 Criterion relating to network trials datasets

SDRC 12: Network data showing performance of selected network technologies by end Oct 2014

This SDRC was completed on time with the location of evidence identified in appendix C.

14 datasets (listed in appendix C) covered the range of network solutions being trialled (EES, EAVC and RTTR) with data from 115 network equipment data points across the Northern Powergrid distribution system, including both primary and secondary substations. In other studies these solutions have been deployed individually and at higher voltages, whereas these datasets cover deployment in combination and at lower voltages, and under the control of the GUS ANM control system. An accompanying guide[98] helps the user to understand the technologies and features of each dataset, and the datasets themselves include charts to enable the reader to quickly understand the data and to illustrate what analysis is possible.

These datasets will allow others to build models of smart grid technologies, and they allow comparison of CLNR and other control techniques, such as WPD's Network Equilibrium project.

Related to this SDRC, we have developed and shared an approach to designing and optimising network trials, which will be useful for other DNOS to plan network trials efficiently. (See closedown report[1], appendix 1, para 15.)

We signalled the release of the network technology datasets with an email campaign (see progress report 3[7], appendix 2) sent to 276 selected DNO and academic mailing list contacts. The email was opened by 30% of recipients representing an excellent response rate for this type of communications activity. We promoted this to a wider audience via social media and PR aimed at the trade press. We have shared our subsequent analysis of the data and what this might mean for our business at industry forums including the Smart Grid Forum.

2.6 Criteria relating to impact of new load and generation profiles

SDRC 13: Publish analysis of load profile data by end Oct 2014
SDRC 14: Publish analysis of generation profile data by end Oct 2014

These two SDRC were completed on time with the location of evidence identified in appendix C.

Our report CLNR-L185[34] fulfils both these criteria. This proposes important updates to the existing industry modelling standards ENA-ACE 49 and 105 and rigorous academic work was undertaken[78] to understand and benchmark how the original research methodology to produce ACE49 was undertaken back in 1981. This exercise included seeking advice from the original ACE49 project team lead (now retired) and documenting the original ACE49 methodology. This was achieved at minimal incremental cost to the project and also provided validation of the feasibility of our CLNR outputs and requirements.

The updates include:

- Published network design coefficients (p and q values in ACE 49/105 terminology, related to mean and standard deviation values of consumption for each half hour of the nominal peak day) for general domestic customers with high, medium and low annual consumption;
- Published new sets of design coefficients, in an industry standard format, suitable for existing industry standard tools, to represent low carbon technologies such as electric vehicles, heat pumps and solar PV. Since ACE 49 does not consider LCTs, this work provides and recommends a new set generic set of load and generation curves representative of the operating regime of LCTs.

Following this analysis, Northern Powergrid will revise the design demands used in our LV designs and will also include PV diversity in our generator connection policy. Wider adoption is subject to normal industry governance via the Electricity Networks Futures Group (ENFG); whilst we cannot envisage a reason why these coefficients should not be adopted across all DNOs for all LV design assessments, the route we plan to take is to present the CLNR findings to the ENA's Collaborative Energy Portfolio (CEP) group (previously the STP) for their consideration. This DNO group is expected to next meet on 24 June 2015. Recommendations for adoption are fed to both the DNOs' R&D Managers meeting and ultimately the ENFG.

We have reviewed the contribution of real generators to system security, using the industry standard method specified in ENA Engineering Technical Reports 130 and 131 and have recommended the review and update of the current F-factors based on the data collected for SDRC 12. This supports DNOs to better recognise the contribution that DG makes to the system security and therefore to comply with the security requirement ER P2/6.

We have also recommended that a future fundamental review and update of G59/3-1 should treat EES facilities as distributed generation for the purpose of protection systems and settings.

We signalled the release of the report CLNR-L185[34] with an email campaign (Progress Report 3, Appendix 2) sent to 276 selected DNO and academic mailing list contacts and via a dedicated press release which was displayed on the CLNR website and sent to trade press contacts. The story was covered by Electrical Engineering Magazine amongst others.

2.7 Criteria relating to disseminating the implications of our findings

The three SDRC in this category were completed on time.

The closedown report[1] and three key learning reports[2,3,4] set out the implications of our findings and these draw on the other preceding high quality outputs where more detail can be found. We undertook a period of consultation to ensure that our stakeholders, in particular DNOs, had the opportunity to explore, absorb and give feedback on our findings. The consultation process was opened on 23 January 2015 when we published these four documents and invited written feedback and the opportunity to participate in face-to-face feedback at a consultation event on 5 February 2015. This was well attended and included delegates from all DNOs, Ofgem, the Department of Energy & Climate Change, academics, consultants and other industry parties. In addition, UKPN undertook a formal peer review of the closedown report[1].

Our reports were accepted with no major changes, demonstrating the quality of the reports written and disseminated in relation to these three SDRC. Appendix 12 of the closedown report[1] provides details of the consultation and peer review process and how they influenced our reports.

SDRC 15: Provide an understanding of, and disseminate by end Dec 2014 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

Our report CLNR-L248[4] provides information on how these technologies can be integrated and was ready at end December 2014 for dissemination to DNOs and the website. At Ofgem's request a copy was provided only to Ofgem and the DNO peer reviewer at that time. Full dissemination followed on 23 January 2015. A view of the costs is provided in a set of papers published in December 2014 (and listed in appendix 5 of report CLNR-L248[4]).

The 'Optimal solutions for smarter network businesses[4]' report is a generic smart grid safety case, backed up by detailed documents for the installation, operation and maintenance of each new technology deployed. We have developed detailed specifications for all the CLNR solutions. Together these form a rich DNO toolkit (appendix D), providing 'how to' guidance on the application of novel network technologies.

To better understand the fundamentals of how customers and networks behave we have also developed new tools for systematic analysis of each, including:

- Development of a socio-technical framework for understanding the provision and use of energy services
- A validation, extension, extrapolation, enhancement and generalisation (VEEEG) framework to specify, prioritise and analyse field trials of new methods (and these models can be made available for others to use)
- New metrics to define network response, including Diversified Voltage Sensitivity Factors and Feeder Voltage Diversity Factors

These are aimed at academic and high-end policy work.

For day-to-day application, the prototype Network Planning and Design Decision Support (NPADDS) tool enables analysis of PV, electric vehicles and heat pumps on a network. It also illustrates a process of ranking, design and analysis of example headroom solutions that were trialled by the CLNR project, within the context of the Smart Grid Forum Workstream 3 solutions. NPADDS is a case-specific tool, not one that uses generic rules to make sweeping statements. It brings in network data from host systems using the Common Information Model, and applies customer demands using the coefficients developed for the key customer groups in CLNR, to carry out a bespoke bottom-up power flow analysis across LV and HV networks.

The quality of the CLNR-L248[4] report was assured through the closedown consultation process and enhanced by supporting papers (with the most significant also listed in appendix 5 of that report).

Regarding the quality of the information provided on costs; the cost analysis papers listed above provided very detailed information explaining the various elements of costs that we had incurred and the basis on which we had arrived at the anticipated cost to replicate. This was not just for advanced voltage control, thermal ratings and storage as required by the SDRC, but also for the GUS ANM system[79] and for network monitoring[82]. The information on costs for AVC, storage and RTTR was provided in the form of solution templates[80] for the Transform model, i.e. in a ready to use format.

SDRC 16: Undertake, and disseminate by end Dec 2014 to other distributors, a critical review of how commercial models and arrangements between distributor and supplier may evolve to facilitate customer-side response

The key outputs in fulfilment of this SDRC were the two commercial arrangements reports. The first report (CLNR-L032[72]) describes existing commercial arrangements. The second (CLNR-L145[81]) describes the economic, commercial and regulatory barriers to the deployment of DSR and storage, their potential solutions, applicable sectors and parties best placed to initiate and implement those solutions. Section 6 of the second report discusses the evolution of commercial models.

We have fed the learning in this area into the Electricity Networks Futures Group (ENFG) and into the Smart Grid Forum Workstream 6 and its sub-groups.

Findings relating to time of use tariffs centre around the importance of Suppliers passing on the peak pricing signals contained within the red/amber/green bands of the CDCM distribution use of system (DUoS) tariffs. Northern Powergrid, together with other DNOs, has recently published such tariffs for profile class 1-8 customers, which lays the foundation for DNOs to influence the price incentives given to customers with the roll-out of smart meters but the migration to half hourly settlement will be supplier driven and so it is important that suppliers and DNOs work together to ensure customers are not disadvantaged and are fully aware of the changes that are being implemented. These changes are being managed by the Distribution Charging Methodology Forum (DCMF), Methodology Issues Group (MIG) which is attended by DNOs, suppliers, other industry specialists and Ofgem.

Residential restricted hours and direct control trials of heat pumps and wet white goods have been shown to be technically feasible and they could become cost effective in the next decade or so if they were applied to more than just a means to avoid reinforcement of DNO networks. Successful implementation therefore requires development alongside energy suppliers to provide additional incentives.

SMEs showed significant reluctance to flex their electricity use due to concerns of how this may disrupt their business activities. Our report CLNR-L103[35] SME Customers: Energy practices and flexibility demonstrates that the industry will have to develop new, potentially bespoke methods, to engage with this heterogeneous customer group.

There are few, if any, regulatory and commercial barriers to the provision of on-demand DSR by I&C customers provided that sufficient customers can be found in specific network locations willing to provide DSR services at a price less than the counterfactual reinforcement costs. DNOs access to the DSR market could be an issue, particularly when other parties are seeking the same resource and may be willing to pay more. We are therefore actively participating in the industry's Electricity Network Futures Group (ENFG) DSR shared services working group to look at arrangements that would allow the sharing of resources, such as STOR participants, currently used by National Grid.

We expect third parties to be better placed to exploit the additional income streams required to make energy storage commercially viable. We think that DNOs are therefore unlikely to commit to investing capital in the purchase of storage assets but storage could play a key role in managing DNO network constraints as a contracted demand-side management service.

SDRC 3: Project close down report produced – Dec 2014

The first version of the project closedown report[1] was completed and submitted to Ofgem on time at end December 2014. At Ofgem's request a copy was provided only to Ofgem and the DNO peer reviewer at that time, prior to full dissemination on January 22nd 2015. The final closedown report[1] was published at the end of the closedown period on 31st March 2015. Ofgem subsequently requested further minor clarifications which were made before reissuing the report on 30th April 2015.

While the closedown report[1] is fully compliant with the specification, we also recognised that there is a diverse range of stakeholders with different interests and that navigating and understanding the reports from a project as complex and multi-faceted as CLNR can be difficult for even the most expert and enthusiastic reader.

Therefore, in addition to the closedown report[1], we delivered three key learning reports[2,3,4] that summarise the learning in way that will be relevant to our stakeholders and also act as a bridge between the closedown report[1] and the hundreds of detailed reports and datasets that we have published.

The quality of the closedown report[1] and the three key learning reports[2,3,4] is assured by the DNO peer review carried out by UKPN and by the consultation process, both described in appendix 12 of the closedown report[1]. The quality of the three key learning reports[2,3,4] is also assured by the consultation process.

3 Cost effective delivery

3.1 Summary

The project has been completed on budget - a significant achievement when completing such a large and ambitious project. This was not only achieved through effective project management and financial control routines throughout the four-year project lifecycle, but also required significant in-kind contributions by partners and routes to external additional funding. We used both underspends on some cost lines and the contingency budget to make up budget shortfalls in other cost lines. In this section we provide detail on the reasons for expenditure on cost lines which exceeded the project direction budget by more than 5%.

For the avoidance of doubt, the current project direction, dated 3 September 2014, confirms the revised project budget agreed as part of the change request process. The reasons for these cost changes were explained in detail during the change request process, and progress report 7[11], section 8 and confidential appendix B summarise the reasons for cost increases (relative to the earlier budget) greater than 5%. In this application, we explain variances between the actual costs and the current project direction budget.

3.2 Cost variances

There are nine cost lines that show a variance of more than 5%:

Box 6 Employment Costs: Overall this cost category has remained within budget with expenditure £75k (1.7%) under the £4,375k budget. However, there are two individual lines within this cost category which exceed the budget by more than 5%.

i. **Box 6 Employment Costs – Technical Engineer:** This cost was £163k (13.2%) above the £1,231k budget. This was due to the deployment of technical engineers for a longer duration than originally considered. This decision was taken in order to leverage the full value from the installed network equipment, by maximising the number and duration of the field trials being run. The final trials were the most complex, collaborative and wide-area smart-grid controlled trials. The final number of field trials run on the four sample networks exceeded 200.

ii. **Box 6 Employment Costs** – **Administrator:** This cost was £11k (10.2%) above the £110k budget. This was due to retention of the project administration resources past the end of 2014 and for the closedown period ending March 2015. This was a sensible and necessary decision was made in order to: catalogue, externally publish and link the project output documents for the benefit of all of our stakeholders. The total number of project outputs published on the project website exceeded 200.

Box 7 Equipment Costs: There are four individual lines within this cost category which exceed the budget by more than 5%; three for EES and one for voltage control. Overall this cost category was £642k (5.1%) over the £12,665k budget. The first three relate to EES:

i. **Box 7 Equipment Costs – 2.5MW storage:** £384k (9.5%) above the £4,024k budget
ii. **Box 7 Equipment Costs – 100kW storage:** £77k (9.5%) above the £809k budget
iii. **Box 7 Equipment Costs – 50kW storage:** £13k (13.1%) above the £996k budget

All these storage devices were purchased under full market tender, with the most competitive commercial and technically compliant supplier being selected. However, there were certain unforeseen costs were incurred across the range of installed storage sites, which included:

- Legal costs to secure delivery of the equipment following the supplier entering US Chapter 11 Bankruptcy mid-production.
- An increase in civil engineering costs at our 2.5MW Rise Carr primary substation site, where we had to excavate significantly more than anticipated, to remove contaminated ground, reinforce with load bearing foundations and a subsequent extra high voltage cable diversion.
- During the installation and commissioning, additional work required for both safety and network protection to connect these 'first of a kind' systems onto our live distribution networks. In order to safeguard both customers and staff, when deploying the six trial devices we took a very prudent approach to the protection, fire and safety systems we installed and commissioned.
- Post installation we had noise issues at our two rural sites in North Northumberland during trials operation, which we had remediate with acoustic enclosures.

We have recorded and disseminated to all other DNOs the approach we took and where we considered costs would not be incurred again in future BAU installations. We have imparted this knowledge via our active participation in ESOF, DNO dissemination events, presentations to the IET and site visits with the Health & Safety Executive. Our project outputs include:

Reference	Title
CLNR-L161[36]	Northern Powergrid operational guidance and training requirements: Electrical energy storage
CLNR-L249[37]	Costs analysis report: Electrical energy storage
CLNR-L25313	ESOF Good Practice Guide on Electrical Energy Storage
CLNR-L147[38]	Technical recommendation for the purchase of EES systems
CLNR-L163[39]	Lessons learned report: Electrical energy storage
CLNR-L168[40]	Training package: Electrical energy storage
CLNR-L118[41]	CLNR trial analysis: Electrical energy storage (100kVA/200kWh) Powerflow Management
CLNR-L121[42]	CLNR trial analysis: Electrical energy storage (2.5MVA/5MWh) Powerflow Management

iv. **Box 7 Equipment Costs: Voltage Control.** This was £291k (60.0%) above the £484k budget.

Voltage control was one of the key enablers for the manipulation of the CLNR trial distribution networks and encompassed many of our sites including 2 primary substations, 2 HV regulator sites, 1 switched capacitor station and 3 distribution substations. However, certain unforeseen costs were incurred across the range of installed control sites, which included:

- The need to develop a safe system of failure redundancy utilising existing modified protection relays in both a main and standby arrangement for our primary sites
- The integration of data acquisition monitoring to enable central voltage control state estimation, via the GUS smart-grid control system
- The development of enhanced reinforcement, security and safety systems for the distribution sites for these first of a kind systems. As with the storage devices, in order to safeguard both customers and staff, we took a similarly prudent approach, especially as three of the units were manufacturer's prototypes. This included the development and installation of ballistic screening shields and housings

Many of these unbudgeted activities would not be required a BAU application of the technology since they were associated with the first of a kind technology deployment. We have recorded and disseminated to all other DNOs the approach we took and where we considered costs would not be incurred again in future BAU installations. We have imparted this knowledge via active participation at DNO events, IET presentations and site visits with the Health & Safety Executive.
Our project outputs include:

Reference	Title
CLNR-L158[43]	Northern Powergrid operational guidance and training requirements: Trials of secondary transformers with integral OLTC
CLNR-L250[44]	Costs analysis report: Enhanced automatic voltage control
CLNR-L209[45]	Technical recommendation for the purchase of EAVC for HV systems
CLNR-L165[46]	Lessons learned report: Enhanced automatic voltage control
CLNR-L170[47]	Training package: Enhanced automatic voltage control
CLNR-L119[48]	CLNR trial analysis: EES1 and EAVC1 with GUS voltage control
CLNR-L135[49]	CLNR trial analysis: collaborative voltage control on HV and LV networks

v. **Box 8 Contractor Costs – Durham University:** This was £252k (6.9%) above the £3,640k budget. This was due to the need to engage additional analyst resources to deliver the full set of detailed analysis and report outputs from the large customer trials dataset. In the summer of 2014, all of the customer trials had closed and the monitoring data was being collated, and transferred to Durham University to be sorted and quality checked. The customer dataset profiles were published at the end of August as per the SDRC milestone, but we considered that the full value of the customer trials data was held within the deeper analysis and written report outputs. Due to the volume of work to be completed and the data quality issues to work through, we committed extra resources in September 2014 to deliver these value enhancing outputs.

Academic institutions, such as Durham University, have limited ability and agility to increase resource numbers for short periods in the way that was required in the run-up to project completion. In order to deliver all the high-quality analysis and reporting outputs from the customer trials that we had specified, we decided to supplement Durham's analysis resources with those from two contractors, Frontier Economics and Element Energy. Whilst Durham University's costs reduced by *ca.* £100k, the majority of their costs were fixed and the net effect was an increase of £252k, of which £226k was funded from contingency. In conclusion, we are satisfied with both the timeliness of the intervention we made and the value we obtained from the use of these quality contractors. We considered and discounted two alternatives: either to deliver the datasets alone (as per the planned SDRC milestone) without the detailed analysis and insight, or to delay the project end by a further three months while endeavouring to retain Durham University's analysts (which would most likely not be successful) and incur up to *ca.* £400k per month in programme burn rate.

Box 10 (Other Costs): There are two individual lines within this cost category which exceed the budget by more than 5%; one for IT costs and one for 'other' costs. At the overall box level (excluding contingency), expenditure is £32k (4.5%) over the £701k budget.

vi. **Box 10 IT Costs:** This cost was £41k (36.8%) above the £110k budget. This was due to the reallocation of £51k costs from Netcontrol and CG Automation, for SCADA upgrades and other communications services. These costs had been incorrectly allocated in 2013 (at the time of the change request) and needed to be correctly moved to the IT cost category

vii. **Box 10 Other Costs:** This cost was £15k (18.4%) above the £84k budget. This was due to late invoices for both a CLNR dissemination event held in London and for Audit fees associated with LCN fund governance compliance.

3.3 Value for money delivery

The table in Appendix H highlights six areas where a cost line constitutes more than 5% of the overall £31,033k budget, i.e. is an area of high value project expenditure. The process for deliVering value for money is provided below:

i. **Box 6 – Project Manager:** This cost line had a budget of £2,537k, 8.2% of the total budget. Our strategy for maintaining cost control and driving efficiencies was to predominantly use direct employees over consultants, to monitor costs via monthly financial reviews with the project accountant, and to report regularly on project budget to the Project Board & Executive Board. The final project expenditure of £2,470k was £67k (2.7%) under budget.

ii. **Box 7 – 2.5MW/5MWh storage:** This cost line had a budget of £4,024k, 13.0% of the total budget. Our strategy was to carry out a full-market competitive tender at the initial procurement stage. This approach was also taken for the smaller capacity (100kW and 50kW), lower value storage devices. As with other cost lines we followed our established financial and project management routines. In addition we secured the personal engagement of both Northern Powergrid’s Field Operations Director and Director of Safety and Environment to provide expertise and access to skilled and scarce resources during the commissioning, training and operation phase of this novel equipment on our live network. The final project expenditure of £4,408k was £384k (9.5%) over budget. The unforeseen costs incurred on storage are discussed in the ‘Cost variances’ section above.

iii. **Box 7 – Control Interfaces:** This cost line had a budget of £3,370k, 10.9% of the total budget. Our strategy was again to carry out a full-market competitive tender as with the storage devices. As with other cost lines we followed our established financial and project management routines and with this equipment we again had the personal engagement of the Field Operations Director providing expertise and skilled and scarce resources for this smart grid state estimation control system which was a first of its kind in Europe. The final project expenditure of £3,189k was £181k (5.4%) under budget.

iv. **Box 8 – British Gas:** This cost line had a budget of £3,867k, 12.5% of the total budget. Our strategy was to predominantly use British Gas direct employees over consultants, to closely monitor costs via the project routines described above and, when appropriate, to reduce resources through flexible deployment onto other projects, such as internal British Gas projects and for example UKPN’s Vulnerable Customers and Energy project. The final project expenditure of £3,925k was £58k (1.5%) over budget.

v. **Box 8 – EA Technology:** This cost line had a budget of £4,086k, 13.2% of the total budget. Our strategy was to predominantly use EA Technology direct employees over sub-contractors, to closely monitor costs via the project routines described above and only to pay for EA Technology employees when deployed on work. When work stopped, then so did the charges, with those employees deployed onto other projects. The final project expenditure of £4,047k was £39k (1.0%) under budget.

i. **Box 8 – Durham University:** This cost line had a budget of £3,640k, 11.7% of the total budget. Our strategy was to closely monitor the workload / work-flow liaison and review processes, deploying the Northern Powergrid workstream managers and the technical architect into both Durham University and Newcastle University. Through this method we maintained a clear view on scope and by checking the analysis work whilst it was still in progress during Q3 and Q4 2014. We also closely monitored costs via the project routines described above. The final project expenditure of £3,892k was £252k (6.9%) over budget. The reasons for the need to engage additional external consultants to complete and element of Durham’s analysis work is discussed in the ‘Cost variances’ section above.

3.4 Additional funding

Additional sources of funding have been obtained during the project to add value and enhance the quality of the outputs, at no additional cost to customers. These additional funding streams include:

- DECC funding of £2.2m secured by the project and contracted to British Gas to subsidise heat pump installations, due to in the absence of a renewable heat incentive. This external funding that was the prime determinant in the project achieving the 380 heat pump installations and trial participants
- The academic partners have combined other grants with the project. Both of these grants are leveraging value from CLNR and were not committed at bid stage:
  - Early in the project a £0.5m grant to Durham University helped to establish much of the modelling simulation capability in the smart grid laboratory that has been so important to delivering both the baseline and additional outputs from the project.
  - More recently, a £2m grant to Newcastle University from the Department for Culture, Media & Sport is creating a national centre for Big Data and Cloud Computing. This will support the work on the legacy data from CLNR post project closedown that we expect to be an important national resource for the next decade.
- We also estimate that the non-funded contributions made by partners of deploying scarce and valuable resources to overcome the challenges inherent in delivering a project as ambitious as CLNR has been in excess of £1m. This includes senior board level engagement, installation of smart meters for customer trials prospects, non-costed resource deployment including project management, technical design expertise, procurement, and operational engineering support including training 100 operational standby engineers. This project required huge organisational commitment from the partners (particularly from Northern Powergrid and British Gas) which was delivered alongside normal service delivery. There is an unquantified cost to the companies that is the opportunity costs of deploying key resources on this project as opposed to other valuable organisational priorities. Whilst provision of this level of support could be expected on a project of CLNR's size and importance, it needs to be recognised that customers have not been asked to fund the totality of the costs associated with the project.
- Northern Powergrid have also funded data analysts and project management valued at ca. £50k, following the project closedown, to prepare disaggregated customer datasets, ready for publication as phase 1 of the CLNR data legacy.
- In addition we have taken the opportunity to reuse some of the decommissioned residential customer monitoring devices which we have re-deployed at no cost to two projects. The first is UKPN's Vulnerable Customers and Energy Efficiency project where UKPN have avoided up to £170k of expenditure on monitoring equipment. The second is South Kesteven district council who were introduced to us by WPD and who are monitoring temperature in *ca.* 200 off-gas households in rural Lincolnshire, in order to size heat pump installations pre-installation.
- Northern Powergrid is currently considering how to deploy the remainder of the CLNR equipment to capture additional value from the sunk investment cost.

3.5 Reallocation of budget between categories

The amount of under and overspend in each cost category can be seen in appendix H. The main movements between categories have been the drawdown of £583k from the contingency budget to cover net increases in other cost categories. The largest increase in any cost category was for Box 7 Equipment Costs at £642k (5.1%). No costs exceeded the 10% threshold requiring prior approval.

3.6 Use of contingency budget

During the four-year project life-cycle we were always mindful to maintain compliance with not spending over 110% of any box total (see appendix H) without prior approval from Ofgem. Our continuing focus was to deliver high quality learning outcomes within the overall project budget and to use contingency where appropriate to ensure delivery of the learning outcomes across the entire programme. We have utilised the remaining £600k contingency budget reported in May 2014 in two key areas: contractor costs and network technology.

Firstly, in order to achieve high quality outputs, we engaged consultancy resources to analyse certain elements of the customer trial data and utilised £226k of contingency to complete this work. The costs for the work undertaken were Frontier Economics (£252k) and Element Energy (£100k). We were able to offset *ca.* £100k of this expenditure from an underspend by Durham University.

These additional consultancy resources were engaged to maintain the quality of our outputs whilst overcoming delays and quality issues with the customer trials monitoring data. Whilst these issues were surmountable through careful data handling, sorting and cleansing, and computer scripts, the outputs were under time and resource pressure. Durham University's analyst resources were a scarce commodity, on fixed term contracts with imminent expiry dates. Additional resources had already been re-deployed from Newcastle University to Durham, but we considered that additional highly skilled resources were still required to expedite the work and to ensure delivery of all the outputs in time for project completion.

Secondly, we secured and maintained additional resources to deliver our network field trials and used an additional £374k contingency to complete over 200 field trials. We supplemented our own resources with engineering resources from Parsons Brinkerhoff (£123k) and Grid & Distribution Professionals (£104k). In addition, we had £38k of civil engineering costs for the large EES site at Rise Carr that were re-allocated, £60k of modifications carried out by the supplier of the energy storage NEC Systems and £11k of noise surveys and remediation for the rural small EES sites by DB Attenuation.

The requirement to commit contingency budget on the network trials came from the decision to maintain the smart grid system to run the field trials for a longer duration than envisaged and to ensure delivery of the most complex full area collaborative control trials. This approach was taken to maximise the outputs from the installed CLNR equipment. We also had multiple trials running simultaneously across the four trial networks and at the height of the trials that ran from October 2013 to November 2014, we had four networks operational with the full range of CLNR equipment maintained under collaborative control by the smart grid GUS controller with up to 87 monitoring points informing the state estimation engine. We maintained the appropriate levels of specialist field and control room resources to maintain accurate inputs to optimise the GUS control system's decision-making and to operate more than 200 trials safely on our live network.

4 Project management

4.1 Summary

Effective project management balances the time, cost, scope and quality of deliverables of a project within the context of seeking to maximise the benefits that can be realised from implementation of those deliverables. In the case of CLNR, the benefits accrue to GB customers and the environment and over an extended period of time, with the benefits calculated as at least £5 billion and 11 million tonnes of CO_2 savings during the period 2020-2050 (see section 8 of the closedown report[1]). Due to the long time frame over which the benefits from CLNR would be realised, our philosophy was to maximise the benefits by maintaining scope and quality at the expense of time to complete the project, while still ensuring that the project would be delivered within the same overall cost.

We sought out and used effectively opportunities to collaborate with other organisations and projects to maximise the delivery of relevant learning, for example through the engagements with ESOF, and the SwitchEV and My Electric Avenue projects. While such collaborations can deliver additional learning, in an already complex project this adds yet more complexity and requires good project management to ensure that it is delivered effectively.

Progress, risks, issues and changes were communicated regularly not just within the project team and associates/suppliers, but also reported externally through the six monthly progress reports and also in other direct communications with Ofgem.

4.2 Management of risks and issues

Our good practice approach to risk management included the following features:

- assigning ownership of a risk;
- assessment of the level of risk considered both the probability of a risk occurring as well as the impact should it occur;
- establishing the level of risk unmitigated and after mitigation; and
- developing mitigating actions and a contingency plan.

All of the above features are evidenced by the project risk register which was included as an appendix to each progress report from progress report 5[9] onwards, the first to be produced in accordance with the revised specification for progress reports.

Following the identification of risks at bid stage and set out in the full submission, progress report 1[5] (section 10) set out a number of additional risks that had been identified in the first six months of the project, and mitigation actions and contingency measures for those risks. All subsequent progress reports contained information on new risks that had been identified as well as updates on previously identified risks, along with information on mitigation and contingency actions (see section 10 of the early progress reports and section 4 of progress reports 5 onwards).

4.3 Opportunities seized

We considered opportunities as well as risks. Examples of opportunities that we exploited successfully include:

Studying customers' usage of Economy 7 tariffs & hot water storage

In 2012 (progress report 3, para 8.7) we reported that our marketing activities had identified that electric hot water is not a suitable load for demand response since majority of customers who heat their domestic hot water electrically typically do so overnight and on an Economy 7/10 tariff. Rather than descope the planned trials of direct control and restricted hours tariffs with households, we sought out an alternative load (smart washing machines) for these trials. However, the learning from the marketing activity also indicated that there appeared to be very limited knowledge around electric hot water usage and customer behaviour in the UK and literature on the subject appeared to be largely theoretical. i.e. there was an opportunity for CLNR to fill a knowledge gap by including households with electric hot water heating and storage heating as distinct sub-groups within the trial of enhanced monitoring of domestic customers without LCTs (ie test cell 2a). This has provided an understanding of these customers' general loads and also how they respond to the existing E7/E10 tariff signals i.e. the extent to which people on these existing and long standing DSM tariffs actually respond to the price incentives and the extent to which the controls are over-ridden. A rich data set has been delivered from this test cell. We have considered whether alternative DSM solutions could be offered to those customers in future.

Heat pumps: customer attitudes, power quality and implications for widespread take-up

We identified the opportunity to generate learning, at minimal additional cost, which will become increasingly relevant in the move towards higher uptake of heat pumps. We went beyond just monitoring heat pump consumption profiles and flexibility to explore customers' attitudes to the operation and performance of heat pumps. The benefit of this has been a wider understanding of issues which need to be addressed (eg to educate in operation and gain 'buy-in') if heat pumps are to become a more active part of the energy system. This was achieved at minimal incremental cost. See CLNR-L104[50] and CLNR-L245[51].

We have studied the effect of heat pumps on power quality, both individually and the impact of a cluster of heat pumps on network power quality, considering the concerns about widespread uptake of these technologies. See CLNR-L146[52]:

When and where EV uptake will challenge networks

A collaboration with the Switch-EV project enabled us to use additional data from thousands of charging events on a bigger dataset of a pre-existing Northeast project and combine it with the CLNR data. This allowed the analysis of data on journeys and recharging away from home. As a result, we have produced a much more accurate view of where, when and how network challenges will emerge due to EV uptake. The key learning provided through exploiting this opportunity has challenged the assumption that if 40% of customers on a LV circuit have EV charging then transformer would be overloaded. In fact, we can have higher penetration rates in urban areas on average (60%) and lower rates in rural areas (15%).This means that GB network investment strategies should be much more appropriate going forward i.e. in the right place, of the right type and at the right time. This learning was reported in a conference paper CLNR-L038[53] and in a journal paper CLNR-L070[54]. This learning was achieved with no additional cost to the project to obtain the data and only a minimal incremental cost for the additional data analysis.

EV power quality monitoring

At the bid stage we planned to monitor just PV and heat pump clusters and not EV clusters because of the scarcity of EVs and also because they were less likely to be clustered. Our partnership with EA Technology and SSEPD on the My Electric Avenue (I2EV) project provided the opportunity to add power quality monitoring on five feeders (4 residential; 1 at a work location) each containing a minimum of 10 EVs each. This power quality monitoring was not part of the I2EV scope and so is unique to CLNR. This was at minimal incremental cost since it required only a few field monitoring devices adding to the main CLNR monitoring system. See CLNR-L146[52].

Energy Storage Operators' Forum

We took the opportunity to actively participate in this working group for practitioners, with the costs funded by NPg rather than CLNR. This engagement had the dual benefit of influencing our thinking and approach to electrical energy storage in CLNR, while providing a forum for sharing our experience and detailed information. This injection of knowledge to ESOF is evidenced by our contributions to the ESOF Good Practice Guide on Electrical Energy Storage13.

4.4 Risk mitigation measures

The tables below set out some of the key risks to the project, illustrating effective mitigation actions and contingency plans were developed and executed so that good outcomes were achieved.

Risk 3: insufficient numbers of customers are recruited to populate the individual test cells
Impact: This would prevent the operation of, or reduce the statistical validity of the results of test cells. Also, insufficient customers in clusters participating would have meant that we could not generate a measurable closed-loop network response.
Mitigating actions: • Strong customer propositions developed including incentive payments. Effective customer engagement strategy (customer selection, engagement and support) in place supported by BG's established sales and customer service infrastructure. Prioritised list of customers and types developed. Links to identified local partners used to source trial participants. Trial populations have been sized to take account of customer drop out.

- DECC funding secured to deploy up to 600 Heat Pump customers for the trial. CESP propositions being worked up by BG to secure sales of these units on a large scale.
- Also working with Charge Your Car initiative to access data from ca. 80 existing installs and to capitalise on their Phase 2 rollout of smart charge points.
- We have fully funded wet white goods for the DC general load test cell.
- We are experiencing difficulty with recruiting SME customers onto the restricted hours and direct control arrangements and are revisiting customers with less severe proposals to try to get them onto the trial or to at least assess the minimum level of control / restriction that they would find acceptable.

Contingency plan:

- Reduce the sample size in affected test cells, while still remaining within acceptable confidence levels.
- Where the customer numbers are below statistical significance we will challenge ourselves to determine the learning that can be obtained from such numbers.

Did the risk materialise?

Yes. See information on issues and the formal change request below for more information.

Risk 25: the GUS central control system may not function as required

Impact:

It may not be possible to conduct the network trials under the control of GUS.

Mitigating actions:

Use testing and commissioning to ensure all required functionality is included and working.

Contingency plan:

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.

Did the risk materialise?

No. The system functioned as expected.

Risk 48: loss of academic personnel

Impact:

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.

Mitigating actions:

Make arrangements which allow contracts to be extended, independent of the outcome of the change request process.

Contingency plan:

Replacement staff to be recruited. This would limit but not entirely mitigate the impact.

Did the risk materialise?

The university extended contracts of staff due to end in 2013 into 2014, reflecting the revised timetable as per the change request. This action largely mitigated the risk. However, the complexities of processing and manipulating customer trials data meant that this aspect of the project was not completed by the time the relevant academic staff were due to leave the project. To ensure that the work was completed we engaged contractors to complete this work at additional cost. This is discussed in the section on costs.

4.5 Issues adversely affecting the project

Issues managed internally, by flexing time and effort/cost

- Low rates of fixed line broadband in social housing (progress report 4, para 8.10, progress report 5, para 2.24): this affected the heat pumps trials since most of those trial participants lived in social housing. This significantly limited the number of homes where we were able to install broadband enabled communication hub devices. Given the scarcity of heat pump households and the additional importance of monitoring each heat pump installed as part of the conditions of the £2.2m grant from DECC, we decided to pay for one year's subscription of broadband and also to provide assistance in setting up the account and hardware. This enabled us to monitor over 380 heat pumps, which we believe to be the largest heat pump dataset ever recorded in the UK.
- A 6 month delay in completing the design and build of the GUS ANM system (progress report 5, para 2.43, progress report 6, para 2.41): the GUS system was built to interface with the monitoring systems and EAVC, RTTR, EES and the DSR platform, using a range of communication protocols. Although this was completed successfully, it this was highly complex and took longer than planned, thus eating into time that was scheduled for the network trials, with a knock on effect on the overall completion date of the project. We reduced the knock on impact of the delay in completing GUS on the network trials through a number of actions; the effective use of pre-trial simulation and emulation, and a phased commissioning of the control system and start of the trials.
- EES inverter failure (progress report 7, para 2.33, progress report 6, para 2.28): the inverter unit of the largest EES unit failed causing damage to the power capacitor and secondary wiring on the inverter unit. Although there were no injuries and the battery cells themselves were undamaged, the unit was out of operation for 5 months while the failure was investigated, designs modified and applied, the repair made and the unit re-energised. We managed the impact of this on the network trials by rescheduling within the suite of planned trials to avoid this issue causing any delay to the overall completion of the trials.

Issues affecting customer trials, managed via scope & design

We encountered a number of issues which affected recruitment to the customer trials (as anticipated by risk 3) and the technologies and commercial propositions for the trials. These issues were largely managed internally, in accordance with the approach set out above and in accordance with our principle of prioritising scope and quality of learning over delivery time while still remaining within the overall budget. The net effect of these issues was that we cancelled some test cells and made changes to the detailed design of some others, but we also took the opportunity to benefit from early insight and introduce subsets within the detailed monitoring of domestic customers to study electric heating and hot water.

An update on the detailed design of the customer profiling and customer flexibility trials can be found in Appendix 3 of the change request which explains in more detail:

- How we extended recruitment to include customers from outside the Northern Powergrid regions to attract more participants for the scarce low carbon technologies;
- How we created subgroups within the enhanced monitoring of general load domestic customers to enable us to study electric space and water heating, a subject for which there was very limited knowledge;
- How we decided to use smart washing machines as the technology of choice for the interventions trials when we found that electric hot water systems were not suitable loads for demand response;
- How we changed the commercial proposition for within-premises balancing for PV customers when we found that the current feed-in tariff arrangement distorts price signals to customers, such that it was not necessary to provide a tariff discount to customers for balancing, and indeed to do so would have incurred unnecessary cost;
- How we adapted our approach to ensure that we could, as intended, study the effect on the network of a cluster or heat pumps with direct control, despite the fact that the practicalities of recruitment meant that the heat customers trialling this intervention were in fact dispersed rather than clustered; and

- How we implemented a three time-band time of use tariff - even though we identified the merits of trialling a four time-band tariff we did not implement this as it would have required major changes to British Gas's billing systems which would have added significant cost and delay.

We had originally planned a total of 27 test cells to study customer profiles and customer flexibility, i.e. 27 different combinations of customer type (domestic/SME/I&C/DG), technology type (none, HP, EV, PV, responsive load/generation, PV load balancing) and commercial proposition (flat rate, time of use (ToU), restricted hours (RH), direct control (DC)) that were trialled. Due to the issues we encountered, we cancelled five of those test cells: direct control with SME customers, heat pumps with restricted hours, and the three flexibility trials with EV customers (i.e. ToU, DC, and RH), and took the opportunity to add two new ones (monitoring of customers with electric water heating or storage heating).

The cancellation of the SME test cell was due to a lack of customer uptake, and we have explored and reported on the reasons for this; which is valuable learning in its own right. The heat pump restricted hours test cell was cancelled as the tariff could only be offered to BG customers, but the heat pump customers were non-BG customers as this was the only way to recruit customers in the face of the scarcity of this technology, as described above. The EV test cells were cancelled because we found that variable rate tariffs for EV customers are increasing becoming the norm, so trialling a range of interventions in CLNR would have added little value.

It is important to note that despite the difficulties faced, we were able to conduct trials with all customer types (domestic/SME/I&C/DG), technology type (none, HP, EV, PV, responsive load/generation, PV load balancing) and commercial proposition (flat rate, ToU, RH, DC), while at the same time delivering additional learning in related areas (see section on 'opportunities' above).

We regularly communicated these issues and our proposed responses to them not just internally, but also externally through formal progress reports and in discussion with Ofgem (see appendix I). Some of the changes were signed off internally, and others required Ofgem approval. For example, before we could expand the scope or recruitment to include non-British Gas customers we needed to prepare updates to the Customer Engagement Plan and Data Protection Strategy and to obtain Ofgem approval of these documents. In these cases we paused recruitment activities while approval was obtained, which sometimes caused delay but meant that we remained compliant with LCN fund governance. In total, through the course of the project we updated three times the Customer Engagement Plan and the Data Protection Strategy.

However, there were some issues that affected the project to the extent that the change could not be managed internally, i.e. addressing the issue would have required either a major descoping or changes to time and/or budget, and LCN fund governance required that these be dealt with by lodging a change request with Ofgem.

Issues requiring a change request to Ofgem

The early and ongoing dialogue with Ofgem about external issues affecting the project (see appendix I), culminated in the submission of a change request. We proposed no change to the method or solution. The change that was requested and approved related to the delivery plan, specifically a 12-month extension to the project completion date and a restructuring of the project budget, although the overall project budget remained unchanged.

These were material changes in external circumstances and since we could not manage them within the parameters set by the LCN fund governance/project direction, we submitted a formal change request to Ofgem setting out the issues and the substantive changes to timing and budget which we proposed to address these.

The issues which we encountered and which led to this change request were:

- Scarcity of customers with heat pumps and EVs, requiring the recruitment of non-British Gas customers which entailed more complex monitoring systems to be designed and installed, and the sourcing of additional funding to achieve heat pump installations.
- Rent-a-roof PV providers not agreeing to the necessary monitoring, requiring the recruitment of additional customers.
- The decision by a manufacturer of smart appliances identified at the bid stage not to enter the UK market, requiring the sourcing of a new supplier.
- The procurement and manufacture of novel network technology taking longer than planned, due to a variety of external factors:
  - Electrical energy storage vendor entering bankruptcy protection proceedings
  - Scarcity of HV transformer with on-load tap changer for EAVC
  - No market-ready solution available for RTTR for underground cables
  - Company takeover of vendor for HV and EHV overhead line RTTR
  - Scarcity of vendor of full specification of RTTR monitoring equipment for primary transformers
  - Component and sub system delays adversely impacting the control system integration

Management of the change request

Throughout the project we used the progress reports and additional meetings with Ofgem to advise issues we encountered, our assessment of the options and proposed and actual actions taken.

At a meeting with Ofgem in January 2013 we apprised Ofgem of the impact of all the externalities on the project and our intention to submit a change request. Ofgem did not ask us to suspend the project while we prepared the change request, or request any further information. The impact of externalities and our intention to submit a change request were reported again in the June 2013 progress report[9], at which time the change request was being prepared.

In our meetings with Ofgem we had set out a range of options for addressing the issues we had encountered, especially in relation to the scarcity of customers with heat pumps, EVs and PV and our formal change request built on that dialogue.

We prepared the change request with an appropriate level of detail, based on guidance from Ofgem and on consideration of the earlier change request from the Low Carbon London project. During the change request process we further provided a large volume of detailed supporting information in response to questions from Ofgem's consultant. In 2014 while the change request was under consideration by Ofgem, we reached the point where we had proceeded with the project beyond the original project completion date and some categories of expenditure were exceeding the 110% above which prior approval was required. This was discussed with Ofgem and we took the decision to continue, rather than halt, the project while the change request was under consideration. We accepted that in doing so we were taking some commercial risk, but we considered that it was not practical or cost effective to suspend the project while we awaited the outcome of the change request.

The change request was accepted in full, i.e. the proposed revised budget and timescales were agreed and a revised project direction issued (since there were no communications/engagement SDRC in 2014, the new final year of the project, we had proposed an additional criterion in 2014, but this was not included in the revised project direction).

Appendix A: Peer-reviewed academic publications

The quality of our outputs is evidenced by the volume of work presented to international conferences, and in journal papers, theses, and book chapters. These are listed in table A7.2 and, where appropriate, mapped to relevant SDRC.

We are particularly proud of CLNR's success in the most highly rated journals in their fields of expertise. Of the total of 12 papers already published in or submitted to academic journals, six (50%) are in journals rated as being in the upper quartile in their field in terms of impact factor, and 10 (over 80%) are in the top half. See table A7.1

Table A7.1

	Journal title	Journal area of expertise	Journal impact factor	Journal ranking
1	Applied Energy (x2 papers)	Energy and fuels	5.3	Q1
2	Energy	Thermodynamics	4.2	Q1
3	Energy Efficiency	Environmental studies	1.0	Q3
4	Energy Research & Social Science		Not been publishing long enough	
5	Environment and Planning A	Environmental studies	1.7	Q2
6	Environment and Planning D: Society and Space	Environmental studies	1.7	Q2
7	Geoforum	Geography	1.9	Q1
8	IEEE Transactions on Power Systems	Engineering, electrical & electronic	3.5	Q1
9	IEEE Transactions on Smart Grids	Engineering, electrical & electronic	4.3	Q1
10	Urban Studies	Environmental studies	1.3	Q2
11	Wind Energy	Energy & Fuels	2.6	Q2

Table A7.2 below lists the 36 pieces of work presented in a range of academic formats (journals, international conferences, books and theses). This includes 32 published or accepted for publication subject to revisions, and another 4 submitted for publication. A further 15 are currently in progress.

Table A7.2
List of work published or accepted for publication, and work (marked by *) submitted for publication. Where the work directly supports a particular SDRC, this is also indicated.

Ref	SDRC	Journal / Document Title	Type	Journal / book /conference details
1	8	*Sociality, intimacy and electricity: the influence of household dynamics on everyday consumption.	journal	Energy Research & Social Science
2	8	Understanding evening peak electricity use in the UK: a socio-technical analysis	conference	Smart Grids and the Social Sciences Workshop, Norwegian University of Science and Technology, 2014.
3	8	*What's in a peak? Rhythms of energy use across home and infrastructure	journal	Environment and Planning D: Society and Space
4	9	Co-evolution of heating and hot water practices: rigidity, disruptions, and systemic challenges	conference	Nordic Environmental Social Science conference 2013
5	9	*An analysis of the economic and emissions reduction benefits of micro-CHP in the UK	journal	Energy
6	9	A probabilistic approach to combining smart meter & electric vehicle charging data to investigate distribution network impacts	journal	Applied Energy

Ref	SDRC	Journal / Document Title	Type	Journal / book /conference details
7	9	*Smart Grids and the Constitution of Solar Electricity Conduct	journal	Environment and Planning A
8	9	FIT-TING SOLAR INTO THE SMART GRID: Systems of Provision and the Constitution of 'Smart' Electricity Conduct	conference	Energy Systems in Transition, Karlsruhe, Germany 2013
9	11	Peak Demand and the Flexibility of Everyday Life	journal	Geoforum
10	11	Household Relations and Domestic Demand Side Response	conference	13th European Association of Social Anthropologists Biennial Conference, 2014
11	11	Prospecting for Flexibility: Findings from a Collaborative Enquiry into Smart Electricity Systems	conference	Nordic Environmental Social Science conference 2013
12	11	Fostering active network management through SMEs practices	journal	Energy Efficiency
13	11	Smart grids and the governing of energy use: reconfiguring practices?	book chapter	Social Practices, Intervention and Sustainability: Beyond behaviour change (2015)
14	12	Programmatic smart grid trial design development and analysis methodology	conference	CIRED 2013
15	12	Findings from the CLNR network trials, with special reference to quantifying the benefits and risks of Real-Time Thermal Ratings in electrical networks.	conference	Probabilistic Methods Applied to Power Systems, 2014
16	12	Use of Real-Time Thermal Ratings to Increase Network Reliability under Faulted Conditions	conference	CIGRÉ Regional South-East European Conference (RSEEC 2012)
17	12	Using Electrical Energy Storage to Support Customers Under Faulted Conditions	conference	CIGRÉ Regional South-East European Conference (RSEEC 2012)
18	12	Demonstrating enhanced automatic voltage control for today's low carbon network	conference	CIRED 2012
19	12	Integrating renewable energy into LV networks using energy storage	conference	CIRED 2012
20	12	Use of real time thermal ratings to support customers under faulted network conditions	conference	CIRED 2013
21	12	Using electrical energy storage to support customers under faulted network conditions	conference	CIRED 2013
22	12	Coordinated voltage and power flow control in distribution networks	conference	CIRED 2013
23	12	Design and analysis of electrical energy storage demonstration projects on UK distribution networks	journal	Applied Energy
24	12	Future low carbon technologies, impacts and energy storage solutions on UK distribution networks	conference	CIRED 2014
25	12	Distribution network voltage control using energy storage and DSR	conference	IEEE PES Innovative Smart Grid Technologies Europe, 2012
26	12	Integrating electrical energy storage into coordinated voltage control scheme for distribution networks	journal	IEEE Transactions on Smart Grids
27	14	Capacity value of distributed generation for network capacity planning	conference	CIRED 2013
28	14	Quantifying the contribution of wind farms to distribution network reliability	journal	Wind Energy
29	14	Defining and evaluating the capacity value of distributed generation	journal	IEEE Transactions on Power Systems

Ref	SDRC	Journal / Document Title	Type	Journal / book /conference details
30	15	An Interdisciplinary Method to Demand Side Participation for Deferring Distribution Network Reinforcement	conference	IEEE PES Innovative Smart Grid Technologies Europe, 2012
31	15	A presentation to the "Advanced Modelling and Control of Future Low Voltage Networks"	conference	IEEE Power & Energy Society general meeting, Washington, USA, 2014
32	15	A network planning and design decision support tool for integration of low carbon technologies and solutions	conference	CIRED 2013
33		Smart Grids in the City: Splintering Urbanism in a Smart Urban Future	thesis	
34		Splintering the Smart Grid: 'Entrenching Social Inequalities in a Technologically-enabled future?'	journal	Urban Studies
35		The Urban Geographies of Smart Energy	book chapter	Smart Urbansim: Utopian Vision or False Dawn? (2015)
36		“Smart Grid Data Cultures” in the session: The role of commercial data in #Census 2022	conference	RGS-IGB Annual International Conference, 2014

Appendix B: Successful delivery reward criteria

The following SDRC are those stipulated in the Project Direction that was revised as part of the change request approved by Ofgem on 4 September 2014.

Ref	Successful Delivery Reward Criteria	Evidence
Criteria related to installation and commissioning of network equipment		
1	Commence installation and commissioning of network equipment relating to learning outcome 3 – September 2011	• Installation and commissioning plan and details of expenditure relating to network equipment installation activities provided to Ofgem/auditors.
2	Complete installation and commissioning of network equipment relating to learning outcome 3 – December 2013	• Equipment on site and operational, available for site audit.
Criteria related to communications and engagement		
4	Project website up and running by end May 2011 and updated in line with project developments	• Website content and breakdown of composition of updates.
5	Industry stakeholder forum held on an annual basis, by end May 2011, May 2012 and December 2013	• Meeting minutes in relation to distributor project review meetings, regional stakeholder panel meetings and industry stakeholder forum • Materials presented in support of the above meetings.
6	Distributor project review meetings held by end July 2012 and December 2013	• Meeting minutes in relation to distributor project review meetings, regional stakeholder panel meetings and industry stakeholder forum. • Materials presented in support of the above meetings.
7	Regional stakeholder panel meeting held on an annual basis by end March 2011, March 2012 and December 2013	• Meeting minutes in relation to distributor project review meetings, regional stakeholder panel meetings and industry stakeholder forum. • Materials presented in support of the above meetings.
Criteria relating to customer trials datasets		
8	Demand profiles grouped by customer type - interim by end 2012, finalised August 2014	• Data sets made available in an open and useable format and issued to distributors and other interested parties.
9	Demand profiles grouped by low-carbon technology type - interim by end 2012, finalised August 2014	
10	Output profiles of existing generation types - interim by end 2012, finalised August 2014	
11	Output/ demand profiles before and after a range of interventions - interim by end April 2013, finalised August 2014	

Ref	Successful Delivery Reward Criteria	Evidence
Criterion relating to network trials datasets		
12	Network data showing performance of selected network technologies by end October 2014	• Data sets in an open and useable format issued to distributors and other interested parties.
Criteria relating to impact of new load and generation profiles		
13	Publish analysis of load profile data by end October 2014	• Proposals for changes to standard load profiles for network planning, issued to: • fellow distributors and website; and • ENA Engineering Committee, with any recommendations to update/replace ACE 49.
14	Publish analysis of generation profile data by end October 2014	• Proposals for changes to standard generation profiles for network planning, issued to: • fellow distributors and website; and • ENA Engineering Committee, with any recommendations to update ETR 130. • Generic GB distribution policy guidance on generator interface protection to secure contribution to system security, issued to: - fellow distributors and website; and - ENA Engineering Committee, with any recommendation to update ER G59.
Criteria relating to disseminating the implications of our findings		
15	Provide an understanding of, and disseminate by end December 2014 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	• Quantified, evidence-based cost/benefit analysis of novel network technologies issued to fellow distributors and website • Generic GB distribution policy guidance on the application of novel network technologies, issued to: • fellow distributors; and • ENA Engineering Committee, with any recommendations to create new engineering recommendations.
16	Undertake, and disseminate by end December 2014 to other distributors, a critical review of how commercial models and arrangements between distributor and supplier may evolve to facilitate customer-side response	• Recommendations for changes to industry codes (for example, this could include DCUSA, CDCM and related industry codes) as relevant to industry bodies such as DCUSA Ltd, BSC Review Panel, Ofgem, ENA.
3	Project close down report produced – December 2014	• Project closedown report[1] issued to Ofgem, our fellow distributors and posted on the CLNR website.

Appendix C: Detailed evidence of timeliness and quality

The following table sets out some of the key evidence to support the reports of timely delivery and high-quality learning associated with each SDRC.

SDRC ref.	Evidence of timeliness - location	Evidence of quality – outputs delivered
Criteria related to installation and commissioning of network equipment		
SDRC 1	Progress report 2[6], appendix 4 (page 35)	• the DNO toolkit – see appendix D
SDRC 2	Progress report 5[9] (para 2.32), progress report 6[10] (para 2.26) and progress report 7[11] (para 2.32-2.35)	
Criteria related to communications and engagement		
SDRC 4	Progress report 1[5], appendix 4 (pg. 31)	• www.networkrevolution.co.uk • LinkedIn • YouTube • Twitter
SDRC 5	Progress report 1[5], appendix 3 (pg. 29) for 10th May 2011 event Progress report 3[7], appendix 2 (pg. 33) for 9th May 2012 event Progress report 6[10], appendix 3 (pg. 51) for 1st October 2013 event	• (2011) - Progress report 1[5], appendix 3 (pg. 29) and slide set • (2012) - Progress report 3[7], appendix 2 (pg. 33) and slide set • (2013) - Progress report 6[10], appendix 3 (pg. 51), slide set and video with third-party testimonials
SDRC 6	Progress report 4[8], appendix 3 (pg. 49) for 31st July 2012 event. Progress report 7[11] (pg. 29) for 2nd December 2013 event	• (2012) - Progress report 4[8], appendix 3 (pg. 49) and slide set • (2013) - Slide set and video with third-party testimonials
SDRC 7	Progress report 1 [5], appendix 2 (pg. 27) for 24th March 2011 event Progress report 3[7], appendix 1 (pg. 31) for 6th March 2012 event Progress report 5[9], appendix 5 (pg. 50) for 21st May 2013 event	• (2011) Progress report 1[5], appendix 2 (pg. 27) and slide set • (2012) Progress report 3[7], appendix 1 (pg. 31) and slide set • (2013) Progress report 5[9], appendix 5 (pg. 50), slide set and video with third-party testimonials
Criteria relating to customer trials datasets		

SDRC ref.	Evidence of timeliness - location	Evidence of quality – outputs delivered
SDRC 8	See appendix G for full details	• Dataset (TC1a[55]): Basic profiling of domestic and smart meter customers • Dataset (TC1b[56]): Basic profiling of small and medium sized enterprise (SME) customers • Dataset (TC2aHW[99]): Enhanced profiling of domestic customers with electric hot water immersion heating • Dataset (TC2aHW+SH[100]): Enhanced profiling of domestic customers electric hot water immersion heating & storage heating • Dataset (TC2b[101]): Enhanced profiling of small and medium sized enterprise (SME) customers • Dataset (TC7[20]): Business (I&C) Impact of the 2010 Tariff Reform North East & Yorkshire
SDRC 9	See appendix G for full details	• Dataset (TC3[24]): Enhanced profiling of domestic customers with air source heat pumps • Dataset (TC4[25]): Enhanced profiling of domestic customers with micro-CHP • Dataset (TC5[26]): Enhanced profiling of domestic customers with solar photovoltaics • Dataset (TC6[27]): Enhanced profiling of domestic customers with electric vehicles (EVs)
SDRC 10	See appendix G for full details	• Dataset (TC8[102]): Establishing a new set of generation profiles to better recognise the contribution of generation to system security

SDRC ref.	Evidence of timeliness - location	Evidence of quality – outputs delivered
SDRC 11	See appendix G for full details	• Dataset (TC9a[57]): Domestic smart meter customers on time of use tariffs • Dataset (TC10a[58]): Domestic customers on the smart washing machine restricted hours trial • Dataset (TC11a[59]): Domestic customers on the smart washing machine direct control trial • Dataset (TC12[60]): Domestic customers with air source heat pump (ASHP) customers on time of use tariffs • Dataset (TC14[61]): Domestic customers with air source heat pumps on direct control trials • Dataset (TC20 Auto[62]): Domestic solar PV customers with automatic in-premises balancing for hot water charging • Dataset (TC20 IHD[63]): Domestic solar PV customers using in-home displays for manual in-premises balancing • Dataset (TC9b[103]): SME smart meter customers on time of use tariffs • Dataset (TC10b): SME customers with restricted hours tariff and customer override **In-depth insight reports:** • CLNR-L093[64]: Insight report: Domestic time of use tariffs • CLNR-L090[30]: Insight report: Domestic solar PV customers • CLNR-L096[65]: Insight report: Domestic direct control trials **Customers' energy use insight reports:** • CLNR-L242[97]: High level summary of learning: Domestic smart meter customers • CLNR-L243[66]: High level summary of learning: Domestic smart meter customers on time of use tariffs • CLNR-L244[67]: High level summary of learning: Solar PV customers • CLNR-L245[51]: High level summary of learning: Heat pump customers • CLNR-L254[68] : High level summary of learning: Electric vehicle users

SDRC ref.	Evidence of timeliness - location	Evidence of quality – outputs delivered
Criterion relating to network trials datasets		
SDRC 12	Progress report 8[12], appendix 3 (pg. 23)	See academic papers in appendix A • CLNR-L200[98] CLNR network trials: A guide to the datasets • CLNR-L186[83]: Distribution substation, electrical energy storage (100kVA / 200kWh) autonomous power flow Management Trial Dataset • CLNR-L187[84]: Primary Substation, electrical energy Storage 2.5MVA 5MWha power flow management trial dataset • CLNR-L188[85]: PV test cell, distribution substation, electrical energy storage (50kVA / 100kWh) autonomous voltage trial dataset • CLNR-L189[86]: Rural distribution transformer, thermal dataset • CLNR-L190[87]: Urban distribution substation transformer, thermal dataset • CLNR-L191[88]: Primary substation transformer, thermal dataset • CLNR-L192[89]: Real time thermal rating for extra high voltage overhead tower lines • CLNR-L193[90]: Real time thermal rating for high voltage overhead lines • CLNR-L194[91]: Enhanced automatic voltage control for low voltage network regulators • CLNR-L195[92]: Distribution substation tap changing transformer • CLNR-L196[93]: GUS voltage control of tap changers and energy storage • CLNR-L197[94]: Real time thermal rating for low voltage underground cables • CLNR-L198[95]: Real time thermal rating for high Voltage Underground Cables • CLNR-L199[96]: Real-Time Thermal Rating for Extra High Voltage Underground Cables
Criteria relating to impact of new load and generation profiles		
SDRC 13 SDRC 14	Progress report 8[12], appendix 4 (pg. 24)	• CLNR-L185[34]: Review of the Distribution Network Planning and Design Standards for the Future Low Carbon Electricity System

SDRC ref.	Evidence of timeliness - location	Evidence of quality – outputs delivered
Criteria relating to disseminating the implications of our findings		
SDRC 15	-	• CLNR-L249[37]: Cost analysis report: Electrical energy storage • CLNR-L250[44]: Cost analysis report: Enhanced automatic voltage control • CLNR-L252[69]: Costs analysis report: Real time thermal rating • CLNR-L257[70]: Voltage control policy, proposals for a voltage control policy from CLNR learning • CLNR-L263[71]: A review of engineering recommendations P15, P17 and P27 (transformers, cables and overhead lines)
SDRC 16	-	• CLNR-L032[72]: Commercial arrangements, phase 1 • CLNR-L145[81]: Commercial arrangements, phase 2 • CLNR-L160 [73]: Application guide CLNR demand side response trials • CLNR-L014[75] and CLNR-L098[76]: Reports on CLNR industrial & commercial demand side response trials (2012 & 2014) • CLNR-L258[76]: Ceiling price calculator
SDRC 3	-	• Project closedown report[1]

Appendix D: DNO toolkit

From our experience of procuring, installing and operating network equipment, we have developed a toolkit for other DNOs comprising the following materials:

	Operational guidance
CLNR-L161	Operational guidance and training requirements: Electrical energy storage systems
CLNR-L157	OHL Real time thermal rating installation guide
CLNR-L158	Operational guidance and training requirements: Trials of secondary transformers with integral OLTC
CLNR-L156	Operational guidance and training requirements: Grand Unified Scheme (GUS)
	Lessons learned
CLNR-L163	Lessons learned report: Electrical energy storage
CLNR-L164	Lessons learned report: Real time thermal rating
CLNR-L165	Lessons learned report: Enhanced automatic voltage control
CLNR-L167	Lessons learned report: Grand Unified Scheme
	Network monitoring
CLNR-L232	Enhanced network monitoring report
	Technical recommendations for purchase
CLNR-L147	Technical recommendation for the purchase of EES systems
CLNR-L149	Technical recommendation for the purchase of overhead line RTTR systems
CLNR-L150	Technical recommendation for the purchase of RTTR for transformers
CLNR-L151	Technical recommendation for the purchase of underground cable RTTR systems
CLNR-L209	Technical recommendation for the purchase of EAVC for HV systems
CLNR-L210	Technical recommendation for the purchase of EAVC for HV-LV systems
CLNR-L154	Technical recommendation for the purchase of Active Network Management
	Training materials
CLNR-L233	A guide to the CLNR training packages
CLNR-L168	Training Package: Electrical energy storage
CLNR-L204	Training Package: Real time thermal rating for overhead lines
CLNR-L205	Training Package: Real time thermal rating underground cables
CLNR-L206	Training Package: Real time thermal rating for transformers
CLNR-L170	Training Package: Enhanced automatic voltage control
CLNR-L172	Training Package: Active network management
CLNR-L173	Training Package: Demand side response

Appendix E: Network equipment installed and commissioned

The following table sets out the network equipment installed and commissioned. Also see our suite of network technology videos on our CLNR YouTube channel.

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) (see picture below)	Rise Carr			
	100kVA battery at distribution substation (EES2)	High Northgate	Wooler Ramsey		
	50kVA battery at distribution substation (EES3)	Harrowgate Hill	Wooler St. Mary		Mortimer Road
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 AND High Northgate	Wooler Bridge AND Wooler Ramsey	Sidgate Lane	
	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			
Monitoring		87 instances of monitoring equipment (of 3 different types) at a range of network locations			

Enhanced Automatic Voltage Control (EAVC)

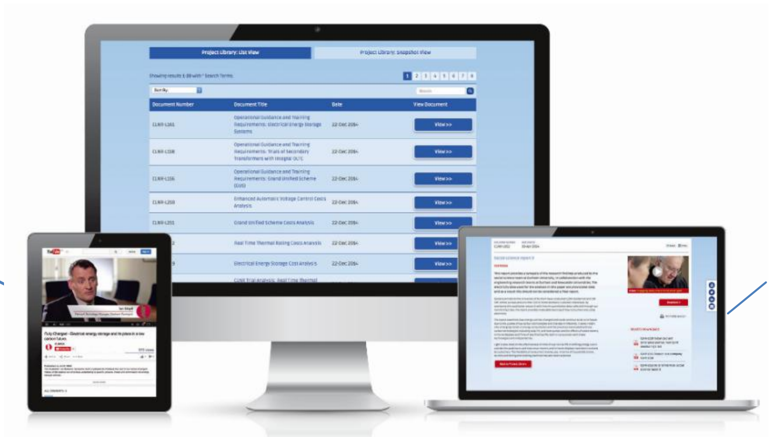
Electrical Energy Storage (EES)

Real Time Thermal Rating (RTTR)

Appendix F: Updating of the project website

The original website featured a simple navigation structure which clearly signposted the important project library resource and clearly communicated the projects drivers, aims and outcomes. In 2012 we launched the CLNR social media channels (Twitter, LinkedIn and YouTube) which we used to increase the reach of the project and drive more traffic to the website.

We recognised however, that as a key part of the enduring legacy of the project and most people's first port of call for information, the website would require regular updates and improvements to its functionality.



Summary pages for every report or output uploaded to the project library provide a brief synopsis of content, help with SEO and provide links to related learning

In July 2014, we completed a major refresh and re-launch of the website to improve the visitor experience and to support the sharing of knowledge with our stakeholders. This was documented in progress report 8[12].

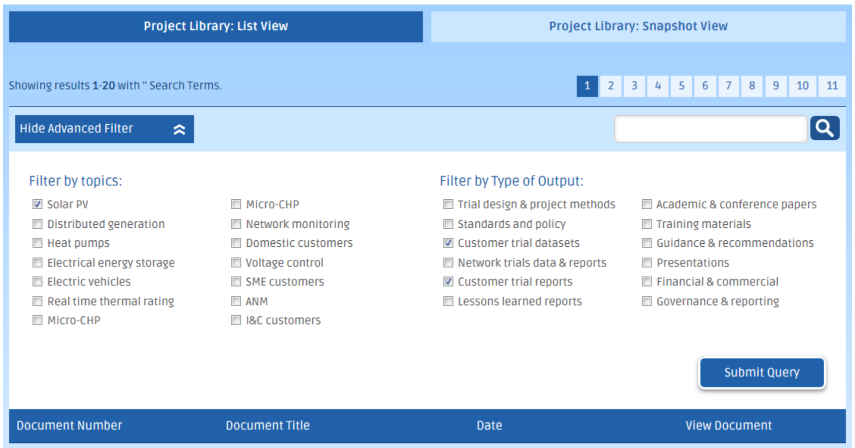
The major upgrades we made were as follows;

- A new content management system allowed us to perform document uploads and content updates in-house, instead of relying on external suppliers. This proved particularly important in the latter stages of the project when it became necessary to upload multiple project outputs.
- A new and improved project library allowed users to search and filter documents, share them via email and social media channels and access any related reports or video content.
- The website was made responsive across all platforms meaning it could be accessed from laptops, tablets and mobile phones.

The website content was written in such a way as to be search engine optimised. Links to the CLNR social media sites and content were displayed and users were given clear signposts of how to 'contact us' with any questions about the project. New pages were added which gave an overview of each of the CLNR trials, its purpose, its progress and links to relevant learning and videos (see solar PV trials example). The usability of the project library was also significantly improved with the addition of a snapshot view and summary pages for every project output uploaded. The summary pages give a concise synopsis of the report or datasets content, helping the user locate the information they are interested in and help with search engine optimisation.

Following feedback from our industry consultation process, we further improved the usability of the project library by implementing an advanced search function which enables users to drill down and locate the specific document or range of documents they were interested in.

We updated the website content to reflect the project's completion and added new pages to clearly signpost the project's findings and conclusions. This final update to the CLNR website was rolled out in April 2015.



Appendix G: Evidence of timely delivery of customer trials datasets

The table below sets out the timing of the publication of each individual dataset within each of the four criteria relating to customer trials datasets 3.

SDRC	test cell	customer type	load, intervention	interim publication				final publication			
				dataset ref	published	timeliness		dataset ref	published	timeliness	
8. demand profiles by customer type, interim Dec 2012, final Aug 2014	**1a**	domestic	general	CLNR-L011	21-Dec-12	**on time**	1	CLNR-L072	28-Aug-14	**on time**	3
	1b	SME	general	CLNR-L011	21-Dec-12	**on time**	1	CLNR-L073	29-Aug-14	**on time**	3
	2a	domestic	general					CLNR-L074	29-Aug-14	**on time**	3
	2aH W	domestic	general					CLNR-L211	29-Dec-14	**late**	
	2aH W+S H	domestic	general					CLNR-L212	29-Dec-14	**late**	
	2b	SME	general					CLNR-L213	28-Dec-14	**late**	
	7	I&C	April 2010 tariff reform	CLNR-L088	21-Dec-12	**on time**		CLNR-L088	21-Dec-2012	**on time**	
9. demand profile by LCT type, interim Dec 2012, final Aug 2014	**3**	domestic	HP	CLNR-L011	21-Dec-12	**on time**	1	CLNR-L075	29-Aug-14	**on time**	3
	4	domestic	CHP					CLNR-L076	29-Aug-14	**on time**	3
	5	domestic	PV	CLNR-L011	21-Dec-12	**on time**	1	CLNR-L077	29-Aug-14	**on time**	3
	6	domestic	EV	CLNR-L011	21-Dec-12	**on time**	1	CLNR-L078	29-Aug-14	**on time**	3
10. outputs profiles of existing generation types, interim Dec 2012, final Aug 2014	**8**	DG	DG					CLNR-L011	21-Dec-12	**on time**	1
11. output / demand profiles before & after interventions, interim Apr 2013, final Aug 2014	**9a**	domestic	general, ToU	CLNR-L013	30-Apr-13	**on time**	2	CLNR-L079	29-Aug-14	**on time**	3
	10a	domestic	general, RH					CLNR-L080	29-Aug-14	**on time**	3
	11a	domestic	general, DC					CLNR-L081	29-Aug-14	**on time**	3
	12	domestic	HP, ToU					CLNR-L082	29-Aug-14	**on time**	3
	14	domestic	HP,DC					CLNR-L083	29-Aug-14	**on time**	3
	20 auto	domestic	PV, auto balancing	CLNR-L013	30-Apr-13	**on time**	2	CLNR-L084	29-Aug-14	**on time**	3
	20 IHD	domestic	PV, IHD balancing	CLNR-L013	30-Apr-13	**on time**	2	CLNR-L085	29-Aug-14	**on time**	3
	9b	SME	general, ToU					CLNR-L214	28-Dec-14	**late**	
	10b	SME	general, RH					CLNR-L215	28-Dec-14	**late**	

Notes: For supporting evidence of timeliness, see **1.** Progress report 5[9], appendix 3 (p. 48) **2.** Progress report 5[9], appendix 4 (p. 49) **3.** Progress report 8[12], appendix 2 (p. 22)

Appendix H: Costs

The following table sets out costs compared to the budget in the Project Direction of 4 September 2014. Figures highlighted are discussed in sections 3.2 and 3.3.

	Budget	Actual Expenditure	Variance compared to budget		% of budget (if >5%)
	£m	£m	£m	%	
Box 6 (Employment costs)					
Project Manager	2.537	2.470	-0.067	-2.7%	8.2%
Technical Engineer	1.231	1.394	0.163	13.2%	
Accountant / Procurement	0.088	0.073	-0.015	-17.0%	
Administrator	0.110	0.121	0.011	10.2%	
Commercial analyst/manager	0.409	0.243	-0.166	-40.7%	
Box 6 total	**4.375**	**4.300**	**-0.075**	**-1.7%**	
Box 7 (Equipment costs)					
600 systems direct management of PV export	0.281	0.290	0.009	3.0%	
450 ‘smart energy’ systems	0.074	0.073	-0.001	-0.7%	
1,670 detailed energy profiling systems	1.378	1.365	-0.013	-0.9%	
600 Load controllable white goods	0.165	0.164	-0.001	-0.4%	
Domestic CHP	0.080	0.080	-0.000	0.0%	
Customer trials equip. subtotal	**1.978**	**1.973**	**-0.005**	**-0.3%**	
2.5MW/5MWh storage	4.024	4.408	0.384	9.5%	13.0%
100kW/200kWh storage	0.809	0.886	0.077	9.5%	
50kW/100kWh storage	0.996	1.126	0.130	13.1%	
Network Monitoring	0.511	0.509	-0.002	-0.5%	
Voltage control	0.484	0.775	0.291	60.0%	
Real time thermal rating	0.493	0.460	-0.033	-6.7%	
Control interfaces	3.370	3.189	-0.181	-5.4%	10.9%
Network trials equip. subtotal	**10.687**	**11.352**	**0.665**	**6.2%**	
Box 7 total	**12.665**	**13.325**	**0.660**	**5.2%**	
Box 8 (Contractor costs)					
British Gas	3.867	3.925	0.058	1.5%	12.5%
EA Technology Limited	4.086	4.047	-0.039	-1.0%	13.2%
Durham Energy Institute (Durham University)	3.640	3.892	0.252	6.9%	11.7%
Expert challenge function	0.050	0.030	-0.020	-40.5%	
DUoS tariff design	0.233	0.184	-0.049	-21.2%	
Dissemination	0.317	0.252	-0.065	-20.6%	
Box 8 total	**12.193**	**12.329**	**0.136**	**1.1%**	
Box 9 (Customer & user payments)					
Domestic customers	0.281	0.235	-0.046	-16.5%	
Small commercial customers	0.218	0.125	-0.093	-42.8%	
Box 9 total	**0.499**	**0.359**	**-0.140**	**-28.0%**	
Box 10 (Other costs)					
IT costs	0.110	0.151	0.041	36.8%	
Contingency	0.600	0.017	-0.583	-97.1%	
Decommissioning	0.507	0.483	-0.024	-4.7%	
Other	0.084	0.099	0.015	18.4%	
Box 10 total	**1.301**	**0.732**	**-0.569**	**-43.7%**	
Total budget	**31.033**				
Total costs, incl. contingency		**31.045**			

Appendix I: Chronology of the Ofgem change request

The table below summarises the interactions with Ofgem in the run up to and during the change request process.

Date	Interaction
17 June 2011	Progress report 1
12 October 2011	Meeting with Ofgem Slideset - slide 7 sets out the options we were exploring to solve scarcity
16 December 2011	Progress report 2[6]
30 January 2012	Meeting with Ofgem Slideset sets out detailed design issues and approaches to solving scarcity
Late May/early June 2012	Ofgem approved changes to CEP and DPS required to enact new recruitment routes to mitigate customer scarcity (recruitment of non-BG customers)
20 June 2012	Progress report 3[7]
12 October 2012	Ofgem approved changes to CEP and DPS required to enact new recruitment routes to mitigate customer scarcity (recruitment of EV customers via Charge Your Car)
20 December 2012	Progress report 4[8]
13 February 2013	Meeting with Ofgem Slideset slides 50 onwards sets out changes to delivery plan and budget, and a summary of the detailed design changes
20 June 2013	Progress report 5[9]
17 September 2013	Draft change request for consultation issued to other DNOs and to Ofgem with an invitation to a conference call
30 September 2013	Conference call to discuss change request
13 November 2013	Formal change request submitted to Ofgem
December 2013 to May 2014	Additional information provided as requested by Ofgem
3 September 2014	Ofgem approve change request

Appendix J: Supporting documents

CLNR-G026	1.	Closedown report
CLNR-L246	2.	Developing the smarter grid: the role of domestic and small and medium enterprise customers
CLNR-L247	3.	Developing the smarter grid: the role of industrial & commercial and distributed generation customers
CLNR-L248	4.	Developing the smarter grid: optimal solutions for smarter network businesses
	5.	Progress report 1
	6.	Progress report 2
CLNR-G013	7.	Progress report 3
CLNR-G014	8.	Progress report 4
CLNR-G016	9.	Progress report 5
CLNR-G018	10.	Progress report 6
CLNR-G020	11.	Progress report 7
CLNR-G024	12.	Progress report 8
CLNR-L253	13.	ESOF Good Practice Guide
CLNR-L010	14.	Initial load and generation profiles from CLNR monitoring trials
CLNR-L071	15.	CLNR customer trials: A guide to the load and generation profiles
CLNR-L216	16.	Insight report: Domestic baseline profile
CLNR-L217	17.	After Diversity Maximum Demand (ADMD) report
CLNR-L261	18.	Test cell report: Baseline SME profiles & SME subgroup analysis
CLNR-L094	19.	Insight report: Enhanced domestic monitoring
CLNR-L088	20.	Datasets: Business (I&C) impact of the 2010 tariff reform North East & Yorkshire
CLNR-L087	21.	April 2010 tariff reform analysis: An introduction to the Common Distribution Charging Methodology (CDCM)
CLNR-L011	22.	Dataset to accompany CLNR-L010
CLNR-L036	23.	Lessons learned from trial recruitment: Customer-Led Network Revolution customer trials
CLNR-L075	24.	Dataset (TC3): Enhanced profiling of domestic customers with air source heat pumps
CLNR-L076	25.	Dataset (TC4): Enhanced profiling of domestic customers with micro-CHP
CLNR-L077	26.	Dataset (TC5): Enhanced profiling of domestic customers with solar photovoltaics
CLNR-L078	27.	Dataset (TC6): Enhanced profiling of domestic customers with electric vehicles (EVs)
CLNR-L086	28.	Report on enhanced profiling of domestic customers with micro-CHP
CLNR-L091	29.	Insight report: Domestic heat pumps
CLNR-L090	30.	Insight report: Domestic solar PV customers
CLNR-L095	31.	Technical note: Solar PV
CLNR-L092	32.	Insight report: Electric vehicles
CLNR-L012	33.	Initial load and generation profiles from CLNR intervention trials
CLNR-L185	34.	Review of distribution network planning and design standards for the future low carbon electricity system
CLNR-L103	35.	SME customers: Energy practices and flexibility
CLNR-L161	36.	Northern Powergrid operational guidance and training requirements: Electrical energy storage
CLNR-L249	37.	Cost analysis report: Electrical energy storage
CLNR-L147	38.	Technical recommendation for the purchase of electrical energy storage systems
CLNR-L163	39.	Lessons learned report: Electrical energy storage
CLNR-L168	40.	Training package: Electrical energy storage
CLNR-L118	41.	CLNR trial analysis: Electrical energy storage (100kVA/200kWh) power flow management
CLNR-L121	42.	CLNR trial analysis: Electrical energy storage (2.5MVA/5MWh) power flow management
CLNR-L158	43.	Northern Powergrid operational guidance and training requirements: Trials of secondary transformers with integral OLTC
CLNR-L250	44.	Cost analysis report: Enhanced automatic voltage control
CLNR-L209	45.	Technical recommendation for the purchase of EAVC for HV systems
CLNR-L165	46.	Lessons learned report: Enhanced automatic voltage control
CLNR-L170	47.	Training package: Enhanced automatic voltage control

CLNR-L119	48. CLNR trial analysis: EES1 andEAVC1 with GUS voltage control
CLNR-L135	49. CLNR trial analysis: Collaborative voltage control on HV and LV networks
CLNR-L104	50. Heat pump survey results
CLNR-L245	51. Report on interviews with domestic customers with air source heat pumps
CLNR-L146	52. Assessment of power quality impacts from disruptive technologies
CLNR-L038	53. IEEE ISGT 2013: Integrating smart meter and electric vehicle charging data to predict network impacts
CLNR-L070	54. Applied Energy Journal: A probabilistic approach to combining smart meter and electric vehicle charging data to investigate distribution network impacts
CLNR-L072	55. Dataset (TC1a): Basic profiling of domestic smart meter customers
CLNR-L073	56. Dataset (TC1b): Basic profiling of small and medium sized enterprise (SME) customers
CLNR-L079	57. Dataset (TC9a): Domestic smart meter customers on time of use tariffs
CLNR-L089	58. Dataset (TC10): Domestic customers on the smart washing machine restricted hours trial
CLNR-L080	59. Dataset (TC11a): Domestic customers on the smart washing machine direct control trial
CLNR-L082	60. Dataset (TC12): Domestic customers with air source heat pump (ASHP) customers on time of use tariffs
CLNR-L083	61. Dataset (TC14): Domestic customers with air source heat pumps on direct control trials
CLNR-L084	62. Dataset (TC20 Auto): Domestic solar PV customers with automatic in-premises balancing for hot water charging
CLNR-L085	63. Dataset (TC20 IHD): Domestic solar PV customers using in-home displays for manual in-premises balancing
CLNR-L093	64. Insight report: Domestic time of use tariffs
CLNR-L096	65. Insight report: Domestic direct control trials
CLNR-L243	66. High level summary of learning: Domestic smart meter customers
CLNR-L244	67. High level summary of learning: Solar PV customers
CLNR-L254	68. High level summary of learning: Electric vehicle users
CLNR-L252	69. Cost analysis report: Real time thermal rating
CLNR-L257	70. Voltage control policy: Proposals for a voltage control policy from CLNR learning
CLNR-L263	71. A review of engineering recommendations P15, P17 and P27 (transformers, cables and overhead lines)
CLNR-L032	72. Commercial arrangements study, phase 1
CLNR-L160	73. Application guide CLNR demand side response trials
CLNR-L014	74. Initial report on CLNR industrial & commercial demand side response trials (2012)
CLNR-L098	75. Report on CLNR industrial & commercial demand side response trials (2014)
CLNR-L258	76. Ceiling price calculator
CLNR-L262	77. Lessons learned report: Customer trials equipment installations
CLNR-L228	78. Reconstruction of the ACE 49 methodology
CLNR-L251	79. Cost analysis report: Grand Unified Scheme (GUS)
CLNR-L256	80. CLNR solutions template
CLNR-L145	81. Commercial arrangements study, phase 2
CLNR-L232	82. Enhanced Network Monitoring Report
CLNR-L186	83. Dataset: Distribution Substation, Electrical Energy Storage 100kVA 200kWh Autonomous Powerflow Management Trial
CLNR-L187	84. Dataset: Primary substation, Electrical Energy Storage (2.5MVA / 5MWh) autonomous power flow management trial
CLNR-L188	85. Dataset: PV test cell, distribution substation, Electrical Energy Storage (50kVA / 100kWh) autonomous voltage trial
CLNR-L189	86. Dataset: Rural distribution transformer, thermal dataset
CLNR-L190	87. Dataset: Urban distribution substation transformer thermal dataset
CLNR-L191	88. Dataset: Primary substation transformer, thermal dataset
CLNR-L192	89. Dataset: Real time thermal rating for extra high voltage overhead tower lines

CLNR-L193	90. Dataset: Real time thermal rating for high voltage overhead lines
CLNR-L194	91. Dataset: Enhanced automatic voltage control for low voltage network regulator
CLNR-L195	92. Dataset: Distribution substation tap changing transformer
CLNR-L196	93. Dataset: GUS voltage control of tap changers and energy storage
CLNR-L197	94. Dataset: Real time thermal rating for low voltage underground cables
CLNR-L198	95. Dataset: Real time thermal rating for high voltage underground cables
CLNR-L199	96. Dataset: Real time thermal rating for extra high voltage underground cables
CLNR-L242	97. High level summary of learning: Domestic smart meter customers
CLNR-L200	98. CLNR network trials: A guide to the datasets
CLNR-L211	99. Dataset (TC2aHW): Enhanced profiling of domestic customers with electric hot water immersion heating
CLNR-L212	100. Dataset (TC2aHW+SH): Enhanced profiling of domestic customers electric hot water immersion heating & storage heating
CLNR-L213	101. Dataset (TC2b): Enhanced profiling of small and medium sized enterprise (SME) customers
CLNR-L011	102. Dataset (TC8): Establishing a new set of generation profiles to better recognise the contribution of generation to system security
CLNR-L214	103. Dataset (TC9b): SME smart meter customers on time of use tariffs
CLNR-L215	**104.** Dataset (TC10b): SME customers with restricted hours tariff and customer override