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SMART STREET

Project Closedown Report

30 April 2018

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CONTENTS

GLOSSARY

Term	Description
BAU	Business as usual
BEIS	Department for Business, Energy & Industrial Strategy
CEP	Customer engagement plan
CHP	Combined heat and power
CRMS	Control room management system
CVR	Conservation voltage reduction
DNO	Distribution network operator
DNP3	Distributed Network Protocol 3
ECP	Engaged customer panel
EV	Electric vehicle
HP	Electric heat pump
I&C	Industrial and commercial
HV	High voltage
ICCP	Inter-control centre communications protocol
IPSA	Software tool developed specifically for power system design and operation applications
LCN Fund	Low Carbon Networks Fund
LCT	Low carbon technology
LV	Low voltage
MATLAB	Multi-paradigm numerical computing environment
NB-IoT	NarrowBand-Internet of Things – low power wide area network radio technology standard developed to enable a wide range of devices and services to be connected using cellular telecommunications bands
NMS	Network management system
OLTC	On-load tap changer
OpenDSS	Electric power distribution system simulator for supporting distributed resource integration and grid modernisation
PSI	Planned supply interruption
PSR	Priority service register
PV	Photovoltaic (solar panel)

Term	Description
RTU	Remote terminal unit
SDI	Short duration interruption
SP5	Siemens Spectrum Power 5
VCB	Vacuum circuit breaker
VVC	Volt/VAr control
XML	Extensible markup language, a markup language that defines a set of rules for encoding documents in a format that is human-readable and machine-readable
Zigbee	IEEE 802.15.4-based specification for a suite of high-level communication protocols

1. PROJECT BACKGROUND

1.1 Introduction

By combining innovative technology with existing assets, Smart Street makes networks and customers' appliances perform more efficiently, and makes it easier to adopt low carbon technologies onto the electricity network.

As Great Britain becomes more reliant on electricity as its main source of power, customers will use more new low carbon technologies such as electric vehicles, heat pumps and photovoltaics/solar panels.

These technologies tend to occur in clusters which has a dramatic effect on the electricity network. While electric vehicles and heat pumps could cause voltage to fall below statutory limits, new generation from photovoltaics exporting electricity to the network will have the opposite effect. If voltage levels fall outside statutory limits, the way customers' appliances perform will be affected.

Using new controllable switching devices, called the Weezap and Lynx, integrated into the Electricity North West network management system, and controlled by Siemens Spectrum Power 5 (SP5), Smart Street stabilises voltage and avoids it falling above or below statutory limits.

Supply voltage to customers can then be reduced to an optimum level so that networks and customers' appliances work more efficiently, a technique known as conservation voltage reduction.

Smart Street was trialled at six primary substations, and 38 associated distribution substations, serving 67,000 customers in Manchester, Wigan, Wigton and Egremont. A series of customer focus groups were organised to help understand if the new project impacted the electricity supply in homes. All the customers confirmed that they had not noticed any changes when using their everyday appliances.

Smart Street demonstrates a step change in the co-ordination and operation of electricity networks in Great Britain and is the first demonstration of a fully centralised low voltage network management and automation system.

This innovative approach will enable low carbon technologies to be connected to the network more quickly, keep costs down for customers, reduce carbon emissions and help get the most from the existing network.

The results from the trials have shown that Smart Street will deliver energy savings for customers by stabilising voltage without impacting on reliability and the quality of the power network.

This closedown report is accompanied by a series of more detailed reports which are available on the project website.

1.2 Background

The UK's decarbonisation journey through to 2050 will see a reduction in the carbon footprint of heat, transport and electricity generation. Current forecasts from the Department for Business, Energy and Industrial Strategy (BEIS) suggest that there may be up to a 60% increase in total electricity demand, mostly between 2030 and 2050. The amount of small scale embedded generation such as photovoltaic (PV) panels on domestic premises is set to increase from 26.5MW in 2015 to 18,700MW by 2040. The substantial increase in new electricity loads from low carbon technologies (LCTs) such as heat pumps (HPs) for heating and electric vehicles (EVs) for transport, coupled with the new generation, will create thermal and voltage challenges for the management of high voltage (HV) and low voltage (LV) networks. Distribution network operators (DNOs) must connect the new LCTs to facilitate customers' transition to a low carbon future, while maintaining statutory voltages, reducing network losses, managing power quality and, against a backdrop of increasing energy bills, help reduce costs to customers. DNOs have historically employed traditional reinforcement to address the problems created by new LCTs; this option is no longer appropriate due to the high cost and associated disruption.

The scale of the challenge is substantial; for an estate of domestic premises with gas central heating, the LV service cables, LV mains cables and transformer are scaled to supply a peak demand after diversity of less than 2kW per property. Changing the gas heating system to an electric alternative could add 6kW per property; and when a household replaces a family car for an electric alternative, a further 3.5 or 7kW could be added. In isolation these new LCT loads may not cause an issue, but LCT clusters will create thermal, harmonic and voltage issues, with the latter being voltages below the statutory threshold due to the effect of the increased loads. Where a household installs distributed generation, often in the form of PV panels on its roof, typically 3.6 kW of generation would be added to the property. When the new PV exports onto the distribution network there will be a voltage rise at the point of connection. Again, in isolation, PV will not cause an issue but clusters will reverse the power flow causing thermal, harmonic and voltage rise issues.

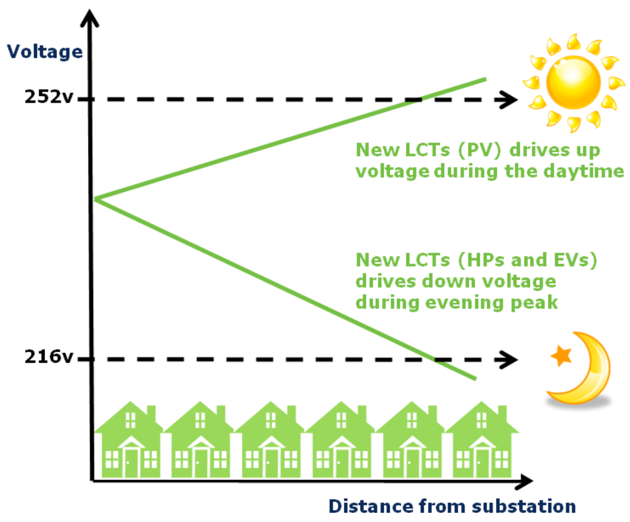
1.3 Voltage management in a low carbon future

Traditionally there has been limited voltage regulation on distribution networks with none on the LV network. Figure 1.1 below shows the steady state effect on the voltage profile from the addition of a new heat pump and PV panels in isolation. The introduction of multiple LCTs with their differing operating regimes will result in complex network flow patterns making managing the real time network voltage within statutory limits a considerable challenge. DNOs must therefore adapt the design and operation of their networks to facilitate efficient connection of the new LCTs, while maintaining power quality and network voltage within mandated limits.

1.4 Efficient distribution networks

As LCT volumes increase, HV and LV networks will require effective and efficient intervention techniques that are a viable alternative to traditional reinforcement. This will enable the networks to manage the thermal, harmonic and voltage challenges created by LCTs. Smart Street is a first intervention technique which is fast, releases significant network capacity and controls network voltages and harmonics within designated limits.

Figure 1.1: Stylised LV network voltage profiles



In addition the innovative voltage management technologies used by Smart Street can deliver true cost savings to customers, beyond network costs, namely reducing losses and reducing energy consumption.

Rather than relying on traditional reinforcement approaches, implementing innovative voltage management techniques will minimise the network costs paid by all customers.

The losses associated with transporting energy across distribution networks typically represent between 5 – 8% of energy distributed to end customers. Electricity North West reported in its Carbon Footprint Report 2011-12 that network losses equalled 1,230 GWh, approximately 5.3% of the energy distributed. These losses equated to 670,540 tCO2e. As approximately 70% of these network losses occur on the HV and LV networks, 23% and 46% respectively, Smart Street looks to demonstrate that actively optimising the network running can noticeably reduce these and provide a financial benefit.

2. EXECUTIVE SUMMARY

The Smart Street project has successfully delivered an ambitious programme of work over its four-year period and has generated significant learning for DNOs and interested stakeholders on the benefits of optimising the running of low voltage networks to minimise energy consumption and losses. The project has also demonstrated how optimising the configuration and controlling voltage can benefit the GB electricity distribution industry.

The project trialled an integrated system of voltage control and switching devices to actively reconfigure the LV networks to respond to changing conditions and maintain the optimum running arrangement. The results from the project have provided new learning regarding the behaviour of LV networks and the impact of clusters of LCT installations.

Smart Street has demonstrated that the application of these techniques can be an effective way of responding to the appearance of LCT clusters, either by resolving the issues or allowing traditional reinforcement to be deferred. In addition the Smart Street system allows for savings of up to 10% of the energy consumed on the LV network, leading to potential customer savings of up to £70 per annum.

2.1 Project scope and objectives

The objectives of the Smart Street project were to test the following hypotheses:

- The Smart Street method will deliver a reduction in customers' energy consumption *(research workstream)*
- Customers within the Smart Street trial area will not perceive any changes in their electricity supply *(customer workstream)*
- The Smart Street method will have no adverse effects on customers' internal installations or appliances *(research workstream)*
- The Smart Street method is faster to apply than traditional reinforcement, supports accelerated LCT connection and reduces network reinforcement costs *(research workstream)*
- The Smart Street method facilitates the prioritisation of the range of solutions across differing LCT adoption scenarios based on a cost benefit analysis to accommodate customers' uptake of LCTs *(research workstream)*
- The Smart Street method will deliver a reduction in overall losses through network configuration and voltage optimisation *(research workstream)*
- The Smart Street method facilitates real time control of a portfolio of LV network solutions, using retrofit technologies with application combined or in isolation *(technology workstream)*.

2.2 Project outcomes

During the project a number of outcomes have been generated:

- 24 months of monitored data from the trial equipment increasing understanding of the behaviour of LV networks
- Creation of a telemetered and actively operated LV network controlled by an autonomous centralised system
- Demonstrated the benefits of actively optimising the network over a more passive system
- Quantified the benefits of minimising LV energy consumption and HV loss reduction by applying Smart Street techniques
- Evaluation of the reduction in carbon impact through the deferment or avoidance of traditional reinforcement
- Proposed modification to ENA specifications have been drawn up and Electricity North West specifications have been modified
- Robust customer research has demonstrated that the use of Smart Street voltage optimisation reduction techniques does not cause any detriment to customers' perception of quality of supply.

2.3 Objectives met

All project successful delivery reward criteria (SDRC) have been met even though this has been an ambitious and challenging project, the following objectives have also been delivered or proven:

- Methodologies for the retrofit installation of network management and voltage regulation equipment onto LV networks
- An optimisation implementation strategy based on the outcomes of the project
- A methodology for interconnecting LV networks, selecting and deploying voltage regulation equipment, and the protection arrangements required for safe interconnected operation including during faults and for cold load pick up
- Changes to industry standards, such as ENA ER P5-5, Ace reports Nos 3, 49 and 105
- Changes required to Electricity North West's engineering policy, codes of practice and authorisation procedures have been noted
- A study into the results of a coordinated optimisation across the HV and LV networks
- The methodology for attracting and engaging customers during the Smart Street trials to test the hypothesis that there was no perceivable change to their quality of the supply.

2.4 Objectives not met

None.

2.5 Main learning generated by the project

The deployment of a number of different technologies and the integration into a unified system controlled by SP5 demonstrated that it is possible to safely use autonomous software to operate on the LV network to ensure optimal running throughout the day.

Analysis of the data generated by the project has shown that implementing these techniques can provide a reduction of up to 10% in energy consumption on the LV network coupled with a reduction in HV losses of up to 15%.

Optimising the LV network in this way allows the connection of LCTs without the need for traditional reinforcement.

The project has demonstrated that customers in the trial areas did not perceive any changes to their electricity supply. A series of customer focus groups were held mid- and post-trial, in each trial region, to elicit feedback about perceived effects on the electricity supply. The customers consulted as part of this investigation did not detect any degradation in the quality of their supply during the trials, demonstrating that Smart Street was indiscernible to all types of customers.

Customer enquiries, potentially associated with any aspect of Smart Street, were captured and managed. In parallel, power quality and voltage issues were recorded and actively managed throughout the trial period to ensure that if any such problem arose on a Smart Street circuit, it was quickly identified, irrespective of whether this was raised by a customer or generated from another source. There were no reported voltage or power quality problems that could be directly attributed to the Smart Street method.

Detailed analysis of the Smart Street customer focus groups, and the absence of any supply-related customer complaints during the trials, indicate that Electricity North West can be confident that the implementation of the Smart Street method across its distribution region would have no detriment to perceived power quality. These findings support the transferability of the method and suggest it can be applied across the wider GB network without customer impact.

3. DETAILS OF THE WORK CARRIED OUT

In order to fully explore the benefits and learning outcomes associated with the Smart Street solution, the trials and reporting were segmented into four key knowledge areas:

- Customer engagement and feedback
- Technology implementation and effectiveness
- Smart Street trials
- Evaluating the benefits of the Smart Street solution.

For each of these areas the method has been implemented and trialled depending on the learning objectives of that area of research.

3.1 Customer engagement and feedback

The project hypothesis related to this activity is:

Customers within the Smart Street trial areas will not perceive any changes in their electricity supply.

The hypothesis that customers would not perceive any changes in their electricity supply was demonstrated by customer acceptance of the method, derived from feedback obtained during the trials.

Communicating with customers in the trial area

While the wider community was not actively involved in Smart Street, Electricity North West launched a targeted awareness campaign to publicise Smart Street among the 67,000 customers in the trial area. This allowed as many people as possible to understand the nature of the project, its objectives, benefits and potential impacts. To investigate the impact and provide confidence that customers did not perceive any degradation in power quality while the new technologies were trialled, extensive customer engagement was essential to demonstrate acceptance of the method and took a number of forms.

Customers on trial networks that may have experienced planned interruptions associated with the installation of new equipment

It was originally anticipated that around 5% of customers on trial networks could have been affected by one or more planned supply interruptions (PSIs) associated with the installation of the enabling technology. These impacts were to be managed by standard written notification procedures, in accordance with commitments under the Quality of Service Guaranteed Standards. An enhanced commitment was made to identify all vulnerable customers affected by a PSI and provide additional proactive notification by telephone. This strategy was designed to highlight and manage the specific needs of priority service register (PSR) customers, to mitigate the impact of planned outages.

However to negate any customer impact associated with technology installation, irrespective of whether or not customers had vulnerabilities, all works were conducted utilising back-feeds, live-line techniques and generation, thereby avoiding any PSIs. Customers whose supplies were maintained by generation, would have experienced a short duration interruption of less than three minutes, while the generator was connected and subsequently disconnected on completion of the work.

Customers on the trial networks who may have experienced short duration interruptions

Due to the application of interconnected configurations to LV networks, Smart Street introduced the possibility that a normally occurring LV fault, on a meshed feeder, would lead to a greater number of customers being affected than on a radial circuit. In these instances, networks were reconfigured automatically and customers not directly affected by the fault, had supply restored within approximately three minutes. During the trials there were four genuine LV faults which were dealt with successfully. Following Weezap firmware updates, to remedy problems that occurred in the early technology installation phase, a total of 13 trip and reclose events were recorded over the remaining trial period which were associated with four LV faults.

As such, commitment was made in the customer engagement plan (CEP) to advise all customers in the trial locations about the theoretical increase in short duration interruptions (SDI) via project awareness materials. However, following customer engagement, this message was omitted from communications materials as it was deemed unnecessary and confusing. This issue is discussed further in Section 6.1 and documented fully in the first ECP interim report published on the project website in December 2014.

Customers on the trial networks who participated in the engaged customer panel

An engaged customer panel (ECP) was convened to embed on-going customer engagement. Consultation with the ECP represented the most important, proactive customer research activities in Smart Street.

The first ECPs focused on developing effective communication to inform a targeted awareness campaign about Smart Street aimed at customers, stakeholders and the wider community in the trial regions. This culminated in the distribution of a customer leaflet in October 2014, which ensured that all customers in the trial regions were informed about the project and critically, the associated trials. The leaflet provided a summary of the Smart Street project, its objectives, the potential customer benefits and explained that installation of enabling technology might, on occasion, require planned supply interruptions. The leaflet provided reassurance that customers were unlikely to notice any impact from the trials and distinguished the project from the smart meter rollout. Importantly, it also provided contact details, in case customers required any additional information or had an enquiry about the project.

This initial phase of customer research involved three 90-minute discussions with 27 customers representing key demographics across the three trial regions of Cumbria, Lancashire and Manchester.

The ECP met twice to share information regarding the trials and to test customer awareness materials. The key findings of this initial stage of research are summarised in the first ECP interim report.

Following distribution of the Smart Street leaflet to customers on trial circuits, a small-scale piece of quantitative research was undertaken to assess the effectiveness of the leafleting campaign, specifically, to ascertain customer reaction to it and gauge the return on investment.

Communicating with customers about street furniture installation

Properties in sight of proposed new street furniture in the public footpath, designed to house enabling technology, were identified and notification letters sent.

A comprehensive planning exercise, which included on-site surveys, established not only connection feasibility and compliance with Smart Street technical design criteria, but ensured each new piece of street furniture was installed in the least obtrusive position for customers.

Monitoring the effects of the Smart Street trials on customers (ECPs)

The second stage of ECP consultation was designed to elicit customer feedback about any perceived effects on the electricity supply, providing evidence to test the customer hypothesis. This involved two phases of customer research; the first was conducted mid-trial in January 2017, with the second following completion of the trials in January 2018.

The key objectives and learning outcomes agreed for these ECP meetings were:

- To understand whether customers within the Smart Street trial areas had perceived any changes in their electricity supply since the start of the trials
- To understand whether any perceived changes to customers' supply were a result of the trials or due to external factors
- To establish if customers experienced SDIs during the trials that were directly associated with Smart Street and understand the impact of these
- To assess if perceived effects had detrimentally impacted overall satisfaction with service.

In both phases of this stage of the research, three 90-minute discussions were administered:

- Group one: Longsight/Denton
- Group two: Wigton/Egremont
- Group three: Wigan.

A total of 46 customers were recruited from across the three Smart Street trial areas. Participants were geographically clustered to enable easy access to the meeting venues.

Monitoring the effects of the Smart Street trials on customers in trial areas

All customers in the trial area were able to contact Electricity North West through normal communication channels regarding any power quality concerns.

Before the Smart Street trials began, a robust process was embedded to ensure that any customer enquiry, that might potentially be attributable to the Smart Street method, was captured and promptly addressed.

This procedure utilised existing business as usual (BAU) processes and involved the registration of all potential Smart Street-related enquires/complaints on Electricity North West's customer contact management system. This automatically generated a prompt for investigative action from the Smart Street project team.

In June 2015, the project team delivered a series of training sessions to Electricity North West's customer contact centre (CCC), to underpin this process.

From a total of 67,000 customers in the Smart Street trial area, of which around 8,500 are fed from Smart Street secondary substations, a total of 37 enquiries about Smart Street were received over the lifetime of the project. Eight enquiries were general in nature. Five were associated with supply disturbance (linked to early technology and communications issues, rather than the application of Smart Street techniques). A total of 23 were expressions of concern or objections to new street furniture. Only one enquiry about a power quality issue could be potentially linked to application of the method. However, subsequent investigations disproved this association.

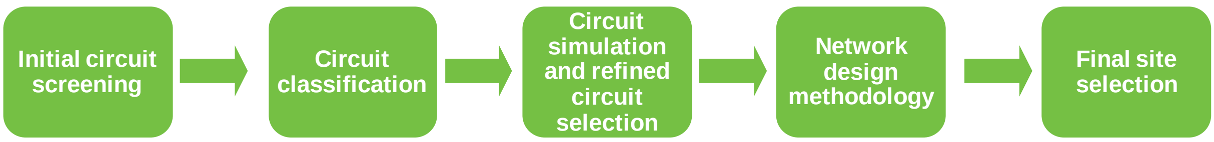
These findings support the hypothesis that Customers in the Smart Street trial areas would not perceive any change in their electricity supply associated with the method.

3.2 Technology implementation and effectiveness

The Smart Street equipment was installed across the HV and LV networks connected to six primary substations. The six primary substations were chosen to give a mix of dense urban, urban and rural networks.

The steps of the site selection methodology are shown in Figure 3.1 below.

Figure 3.1: Site selection methodology



Initial circuit screening

An initial screening process was applied to the total population of primary substations within the Electricity North West network to avoid locations where the system configuration or system operation could affect the implementation of the trial or the trial results. The criteria below were used to either give preference to or exclude specific HV circuits:

- CLASS sites
- C_2C rings
- System works.

The Smart Street project used assets deployed as part of the Second Tier Low Carbon Networks (LCN) Fund projects Customer Load Active System Services (CLASS) and Capacity to Customers (C_2C), therefore any sites that best demonstrated the Smart Street method and also fell under the CLASS or C_2C trial areas optimised the use of assets already installed.

One of the approaches of C_2C was to run closed ring circuits on the HV networks. By incorporating C_2C rings in the Smart Street trial, benefits and efficiencies were realised as system studies had already been carried out. These included a reduction in planning time and savings in equipment costs as the technologies required were already installed.

Primary substations where outages were expected due to works planned during the trial period were excluded to minimise any disruption to the Smart Street trial programme.

Circuit classification

To maximise the learning outcomes of the trial and ensure transferability to other GB distribution networks, the HV and LV circuits selected for the trial were representative of the range of circuits on Electricity North West's network. The circuits shortlisted by the initial screening were classified according to the following criteria:

- Voltage levels – to ensure 11kV and 6.6kV HV networks were included
- Circuit types – to ensure there was representation from dense urban, urban and rural networks
- Customer types – to ensure a range of domestic and non-domestic customers as well as customers with generation were included
- LCT uptake – as Smart Street is a solution for the increase in demand and generation caused by LCT uptake it was important to include areas with LCTs installed
- Physical and electrical constraints – to ensure that there was physical space to install the equipment and also check the provision of backfeeds to minimise any customer interruptions during the installation process
- LV interconnection – one element of the trial was to test the applicability and suitability of LV interconnection, this criterion checked where there were already facilities which would negate the need to install new link boxes.

Circuit simulation and refined circuit selection

The circuits were simulated (using the IPSA network planning design tool) to identify any thermal, voltage or fault level issues that may arise as a result of operating the two radial HV feeders as a closed loop. This resulted in a refined shortlist of circuits.

Network design methodology

Once the shortlist had been derived, the HV and LV system was modelled as a whole to establish load flows and volt drop, ideal interconnection points at LV and where it would be most beneficial to install the various HV and LV capacitors.

Final site selection

Applying the methodology led to the final site selection of 38 distribution substations fed out of six primary substations covering rural networks (Wigton and Egremont), urban networks (Green Street and Hindley Green) and dense urban networks (Longsight and Denton East).

More detailed information on this process can be found in the site selection methodology published on the Smart Street trials webpage.

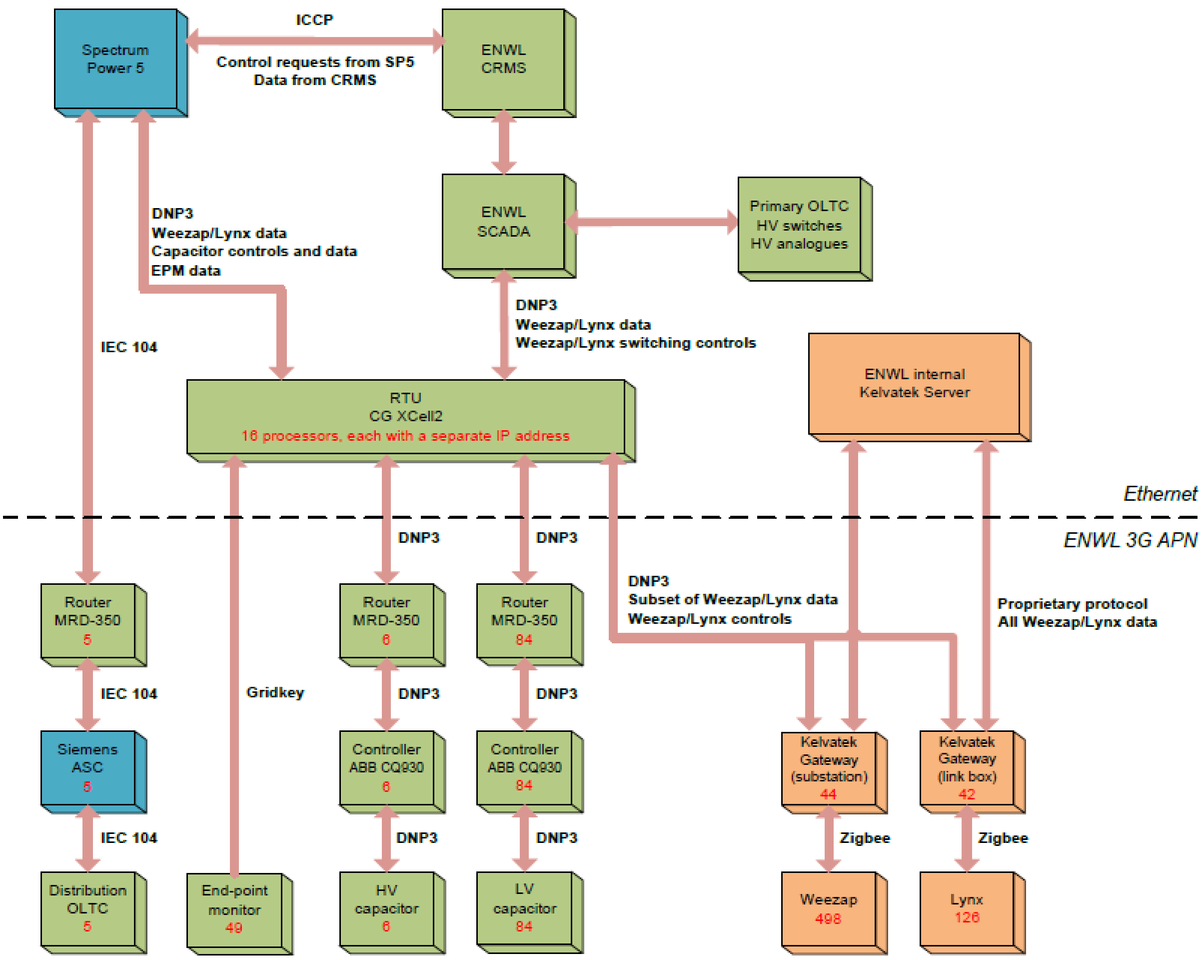
Smart Street Installations

System overview

A centralised control system, SP5, was installed in the Electricity North West central control room and connected to the existing control room management system (CRMS) via an inter-control centre communications protocol (ICCP) link. This arrangement was utilised to demonstrate that a network management system (NMS) available off-the-shelf for use by GB DNOs could be set up to run the Smart Street system.

- The Weezap and Lynx devices (see description below), which were designated as switching devices, connect locally to a Gateway using the ZigBee wireless protocol.
- The Gateway then communicates over the 3G network, using the Distributed Network Protocol 3 (DNP3) to one of a set of remote terminal units (RTUs) located in the control centre.
- The capacitors, which are designated voltage control devices, are also connected over the 3G network to the central RTUs via DNP3.
- The on-load tap changers (OLTCs) communicate directly with the SP5 system utilising the IEC104 protocol.
- The GridKey monitoring units connect using a proprietary protocol to the centralised RTUs via the 3G network. These units were used as end point monitors (see description below) to record the voltages at the end of feeders with no link boxes
- The bank of RTUs act as a data collector and splitter as the voltage control devices which are connected to them have the data sent on to the SP5 system, while the switching devices have the data sent to the CRMS system.
- CRMS and SP5 are connected via an ICCP link across which data is passed to ensure the network models on both systems remain synchronised. This connectivity is shown below in Figure 3.2.

Figure 3.2: Smart Street data model



All the field devices installed for Smart Street recorded the voltage as one-minute averages and reported it back to the SP5 system, with the Lynx and Weezap also recording current measurement on the same frequency. The existing telemetered analogues for the remaining plant within the trial areas were passed from CRMS to SP5 via the ICCP link as 30-minute averages. The switching devices also communicated with a proprietary server hosted within the Electricity North West firewall, which allowed use of the fault identification and location ability of these devices to provide an ancillary benefit outside the scope of the project.

Devices

Weezaps

The Weezap is a 400A-rated miniature vacuum circuit breaker (VCB) designed to be installed on most of the currently used LV fuse boards. It can be programmed to mimic the protection characteristics of a number of BS standard fuses. The VCB itself is rated to break up to 8kA of fault current; for faults in excess of this there is an inline 500A fuse which operates to protect the device. The Weezap will auto reclose onto faults a configurable number of times to clear transient faults from the network. The device is designed so that it will automatically open on loss of volts, ie during a HV fault, and reclose once the supply is restored.

Lynx

The Lynx is a 400A-rated vacuum switch which is designed to fit into a link box replacing the standard solid links or fuses. This allows the LV circuit to be meshed and unmeshed remotely as determined by the optimisation software. As with the Weezap above the Lynx device will open automatically on a loss of volts, however it will not reclose once power is restored.

Capacitors

The capacitors were installed to provide voltage control only and were not set up for power factor correction as part of the project. The LV units were multi-stage devices with stages of 50 and 100kVAr available. They were installed as 100, 150 and 200kVAr units, with the largest units being positioned at the distribution substation and the smaller ones at around the two thirds point of the circuit. The HV capacitors both ground-mounted and overhead were single stage units sized at 200, 400 or 500kVAr.

On-load tap changers

The OLTCs used during the Smart Street trials required the replacement of the standard free breathing transformer with a hermetically sealed unit as the tap changer was positioned on top of the transformer core. These were controlled locally by a Siemens autonomous substation controller (ASC) which also provided the communications link to the centralised NMS. The OLTCs had nine tap positions with each step giving a 2% change in voltage. The OLTCs were set up to maintain the voltage around an adjustable set point and if a communication failure was detected to return to a default position of 245V.

End-point monitors

The end-point monitors were installed at the end of all radial LV circuits to provide visibility of the voltages at these points. They communicated via a proprietary protocol over the 3G network with the RTUs located in Electricity North West's central control room, sending voltage readings as one-minute averages every sixty seconds.

3.3 Developing the Smart Street trials

As defined in the full submission document the five trials explored were:

- LV voltage control
- LV network management and interconnection
- HV voltage control
- HV network management and interconnection
- Network configuration and voltage optimisation.

In order to understand how each of the different types of kit can impact each of the trials, a series of test regimes were devised as shown in Figure 3.3 below.

Figure 3.3: Smart Street trials

Smart Street trial	Test regime
Trial 1: LV voltage control	T1.1 On-load tap changing distribution transformer only
	T1.2 On-load tap changing distribution transformer and capacitor(s) on LV circuits
	T1.3 Capacitors at distribution substation only
	T1.4 Capacitors at distribution substation and on LV circuits
	T1.5 Capacitor(s) on LV circuits only
Trial 2: LV network management and interconnection	T2.1 LV radial circuits
	T2.2 LV interconnected circuits
Trial 3: HV voltage control	T3.1 Voltage controllers at primary substation only
	T3.2 Voltage controllers at primary substation and capacitors on HV circuits
Trial 4: HV network management and interconnection	T4.1 HV radial circuits
	T4.2 HV interconnected circuits
Trial 5: Network configuration and voltage optimisation	T5.1 Losses reduction
	T5.2 Energy consumption reduction.

- Trials 1 and 3 reduced network losses or energy consumption via a combination of conservation voltage reduction (CVR) and voltage optimisation techniques. The trials tested the voltage control equipment in isolation and in combination to fully assess the benefits of these techniques.
- Trials 2 and 4 compared the benefits of radial and interconnected circuits across the LV and HV trial areas.
- Trial 5 assessed the reduction in losses and energy consumption achieved by the optimisation software.

The trial regimes were designed to apply all of the test criteria while allowing for direct comparison over each trial area at different times of the year. Direct comparisons were also made to the overall benefit of each technology type installed on rural, urban and dense urban networks.

The trials took place over a two-year period using an off/on test regime which resulted in data for both normal network running configurations and for Smart Street operation This allowed for the two scenarios to be compared and analysed enabling the overall benefits of Smart Street to be calculated. The full trial design is detailed in the network design report on the trials webpage.

Optimisation

At the core of Smart Street is the ability to simultaneously optimise network configurations and voltage profiles in real time. This will enable utilities and consumers to save energy and lower operating costs by reducing the need to generate additional energy. As a consequence it also helps to lower greenhouse gas emissions and enable a greener network.

Siemens Spectrum optimisation software optimised both interconnected configurations and voltage profiles across HV and LV networks. This trial assessed the reduction in losses and energy consumption achieved by the optimisation software.

The Volt/VAr Control (VVC) application available on Spectrum is able to determine control actions of OLTC transformers, shunt capacitor banks and remote-controllable switches to optimise the network for a chosen function. The specific user-defined functions that are available are:

- Minimise limit violations
- Minimise power losses and limit violations
- Minimise active power consumption (power demand) and limit violations
- Minimise reactive power consumption and limit violations
- Maximise power revenue and minimise limit violations
- Minimise violations and power losses (HV) and active power consumption (LV).

The VVC optimisation consists of three basic components:

- A set of variables
- An objective function to be optimised (minimise or maximise)
- A set of constraints that specify the feasible values of the variables.

The aim of the optimisation routine was to find the total objective function extreme, while satisfying all constraints. These constraints include power flow equations and operational voltage limits. The VVC therefore provides a centralised coordinated control of the network regulating controllers and provides the following modes of operation:

- *Open loop:* The optimal setting/switching orders calculated from VVC are not automatically executed, but available for review in the user interface
- *Closed loop:* The optimal setting/switching orders calculated from VVC are immediately executed after VVC calculation.

For the Smart Street trials the VVC was run in 30-minute closed loop cycles. All VVC commands to OLTC transformers were sent as voltage set-points, while all commands to capacitor banks were in the form of open/close instructions due to the capacitor control interface.

Figure 3.4 highlights the eight-week cycle of the trial combinations; this cycle allows all of the individual trials to be assessed.

Figure 3.4: Summary of optimisation test regimes

	Trial 1	Trial 2	Trial 3	Trial 4
Week 1	Off	Off	Off	Off
Week 2	Off	Off	Off	Off
Week 3	T1.1/T1.3/T1.5	On	T3.1	On
Week 4	T1.2/T1.4/T1.5	On	T3.2	On
Week 5	Off	Off	Off	Off
Week 6	Off	Off	Off	Off
Week 7	T1.1/T1.3/T1.5	On	T3.2	On
Week 8	T1.2/T1.4/T1.5	On	T3.1	On

Trials summary

The Smart Street test regimes were designed to allow for monthly comparisons of each trial technique over the two-year trial period. 52 weeks of the 'trial-off' period provided baseline data, while 52 weeks of 'trial-on' data aimed to compare the various Smart Street technologies.

These trials were designed to maximise the learning on circuits fitted with OLTCs and substation capacitors which are capable of CVR due to the limited number of test circuits available.

The academic partners analysed the research data and made suggestions for changes to the test schedule to maximise learning.

Revision to trial regime

During the trial phase some of the equipment required safety-related modifications which subsequently led to a period when these assets were inhibited. Data was collected when these devices were inhibited; therefore once the modifications were made the devices were enabled when the optimisation was active. This represented a deviation from the trial regime proposed at the beginning of the project but had no effect on the complete data set or learning.

During the trials, issues arose with the Spectrum software and its optimisation algorithm which led to erroneous setpoints being sent to some devices. After a period of consultation with Siemens and their resulting investigations, it became apparent that some of the base parameters needed to be altered. This meant that there could have been issues comparing data collected later in the project, with data collected before the parameters were changed. In order to maximise the learning following this change Electricity North West worked with its academic partners to devise a new trial regime.

In the new regime Wigton was used as a 'control' area. In the other areas different devices were enabled on different weeks to understand the effects of the different combinations. This regime continued until the end of the trials in December 2017.

Figure 3.5: New trial regime

Week	Trial Areas										
	Denton East		Egremont		Green Street		Hindley Green		Longsight		Wigton
	NLTC	OLTC	NLTC	OLTC	NLTC	OLTC	NLTC	OLTC	NLTC	OLTC	
31	Caps HV meshing	OLTC HV meshing	Caps HV meshing	OLTC HV meshing	Caps+Lynx	OLTC	Caps	OLTC	Caps+Lynx HV meshing	OLTC+Caps +Lynx HV meshing	No CVR
32	Caps+Lynx HV meshing	OLTC+Caps HV meshing	Caps HV meshing	OLTC+Caps HV meshing	Caps+Lynx	OLTC+Caps +Lynx	Caps	OLTC	Caps+Lynx HV meshing	OLTC+Caps +Lynx HV meshing	
33	Caps HV meshing	OLTC HV meshing	Caps HV meshing	OLTC HV meshing	Caps+Lynx	OLTC	Caps	OLTC	Caps+Lynx HV meshing	OLTC+Caps +Lynx HV meshing	
34	Caps+Lynx HV meshing	OLTC+Caps HV meshing	Caps HV meshing	OLTC+Caps HV meshing	Caps+Lynx	OLTC+Caps +Lynx	Caps	OLTC	Caps+Lynx HV meshing	OLTC+Caps +Lynx HV meshing	
35		OLTC		OLTC		OLTC		OLTC		OLTC	
36	Caps+Lynx HV meshing	OLTC+Caps HV meshing	Caps HV meshing	OLTC+Caps HV meshing	Caps+Lynx	OLTC+Caps +Lynx	Caps	OLTC	Caps+Lynx HV meshing	OLTC+Caps +Lynx HV meshing	
37	Caps HV meshing	OLTC HV meshing	Caps HV meshing	OLTC HV meshing	Caps+Lynx	OLTC	Caps	OLTC	Caps+Lynx HV meshing	OLTC+Caps +Lynx HV meshing	

3.4 Evaluating the benefits of the Smart Street solution

Data transfer and analysis summary

For the optimisation software to run successfully SP5 needed the measured voltage and current at strategic points on the network as well as an awareness of the states of all devices. The analogue data was collected on a one-minute average and stored in the Spectrum historian along with a record of any changes of state.

Each month the data was extracted from the historian system in a comma separated values (csv) format and transferred to the academic partners via Electricity North West's secure file transfer system. To assess the impact and benefits of Smart Street, the academic partners used this data to create and validate models as well as conducting a direct assessment of the data to assess the benefits of optimisation.

Trial 1: LV voltage control

Trial 1 looked at the LV voltage control techniques optimised by SP5 and quantified the benefits of LV voltage optimisation. The academic partners modelled the LV trial networks to calculate and quantify the benefits of the voltage control techniques. In particular they carried out analysis and modelling of the trial networks to develop CVR and voltage optimisation models and to calculate the reduction of losses and demand. The data collected during Trial 1 was used to validate and improve these LV models.

Trial 2: LV network management and interconnection

The academic partners modelled the LV trial networks to produce practical rules to determine optimal locations for interconnection. Further rules were developed for network operation taking into account the characteristics of the meshed feeders, different penetrations of LCTs, and coordination with voltage regulation devices. Simulations were also carried out to quantify the potential impact on a customer's electrical installation of interconnecting LV networks while managing voltages within a tighter band. This work was reviewed by the IET wiring regulations group.

Trial 3: HV voltage control

This trial collected monitoring data across the HV trial networks which was used to quantify the benefits of the HV voltage control techniques. The academic partners modelled the HV trial networks to calculate and quantify the benefits of these control techniques. The circuit data was used to validate the results of the modelling.

Trial 4: HV network management and interconnection

This trial collected monitoring data across the HV trial networks which was used to quantify the benefits of the Smart Street network management and interconnection techniques. The data collected during Trial 4 was used to validate and improve the HV network models that were used to develop practical rules to determine the most suitable location of voltage control equipment and optimal scenarios for HV interconnection.

Trial 5: Network configuration and voltage optimisation

This trial used all the data collected in the previous four trials to calculate the overall reduction in losses and energy consumption, comparing the Smart Street network with the historical network. The trial also quantified the trade-off in performance between reducing losses on the HV network and the implementation of CVR on the LV network. The learning outcomes will be used to publish the specifications, settings and configuration parameters required to optimise the operation of the distribution networks.

Academic work

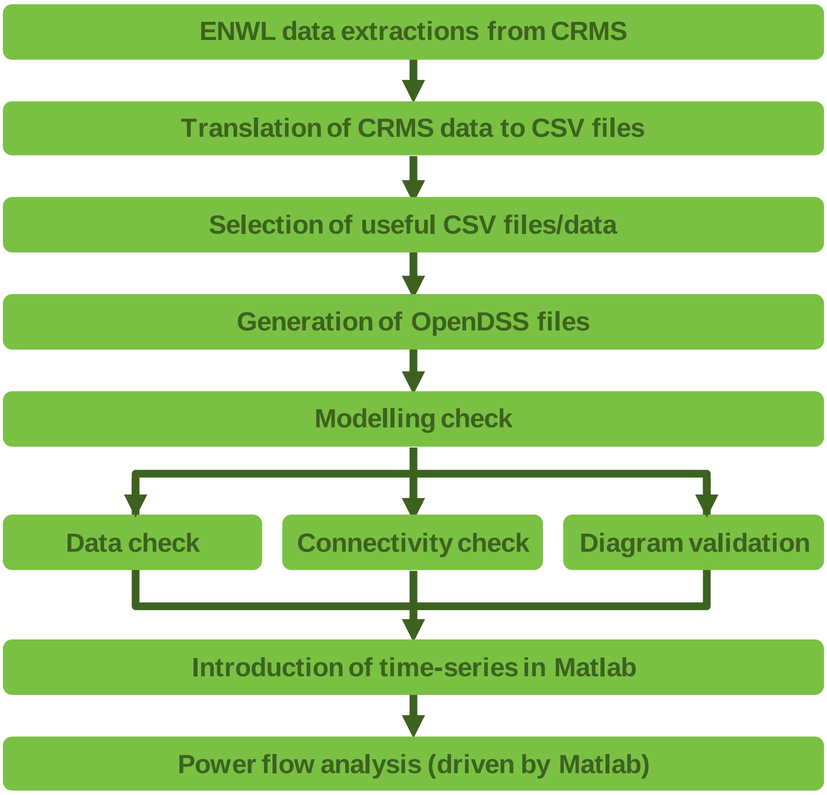
The University of Manchester and Queens University, Belfast were contracted to conduct the analysis work required to assess the five different trials. The research was split into three work packages. One work package covered Trials 1, 3 and 5; the second covered Trials 2 and 4. The third work package produced the cost benefit analysis and carbon impact studies.

Development of network models

The University of Manchester developed the HV and LV network models which were used by all three work packages of the academic research to analyse the impact and benefits of Smart Street. Electricity North West provided the HV and LV networks as an extract from CRMS in extensible markup language (XML) format.

To complete the analysis the universities chose to use OpenDSS which is an open source software package to solve power flows, harmonics analysis and fault current calculations in electrical distribution systems. This software is able to solve unbalanced networks and can be driven from other software, such as MATLAB. One of the main characteristics of OpenDSS is the ability to represent the time dimension (daily and yearly simulations with different time steps) in networks with distributed generation. This is important to quantify the impacts of intermittent sources (PV, micro-CHP, etc.) and loads (EV, HP etc.) on distribution networks. Figure 3.6 details the steps taken to convert the XML files to a format suitable for OpenDSS.

Figure 3.6: Conversion of XML files to OpenDSS



The XML data was read into Matlab by using the 'xmlread' function and the data was categorised by type (ie transformers, switches and fuses) and stored in different matrices. The data matrices were written into csv files where all elements are arranged in rows and all element features are arranged in columns.

Some of the csv files produced were not required for the OpenDSS modelling and those that were required contained data elements that were also superfluous. Therefore the next step identified and extracted the useful files and data elements to create readable txt files for OpenDSS. The txt files were generated using Matlab.

Once the OpenDSS files were generated, a check of each model was carried out by:

- Checking the data to ensure the generated OpenDSS files were correct and complete
- Checking the connectivity checks to ensure all elements in the networks were connected and no isolated zone existed
- Validating against network diagrams to ensure all the elements were connected in the right position.

In order to assess the effect of CVR and the impacts of LCTs in distribution networks, it was necessary to perform time-series power flow analyses with high resolution load and LCT models. This required not only adequate profiles but also load models to cater for voltage dependencies.

Load modelling

Domestic load profiles based on the CREST tool produced by Loughborough University were applied to the models. For non-domestic customers the profiles based on data from ELEXON was used.

Electricity North West's First Tier LCN Fund Low Voltage Network Solutions provided a methodology to generate realistic PV profiles and this methodology was used to provide the PV profiles for this analysis.

SSE's Second Tier LCN Fund project My Electric Avenue produced real data on EV charging. This data was coupled with statistical analysis on when the car is charged, how many cars are being charged as well as the initial and final state of charge to give a range of profiles for this analysis.

Once the models were complete a test power flow analysis was carried out to prove the models worked.

Adopted methodology

Data analysis was based on a Monte Carlo approach, which caters for the stochastic nature of demand and generation and for tackling the unknown location of LCTs in distribution networks. The Monte Carlo method can be defined as a computational algorithm that depends on repeated random sampling of unknown parameters to acquire numerical results. Monte Carlo methods are usually used in mathematical problems such as optimisation and the generation of draws from a probability distribution. It is very useful in situations where the application of a deterministic algorithm is not representative, such as in the case of unknown locations/sizes/behaviour of PVs or EVs in the network.

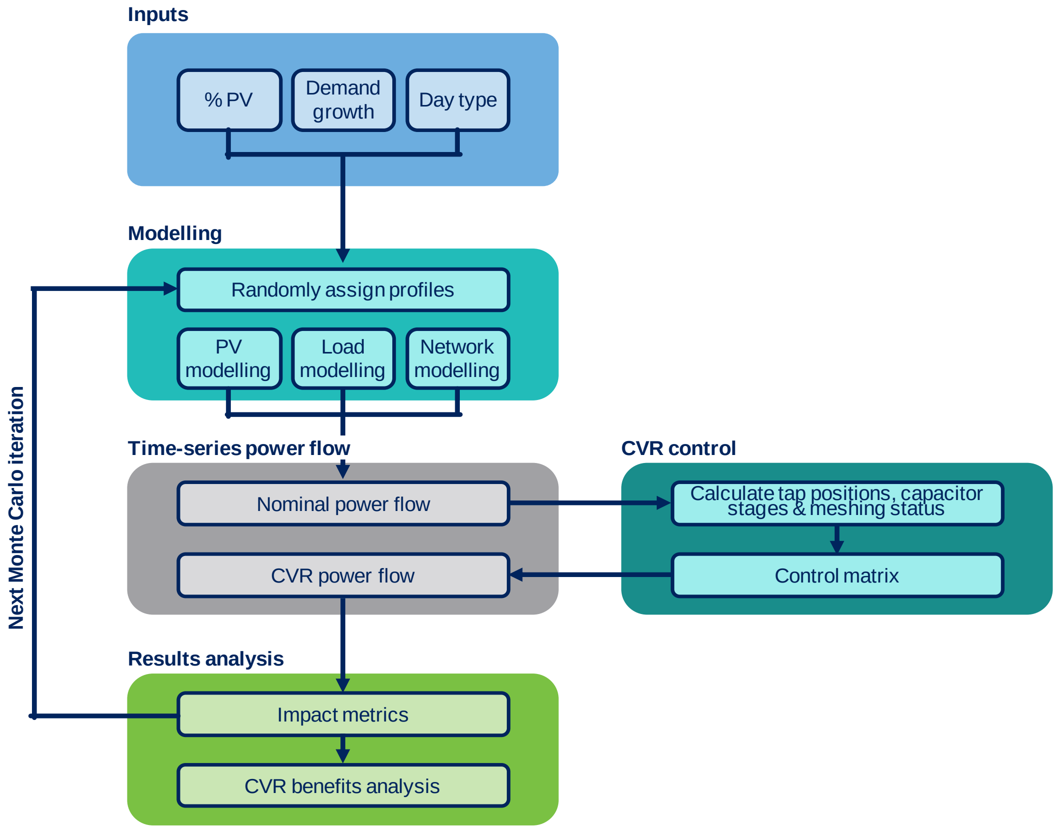
Two pools of 1,000 individual domestic profiles for PC1 and PC2 customers were randomly generated for the type of day (season/day of the week) to be assessed with their corresponding time-varying load models using the CREST tool. Non-domestic loads were represented by ELEXON profiles.

In order to model PV profiles, a set comprising the 30 sunniest irradiation curves of 2012 from the Whitworth Meteorological Observatory of The University of Manchester was considered. It was assumed that all the PV systems will get the same irradiation as the length of the LV networks do not exceed 1 km. Statistics from 2014 showed that the domestic scale PV panels currently installed in the UK have a distribution of 1%, 8%, 13%, 14%, 14%, 12% and 37% of 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0kW, respectively. This distribution of PV sizes was used for power flow simulations when allocating PV panels.

A representative pool of 1,000 EV profiles was generated using the methodology described earlier.

The Monte Carlo method was then applied to the 38 Smart Street LV networks to assess the impact of LCTs and benefits of operational actions. The steps to carry out the Monte Carlo analysis are summarised in Figure 3.7 and listed below.

Figure 3.7: Flow chart for modelling process



- The operational statuses of capacitors, switches and tap changers were set.
- Random demand profiles were selected from the pool and allocated to each domestic customer respecting their profile class.
- A random irradiance from the pool of 30 days was taken.
- A percentage of the total customers were randomly assigned a PV panel according to the statistics detailed above. All the customers shared the same irradiance.

- A percentage of the total customers were randomly assigned an EV profile.
- A one-minute resolution time series power flow was performed using OpenDSS.
- Impact metrics were calculated from power flow results.
- When assessing the impact of an operational action (eg tap position for CVR) the process was repeated from step 2 to give the same initial conditions.
- The process was repeated from step 1 a predefined number of times.

The metrics listed below were calculated after every Monte Carlo simulation. The median and standard deviations were obtained for each metric when all the simulations were complete. The latter contains the required information to conclude about any impact and benefit.

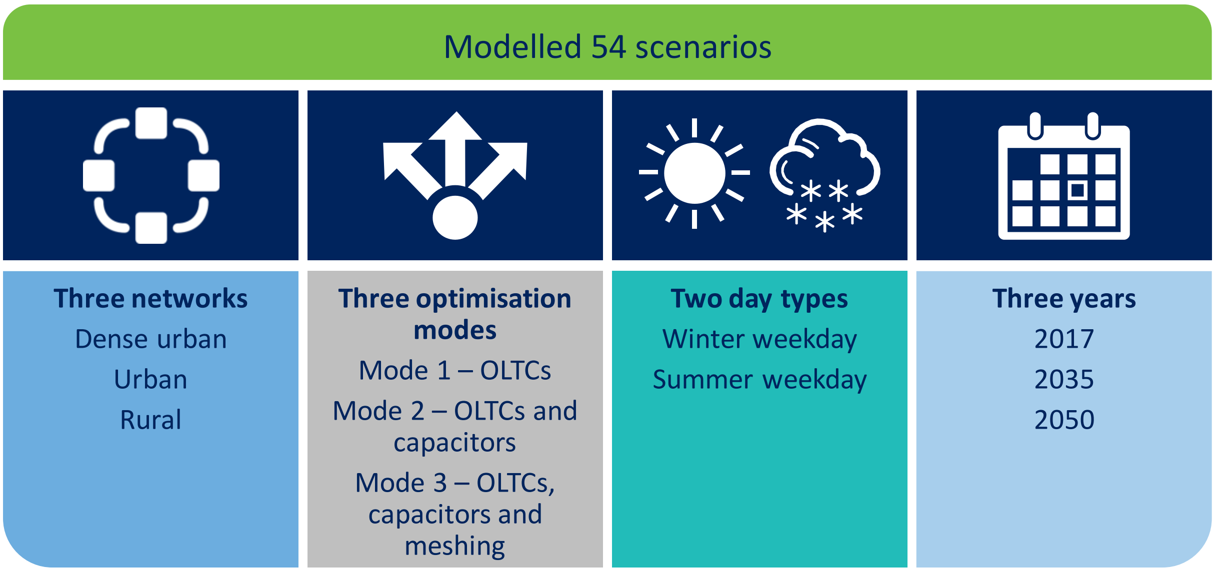
- Percentage of customers with voltage problems
- Utilisation factor of transformers
- Percentage of overloaded cables/lines
- Location of overloaded cables/lines
- Energy losses
- Total energy
- CVR factor.

Modelling scenarios

As well as assessing the impact Smart Street has on today's network it was important to understand the benefits for future networks with different levels of demand and generation, as well as the impact it has for different types of networks.

The outputs from the trials were used by the universities as inputs to a model to assess the benefits of Smart Street across a range of scenarios. These were developed to ensure all network types and demand variations were covered both for current and future scenarios.

Figure 3.8: Models and scenarios



The combinations of all the above criteria resulted in 54 scenarios modelled and analysed.

In order to project the demand and generation growth for years 2035 and 2050, an average was taken of the four National Grid Future Energy Scenarios which resulted in 20% and 40% PV penetration and multiplication factors of 1.0535 and 1.1859 for demand.

4. THE OUTCOMES OF THE PROJECT

4.1 Customer engagement and feedback

Communicating with customers in the trial area

The ECP described in Section 3.1 helped formulate effective communication plans and provided relevant and clear information to customers on trial circuits.

This section summarises the findings from the ECP feedback which was designed to address three key questions:

- Which awareness materials were most effective in educating the ECP on the role of Electricity North West and the Smart Street method?
- Which key elements of Smart Street should be highlighted in customer communications?
- What was learned from evaluating and appraising the proposed customer leaflet and which version of the materials was deemed the most appropriate to send to customers?

Which awareness materials are most effective in educating the ECP on the role of Electricity North West and the Smart Street method?

The ECP provided an essential forum to gain constructive and independent feedback on Electricity North West's initial drafts of the customer leaflet. The research found that with appropriate education customers generally understood the role of Electricity North West and the Smart Street method.

In Electricity North West's previous Second Tier LCN Fund projects, CLASS and C_2C, a key learning outcome was that generally, customers initially required educating about the identity and role of Electricity North West before they were able to digest project awareness material. Only when Electricity North West's responsibility as a DNO had been established and an understanding reached about how this differs from the role of electricity generators and suppliers, could awareness material be effectively presented. The ECP also needed some information about why projects such as Smart Street are necessary to meet future expected electricity demand.

Which key elements of Smart Street should be highlighted in customer communications?

In common with learning from previous innovation projects, the Smart Street ECP collectively agreed that the most effective ways of communicating with customers on the trial circuits was through a customer leaflet. The leaflet produced on the basis of ECP feedback offered a cost-effective way of reaching all affected customers and disseminating key aspects of the trials. It also overcame restrictions in communicating with customers without access to the internet.

Previous leaflets for C_2C and CLASS were designed on the basis of the respective ECP feedback and both leaflets varied significantly. As such, feedback from the Smart Street ECP was influential in the design of the leaflet and ultimately the effectiveness of the awareness campaign. The panel guided the graphics, content and layout of the leaflet by evaluating concise and abridged drafts.

The final version included a succinct, 'frequently asked questions' section on the front cover. This was intended to differentiate the leaflet from 'junk mail' or marketing materials and reassure customers that they were unlikely to notice any difference in their supply when the Smart Street trials were implemented. It also addressed the most anticipated enquiries and key messages, including:

- Who is Electricity North West?
- What is Smart Street?
- Why is it happening?
- How will it affect me?

This was supplemented with further information inside the leaflet for those who may have wanted to know more about the project.

What was learned from evaluating the proposed customer leaflet and which version of the materials was deemed most appropriate to send to customers?

The outcome of the work was an endorsed customer leaflet that was distributed to customers on trial circuits in October 2014 and published on the customer webpage. The leaflet explained the problem, the Smart Street solution and the likely effect of the method on customers. It also provided contact details for Electricity North West, for those wanting more information.

Following distribution of the leaflet, a small-scale telephone survey of 150 customers was undertaken to assess the effectiveness of the awareness campaign, ascertain customer reaction to the leaflet and gauge the return on investment.

Over a third of customers surveyed recalled receiving the leaflet, which was generally well received and understood, thereby fulfilling its objectives. However, this research demonstrated the low level of awareness about Electricity North West as an organisation and its role in the electricity industry.

This lack of awareness corroborated feedback from the first phase of ECP consultation in Smart Street, which was also replicated in the mid- and post-trial research. This is consistent with similar learning from other innovation projects and demonstrates the barrier to reaching customers through printed materials, which are often perceived as junk mail, or marketing from a supplier, particularly where the mailing is not specifically addressed to the recipient.

However, as DNOs are now placing greater emphasis on social responsibility and more focus is directed to engagement programmes, it is anticipated that publicity campaigns such as this will start to improve customers' understanding of the relevance of Electricity North West to their homes and businesses.

Communicating with customers about street furniture installation

As an enhancement to the CEP, all properties in sight of new enabling technologies and those likely to be subject to short-term inconvenience associated with construction work were identified. Approximately 1,500 advisory letters were posted to these customers. This proactive engagement strategy was designed to ensure that Electricity North West was as transparent as possible about potential impacts on customers likely to be most directly affected by the technologies. This approach was designed to maximise customer acceptance, mitigate the risk of complaints and provide sufficient opportunity to modify the technical design, most economically, in circumstances where public discord necessitated compromise in the location of new technologies.

A total of 37 customer enquiries were received across the two-year trial period and 23 of these were expressions of concern or objections to the installation of new street furniture. The majority of the street furniture complaints were reported by customers, on receipt of the notification letter or shortly after when the position of new equipment was marked up in the public footpath.

This early, proactive engagement strategy ensured that the project team was able to manage these complaints on a case by case basis. Each was resolved amicably. Most objections were from domestic customers residing in relatively affluent areas and a number of on-site meetings took place, where the individual customer's concerns were discussed to reach the most appropriate outcome.

Most resistance was in relation to the metal cabinets, located in the public footpath, designed to house LV capacitors and end-point monitors. A small amount of work was required to relocate some of these cabinets to a position that was more acceptable to the customer. In a small number of cases, where this was not possible, commitments were made to remove street furniture at the end of the trial period.

Sloping lids were retrofitted to three cabinets, where there was a concern that the flat top could provide a seating area, encouraging the unwelcome congregation of young people and a potential nuisance problem. In two instances this action was simply to mitigate a perceived potential risk to customers neighbouring the installations. In one instance a cabinet was used as a climbing aid, which resulted in a short-term anti-social behaviour problem. This was quickly resolved by fitting the sloping lid and this cabinet is in the process of being removed.

Only one enquiry was generated in response to the installation of an HV ground-mounted capacitor, following notification of the proposal to site the equipment on land adjacent to the customer's home. The enquiry was focused on visual amenity and concerns about exposure to electromagnetic fields. The proposed location was subsequently changed, prior to any on-site preparatory works, on the basis of planning consents. No other customer complaint relating to any issue concerning the six installed HV capacitors (three ground-mounted and three pole-mounted) were received over the life of the project. There were no customer objections to the installation of new Lynx devices.

The success of this strategy demonstrates that early and proactive engagement with those customers, most directly affected by the installation of new street furniture, was critical in achieving customer acceptance.

Monitoring the effects of the Smart Street trials on customers (ECPs)

Feedback from the ECP was valuable in gauging customer perception of power quality and how it might have changed since implementation of the Smart Street trial regime.

The only perceived changes to power quality were positive, with a substantive number of the panel (both mid- and post-trial) citing a slight improvement since the trials commenced. This improvement was largely associated with the negative effect that poor weather conditions (most notably, storms Desmond and Eva) had on perceptions before the trials began. It was only after sensitising the panel with information about SDIs and prompting them to carefully reflect on changes, with detailed questioning, that customers were able to recall if there were any changes in power quality. Panel members, who reported a change after prompting, described these events as SDIs, minor disturbances that could potentially have been associated with a depression in voltage or flickering. However, all stated that these were insignificant and so infrequent as to have had no impact on themselves or their households. Both mid- and post-trial panellists confirmed that these events did not adversely affect perception of power quality, which was already very high before the trial period, even among those with experience of prolonged outages associated with extreme weather conditions.

Events recalled by the ECP were recorded and subsequently investigated to determine if any could potentially have been associated with Smart Street. Most SDIs and the overwhelmingly majority of prolonged supply interruptions were found to be the result of network faults. Similarly, the small number of power quality issues, such as very infrequent and slight voltage depressions, were associated with faults. A number were found to have occurred early in the trial period and coincided with issues arising from the integration of enabling technologies and communications platforms, which resulted in some customers experiencing a small number of SDIs. These early technology-related problems were quickly identified and resolved by implementing firmware updates and customers on trial circuits experienced no further problems following this remediation. The accounts of SDIs, early in the trial period, combined with the failure of the ECP to recall more recent events, substantiates that any early impact was associated with technology refinement and interconnectivity issues, rather than application of the voltage optimisation trial regime. However, even when SDIs, more prolonged supply interruptions or power quality issues, such as slight voltage dips were reported, they had no negative impact on customers' satisfaction with supply.

ECP feedback demonstrates that customers are not sensitive to voltage control techniques and that a small increase in SDIs has no negative impact on overall perception of power quality. These findings demonstrate that customers in the trial area would not perceive any changes in their electricity supply and that introducing a theoretical risk of an increase in SDIs, resulting from interconnected configurations of LV networks, would be acceptable to customers.

The absence of reported problems with appliances or other equipment from the ECP also supports the research workstream hypothesis that *Smart Street has no adverse effects on customers' internal installation or appliances.*

Monitoring the effects of the Smart Street trials on customers (outside of ECPs)

In parallel to the ECPs, a robust framework was embedded to ensure that all enquiries and complaints received by Electricity North West, via its traditional reporting mechanisms, which could potentially be related to any aspect of Smart Street, were captured.

From a total of 67,000 customers in the Smart Street trial area, of which around 8,500 are fed from Smart Street secondary substations, a total of 37 enquiries about Smart Street were received over the lifetime of the project. Of these, eight enquiries were general in nature. Five were associated with supply disturbance, which was the direct result of early technology installation and communications problems, rather than the application of the Smart Street technique. A total of 23 were expressions of concern or objections to new street furniture. Over the entire Smart Street trial period, there was only one event, which could potentially be attributed to a power quality issue, linked to application of the method. However, investigations at that time have disproved this association.

The five enquiries received in the early installation phase of the project were directly associated with the integration of enabling technologies and communications platforms. Of these enquiries three were the result of customers experiencing a small number of SDIs. These early technology-related problems were resolved quickly by implementing firmware updates in each instance the matter was resolved amicably. The other two issues were simply the report of noise from Weezap alarms, which were trigged as a result of these early technical problems.

In parallel all power quality/voltage complaints/enquiries recorded by Electricity North West were actively monitored throughout the trial period. This ensured that if any such problems arose on a Smart Street circuit, they were quickly identified, irrespective of whether an issue was raised by a customer or generated from another source.

During the live trial period a total of 21 voltage power quality related complaints were recorded at properties served by Smart Street primary substations. These were all thoroughly investigated and were found to be the result of a local issue or network fault, or a problem with the customer's own installation, equipment or load.

These findings, along with the absence of any enquiries or complaints directly associated with application of the trials support the hypothesis that *Customers within the Smart Street trial areas will not perceive any changes in their electricity supply* is upheld.

The absence of reported problems with customers' appliances or equipment during the trial period also supports ECP feedback and proves the research workstream hypothesis that *Smart Street has no adverse effects on customers' internal installations or appliances.*

4.2 Technology implementation and effectiveness

A detailed list of the sites selected for the installation of equipment for the Smart Street trials can be found in the site selection methodology on the trials webpage. In brief:

- 489 Weezaps installed across 80 substations
- 126 Lynx installed in 44 link boxes
- 84 LV capacitors installed
- Three ground-mounted HV capacitors
- Three pole-mounted HV capacitors
- 60 end-point monitors.

These installations were spread across six primary substations to ensure that the equipment was installed in conditions representative of those present on the Electricity North West system. During the trials the system was able to operate the equipment installed on all the trial networks to facilitate optimisation.

4.3 Smart Street trials

The trials schedules were executed, with some changes to the regime as explained in Section 3, providing:

- Data for the University of Manchester and Queens University, Belfast to test the project hypotheses
- Customer learning though quantitative analysis
- Useful feedback and lessons learned by testing the capability of new technology.

All trial data was uploaded to the Electricity North West website. Although the data was primarily for use by academic partners, it was also available for stakeholders.

4.4 Evaluating and enabling the benefits of the Smart Street solution

Energy consumption benefits

The charts below demonstrate the reduction in energy consumption achievable using the Smart Street method.

- Optimisation 1 is with only the primary and distribution on-load tap changers active
- Optimisation 2 is with the on-load tap changers and all capacitors active
- Optimisation 3 is with on-load tap changers, capacitors and interconnection active ie all devices.

Figure 4.1: Energy consumption reduction in 2017

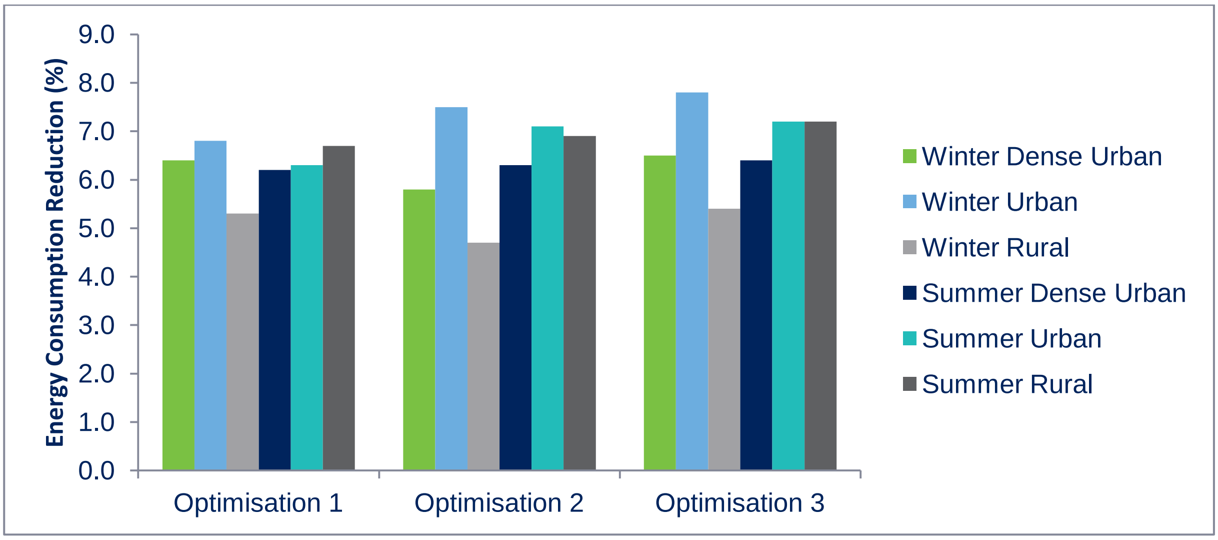


Figure 4.2: Energy consumption reduction in 2035

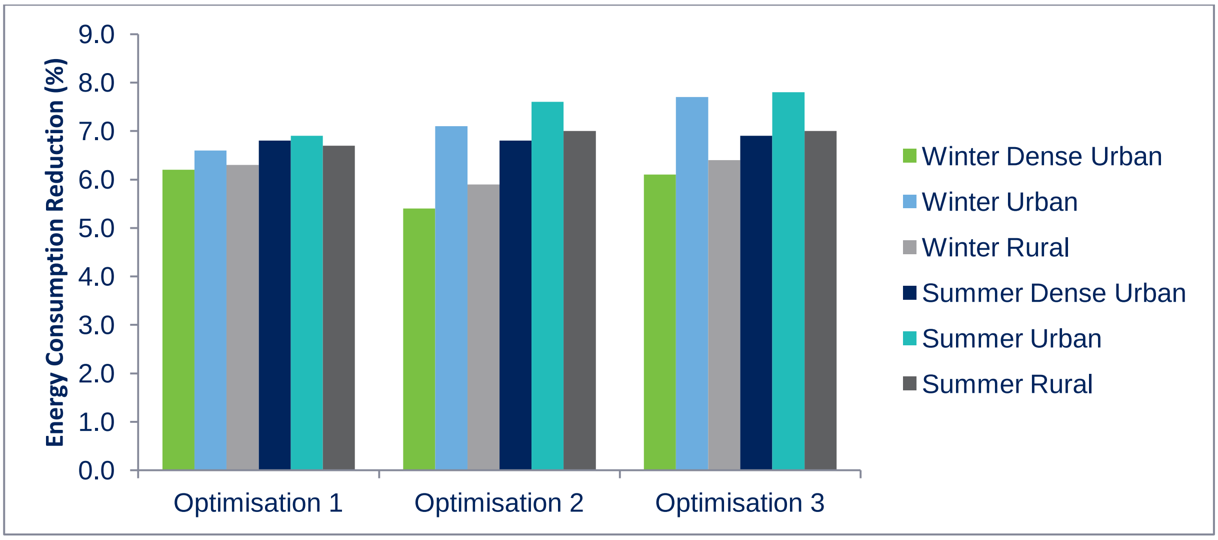
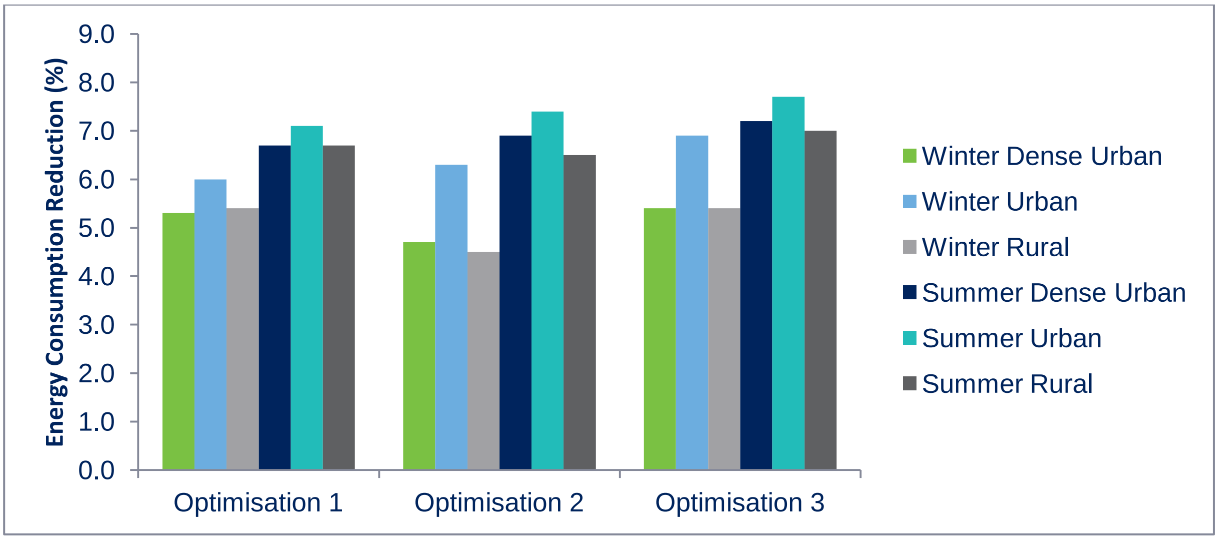


Figure 4.3: Energy consumption reduction in 2050



As can be seen from the charts, Smart Street can deliver around 5 – 8% energy consumption reduction.

Larger voltage reductions are observed in the summer scenarios as:

- Energy consumption is less in summer than in winter which results in a lower voltage drop giving more headroom for voltage reduction
- PV generation increases the feeder voltage which provides more headroom for voltage reduction.

With the demand growth and PV growth in 2035 and 2050, the reduction of energy consumption is slightly increased in summer, but decreased in winter in all three networks.

Applying interconnection in optimisation 3 has provided larger voltage reduction, energy reduction and loss reduction. Adding capacitors gives more energy reduction in the summer scenarios.

The voltage at the primary substation was reduced by 1 – 4% by using the primary OLTC. Further voltage reduction was achieved by adding the LV off-load and on-load tap changers. This gave a total voltage reduction at the customer side of around 5 – 8% and overall energy reduction of 5 – 8%. This results in an average CVR factor roughly equal to 1, which means the relationship between voltage reduction and energy saving is roughly linear.

These results assume that DNOs would optimise the position of the off-load tap changers as the demand/generation changes – this could occur seasonally. If it is assumed that the off-load tap changers remain at a static value until 2050 the reduction in energy consumption is lower at around 1 – 4%. Therefore it is more beneficial to optimise the voltage as demand changes.

Analysis of the measured data showed a reduction in energy consumption of around 6 – 8% which provides further validation to the modelling work and proves the hypothesis that *The Smart Street method will deliver a reduction in customer's energy consumption*.

Losses benefits

The charts below demonstrate the reduction in losses achievable using the Smart Street method.

- Optimisation 1 is with the primary and distribution on-load tap changers active
- Optimisation 2 is with the on-load tap changers and all capacitors active
- Optimisation 3 is with on-load tap changers, capacitors and interconnection active ie all devices.

Figure 4.4: Losses reduction in 2017

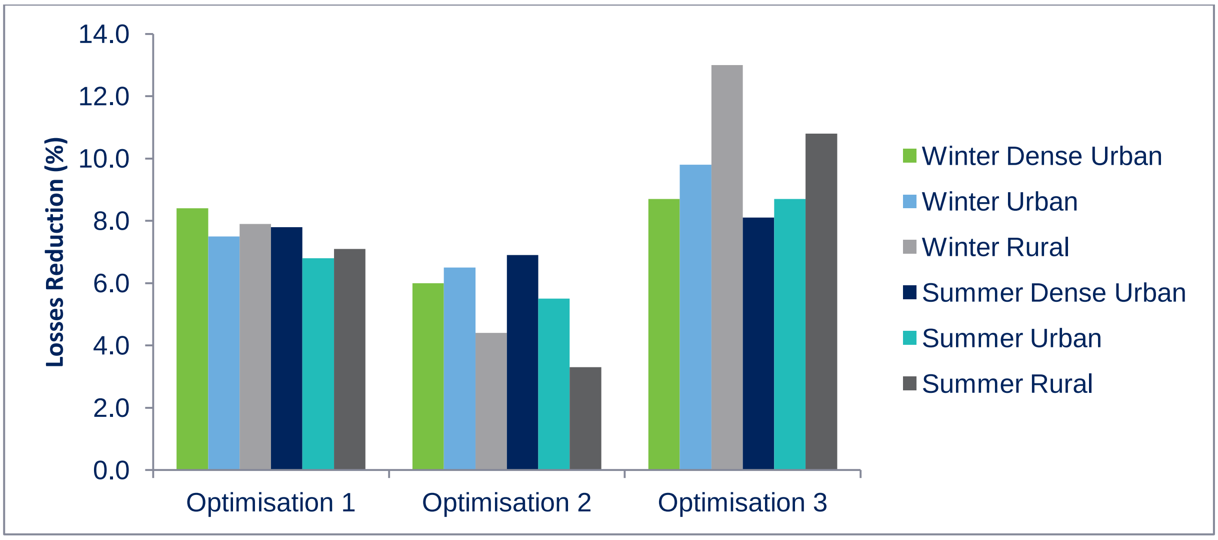


Figure 4.5: Losses reduction in 2035

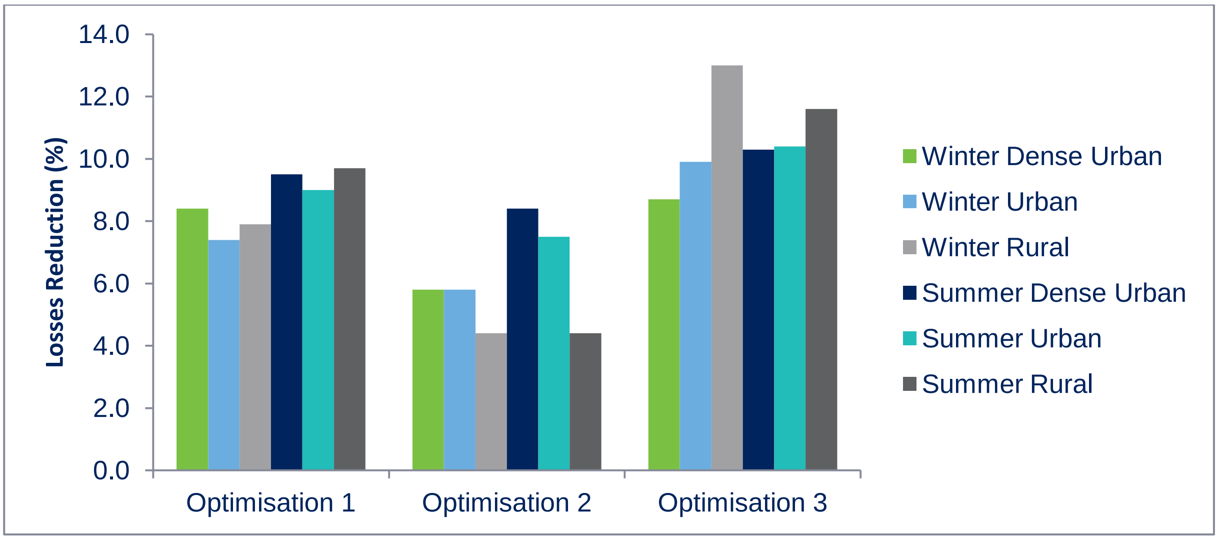
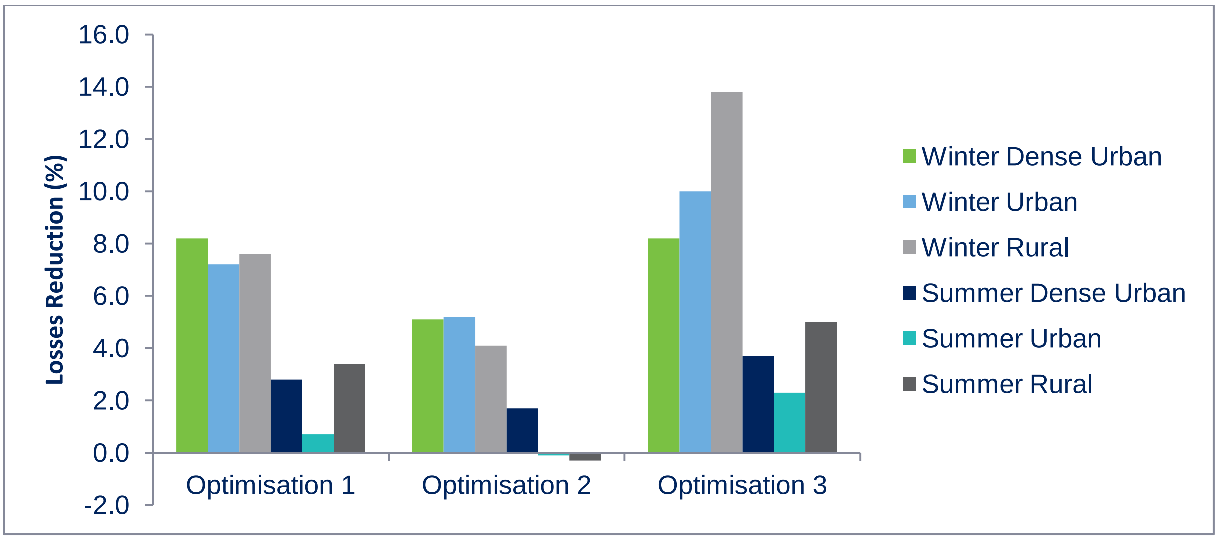


Figure 4.6: Losses reduction in 2050



The addition of capacitors to the voltage control has a negative effect on the loss reduction whereas interconnection gives a positive effect. Interconnection offers a similar benefit to losses to the use of the on-load tap changers but it does give more benefit on rural networks.

The effects increase with demand and generation growth until a 'tipping point' is reached due to the penetration of PV and subsequent reverse power flows; after this point the losses reduction reduces.

Optimisation 2 provides the lowest loss reduction as the reactive power provided by LV capacitors is too large when compared to the reactive power required by the network. In 2050 negative loss reductions are seen in summer scenarios for the urban and rural networks.

This analysis proved the hypothesis that *The Smart Street method will deliver a reduction in overall losses through network configuration and voltage optimisation*.

Trade-off between energy consumption versus losses

The analysis has shown that trade-off between energy consumption versus losses varies with the time of day and with the load on the network. However, the much larger scale of energy consumption reduction compared to losses means that the most effective solution is dominated by energy consumption. This means that it is better to optimise for energy consumption but this will still deliver a reduction in losses.

It should be noted that while the overall trade-off patterns are similar, there are some clear differences between the use of capacitors and tap position with the different load scenarios. The HV capacitor and tap positions of the OLTC transformer combine in order to help flatten the voltage profile for each load scenario. When the HV capacitors contribute more to the system (especially in the summer load scenarios), lower tap positions are selected on the OLTC transformers and vice versa.

To show the benefit of optimising off-load tap changers, further analysis was conducted. If the off-load tap changers are not changed the analysis showed fewer feasible solutions as there is less headroom for the primary transformers tap changers to be adjusted. In addition the magnitude of energy consumption and loss reduction is much less than when the off-load tap changers are optimised.

Voltage control

The analysis carried out demonstrates that optimised control of voltage setpoints for tap changers can offer significant benefits for energy consumption and losses. Optimising setpoints as the demand and generation changes provides greater benefit than just applying global setpoints. Given the positive benefits that tap changers have proven to offer, Electricity North West has amended its distribution transformer specification to include them as an option.

The capacitors were selected based on analysis using Electricity North West's current planning policy. This policy assumes a voltage drop along the feeders which could be boosted by a capacitor. When the trials were conducted it was noticed that the voltage drop is almost negligible which meant that the capacitors were rarely required to maintain the voltage. From the academic analysis it can be seen that capacitors can provide benefits for energy consumption but they have a negative effect on losses. It may be that future demand, generation and network topology means that a capacitor will offer benefits but based on these findings it is not currently Electricity North West's intention to deploy them at scale.

Interconnection

Interconnecting feeders brings benefits in terms of voltage regulation and utilisation factor of the feeders. The equivalent impedance of the interconnected feeders is smaller than just the feeder with the largest impedance which results in smaller deviations from the LV busbar voltage.

There are only certain conditions in which the network and customers would benefit from being interconnected to improve the voltage and feeder utilisation. At other times keeping the interconnection point closed would subject more customers to interruptions in the event of a fault. Therefore using the optimisation routine to only close the interconnection point when required offers benefits to both customers and the network operator.

Impact on customers' supplies

The University of Manchester, Queen's University, Belfast and project partner TNEI analysed all the power quality metrics with the different optimisation modes. The majority of the metrics were improved by voltage control and/or interconnection. Fault levels did increase with interconnection but no networks in the Smart Street trial area increased beyond current design levels. When deploying interconnection at scale it would be beneficial to check the fault level particularly as demand and generation increases.

To provide validity to this analysis it was submitted to the IET Wiring Regulations working group for review and feedback. They ran a four-week consultation on the work followed by a workshop to discuss the findings. The outcome backed up the university conclusions and proved the hypothesis that *The Smart Street method will have no adverse effects on customers' internal installations or appliances.*

Carbon benefits

This study evaluated the carbon impact of Smart Street interventions in comparison with BAU network management under different future energy scenarios. The assessment was applied to dense urban, urban and rural HV and LV network types. The analysis investigated the implications of the carbon savings in the trial networks, for the Electricity North West area and GB as a whole.

Smart Street offers the potential for wider system benefits than reducing network carbon emissions through lower energy losses and avoided asset reinforcement, by reducing electricity consumed by customers. The voltage management allows the possibility to save customers electricity while providing the same end use energy services. This reduction in overall electricity consumption is Smart Street's greatest contribution to emissions reduction at the system level. The change in electricity consumption by customers accounts for ~99% of the change in the emissions between the Smart Street interventions and the BAU case over the 2016 to 2060 timeframe.

Figure 4.7: Summary of greenhouse gas emissions savings (MtCO2e) potential with full Smart Street rollout across Electricity North West area, 2016-2060

Scenario		HV	LV Low	LV High
Two degrees	OLTC	5.13	7.24	10.84
	OLTC + Cap	5.11	7.07	10.81
	OLTC + Cap + Mesh	5.11	7.13	10.78
Slow progress	OLTC	6.3	8.91	13.33
	OLTC + Cap	6.28	8.74	13.26
	OLTC + Cap + Mesh	6.28	8.79	13.26
Steady state	OLTC	15.14	21.45	32.06
	OLTC + Cap	15.11	21.28	31.99
	OLTC + Cap + Mesh	15.11	21.3	31.93
Consumer power	OLTC	8.09	11.43	17.12
	OLTC + Cap	8.08	11.28	17.05
	OLTC + Cap + Mesh	8.08	11.31	17.05

Figure 4.8: Summary of greenhouse gas emissions savings (MtCO2e) potential with full Smart Street rollout across GB, 2016-2060

Scenario		HV	LV Low	LV High
Two degrees	OLTC	64.17	90.51	135.54
	OLTC + Cap	63.94	88.42	135.13
	OLTC + Cap + Mesh	63.94	89.15	134.73
Slow progress	OLTC	78.81	111.39	166.63
	OLTC + Cap	78.52	109.26	165.8
	OLTC + Cap + Mesh	78.52	109.93	165.8
Steady state	OLTC	189.2	268.15	400.73
	OLTC + Cap	188.84	266	399.93
	OLTC + Cap + Mesh	188.84	266.27	399.13
Consumer power	OLTC	101.15	142.92	214.02
	OLTC + Cap	100.95	141.05	213.16
	OLTC + Cap + Mesh	100.95	141.34	213.16

The results of the carbon impact assessment show that overall electricity system emissions reductions of ~5% may be possible, assuming a full application of Smart Street with OLTCs at the HV level, and 7 – 10% savings maybe possible where applied at the LV level. These results are indicative and based on a comparison to BAU practices and the assumptions of the modelling work. The range in values between the high and low case for LV level interventions highlights the range of uncertainty of scaling up from the trial networks to the nation as a whole.

The greatest savings were identified at the LV level interventions. Even without LCT uptake on the network, as in the steady state scenario, savings in order of 400 MtCO2e may be possible over the 2016 to 2060 period for GB. Where climate change mitigation strategies are pursued most rigorously (two degrees), through reduced grid emissions and LCT uptake, LV level savings of 90 MtCO2e to 135 MtCO2e may be achieved.

For HV and LV network levels, the greatest overall system savings are achieved through the application of the OLTC. The emissions associated with capacitors are in some instances not fully offset by reduced customer energy demand or network losses, meaning that little additional gain is achieved by capacitors and meshing for the system overall.

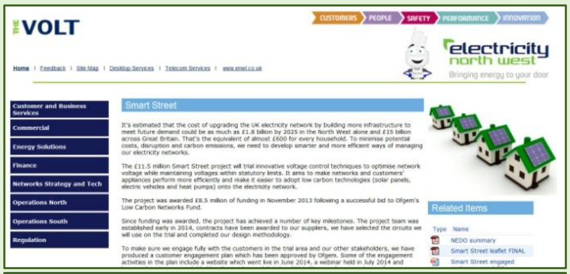
For emissions associated with the operation of the LV electricity network (assets and operational losses), network meshing through Weezap, Lynx and Gateway devices, asset emissions are offset by increased savings in avoided operational energy consumption on the network. Therefore meshing reduces the net emissions of the DNO itself. In the rural network trial, meshing had a more significant impact.

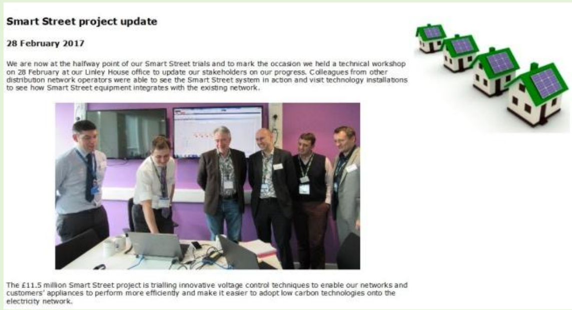
5. PERFORMANCE COMPARED TO THE ORIGINAL PROJECT AIMS, OBJECTIVES AND SDRC

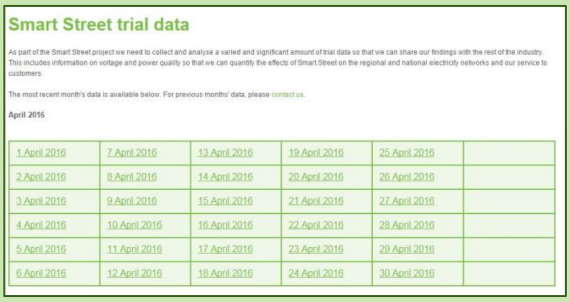
Figure 5.1: Successful delivery reward criteria

Ref	Description	Date	Evidence
9.1	**Technology workstream**		
9.1.1	Publish on the Smart Street website a report detailing the site selection methodology, and a map of the trial areas	Jul 2014	Site selection methodology Map of trial areas
9.1.2	Contracts for the supply of networks equipment signed	Jul 2014	*Copies of contracts on file*
9.1.3	Publish network equipment specifications and installation reports	Jan 2016	Equipment specification installation report
9.1.4	Publish NMS, interface and optimisation configuration and commissioning reports	Jan 2016	Commissioning and implementation report
9.1.5	Publish new LV network management protocols	Jun 2015	LV network management protocols
9.1.6	Electricity North West operational personnel, including control engineers briefed and/or trained on LV network management protocols	Jun 2015	Operations briefing
9.2	**Trials workstream**		
9.2.1	Publish the trial and test regimes design report on Smart Street website	Jan 2016	Trial design and test regime

Ref	Description	Date	Evidence
9.2.2	Publicise commencement of live trial on Smart Street website	Jan 2016	
9.2.3	Publish on Smart Street website a summary overview of each trial; with summaries of all trials and tests available on the website	Apr 2018	Trial overview
9.2.4	Confirmation received from University of Manchester and Queen's University Belfast confirming successful receipt of/completion of data transfer process	Jan 2016	*Email confirmation on file*
9.3	**Customer workstream**		
9.3.1	Send customer engagement plan and data privacy statement to Ofgem	Jun 2014	Customer engagement plan Data privacy statement
9.3.2	Deliver general awareness materials and publish on the Smart Street website	Oct 2014	Customer leaflet
9.3.3	Engaged customer panel workshop delivered by September 2014, lessons learned published on the Smart Street website by October 2014	Oct 2014	Engaged customer panel lessons learned
9.3.4	Customer contact centre training delivered and materials published on the intranet	Jul 2015	Contact centre briefing
9.3.5	Publish on Smart Street website an interim and final customer survey report	Apr 2018	First interim ECP report Second interim ECP report Final ECP report
9.4	**Research workstream**	**Date**	
9.4.1	Publish on Smart Street website an interim and final HV and LV voltage and configuration optimisation study report	Feb 2017	Interim HV and LV voltage and configuration optimisation study
		Apr 2018	Final HV and LV voltage and configuration optimisation study

Ref	Description	Date	Evidence
9.4.2	Publish on Smart Street website an interim and final retrofit design and operation of interconnected LV networks study	Feb 2017	Interim design and operation of interconnected LV networks study
		Apr 2018	Final design and operation of interconnected LV networks study
9.4.3	Publish on Smart Street website an interim and final cost benefit assessment study	Feb 2017	Interim cost benefit assessment study
		Apr 2018	Final cost benefit assessment study
9.4.4	Publish on Smart Street website the interim and final carbon impact assessment report	Feb 2017	Interim report on carbon accounting
		Apr 2018	Final report on carbon accounting
9.4.5	Publish on IET.TV and Smart Street website the results from the consultation process on impact on customers' electrical installations from application of the Smart Street method	Apr 2018	Workshop recording
9.4.6	Produce and publish optimisation implementation strategy	Feb 2018	Optimisation implementation strategy
9.5	**Learning and dissemination workstream**		
9.5.1	Smart Street website and social media forums live	Jul 2014	Project website
9.5.2a	Publicise Smart Street within Electricity North West in monthly team brief pack and Volt (intranet) and/ or Newswire (bimonthly colleague magazine)	Jan 2014	 

Ref	Description	Date	Evidence
		Sep 2014	 Getting ready for Smart Street... more 23 Sep 2014
		Jun 2015	 From the Volt...what's been in the news this week Next steps for Smart Street Our £11.5 million Smart Street project is trialing innovative voltage control techniques to make networks and customers' appliances perform more efficiently and make it easier to adopt low carbon technologies (solar panels, electric vehicles and heat pumps) onto the electricity network. Since the project began last year we have installed most of the technology needed for the trials to take place on parts of the network serving 67,000 customers in the Manchester, Wigan, Egremont and Wigton areas. We have also issued a leaflet to customers served by the trial circuits and contacted customers affected by the installation of Smart Street equipment. We will be holding briefings for our contact centre teams next month ahead of the trial start date in September 2015. As part of the Smart Street project we need to review our procedures and codes of practice relating to our low voltage networks. The review will influence the changes that Electricity North West and other distribution network operators might need to make if the Smart Street trial is successful and subsequently rolled out across Great Britain. The review document entitled LV network management protocols is available to view on The Volt. You can find out more about Smart Street and our other low carbon projects at www.enwl.co.uk/thefuture Back to top
		Feb 2017	 **Smart Street project update** **28 February 2017** We are now at the halfway point of our Smart Street trials and to mark the occasion we held a technical workshop on 28 February at our Linley House office to update our stakeholders on our progress. Colleagues from other distribution network operators were able to see the Smart Street system in action and visit technology installations to see how Smart Street equipment integrates with the existing network. The £11.5 million Smart Street project is trialling innovative voltage control techniques to enable our networks and customers' appliances to perform more efficiently and make it easier to adopt low carbon technologies onto the electricity network.
		Feb 2018	 Connect The weekly bulletin for our people Stay connected... electricity north west Bringing energy to your door ISSUE 189 23 February 2018 LATEST NEWS **End of the road for Smart Street** Our £11 million innovation project is almost complete. Initial reports show that Smart Street will deliver energy savings by stabilising and reducing voltage – without affecting our customers' power quality. Using intelligent software to control smart devices installed on our low voltage network, Smart Street stabilises and lowers voltage levels, which saves money for customers by making their electrical appliances perform more efficiently. The project will also help prepare the electricity network for the expected increase in low carbon technologies such as electric vehicles, heat pumps and solar panels. The trials were carried out over a two-year period and involved a number of substations serving 67,000 customers in Manchester, Wigan, Wigton and Egremont. A series of focus groups were held with some of the customers in the trial to understand if the new system affected their electricity supply. All the customers confirmed that they hadn't noticed any changes. Project manager Ben Ingham said: "Smart Street has proved that controlling voltage on our low voltage network brings a number of benefits to customers. It can reduce their electricity bills, reduce carbon emissions and will provide more flexible solutions to help us connect low carbon technologies to the network – all without impacting power quality." Next week, stakeholders from across our industry will attend our final learning event in Manchester to hear about the results of the trials. The project closedown report and a series of detailed academic reports will be published on our website in April 2018.
9.5.2b	Publish advertorials	Jul 2014	Advertorial
		Jul 2015	Advertorial
		Feb 2016	Advertorial
		Feb 2017	Advertorial
		Apr 2018	Advertorial

Ref	Description	Date	Evidence
9.5.3	Active participation at four Annual LCNI conferences	2014	Slide presentation
		2015	Slide presentation
		2016	Slide presentation
		2017	Slide presentation
	Hold two Smart Street webinars	Jul 2014	Webinar recording Webinar slides
		Apr 2015	Webinar recording Slide presentation
	Hold three Smart Street knowledge sharing events	Oct 2015	Event slides
		Feb 2017	Event slides
		Feb 2018	Event slides
9.5.4	Raw monitoring data is available via Smart Street website	Apr 2016	 Webpage
9.5.5	Project progress reports issued in accordance with Ofgem's June – December production cycle and publish on Smart Street website.	Jun 2014	Project progress report
		Dec 2014	Project progress report
		Jun 2015	Project progress report
		Dec 2015	Project progress report
		Jun 2016	Project progress report
		Dec 2016	Project progress report
		Jun 2017	Project progress report
		Dec 2017	Project progress report
9.6	**Closedown and business as usual handover phase**		
9.6.1	Smart Street closedown report issued to Ofgem and published on Smart Street website	Apr 2018	
9.6.2	Publish on Smart Street website Electricity North West's approach to managing LCT clustering	Apr 2018	Management of LCT clusters

Smart Street hypotheses

The Smart Street method will deliver a reduction in customers' energy consumption (research workstream).

The analysis of the data generated during the Smart Street trials indicated that a reduction in energy consumption of up to 10% could be expected on the LV networks.

Customers within the Smart Street trial area will not perceive any changes in their electricity supply (customer workstream).

Following extensive engagement with customers in the trial areas over the course of the project, there were no reports of any issues relating to the implementation of the Smart Street techniques.

The Smart Street method will have no adverse effects on customers' internal installations or appliances (research workstream).

As part of the project a consultation was held in conjunction with the Institute of Engineering and Technology (IET) to explore the possible effect of the techniques being trialled on customer installations. The outcome of this was that while there was an increase in fault level, albeit still within design limits, the concurrent reduction in earth loop impedance would lead to faster fault clearances. Overall the consultation found no adverse impacts on customer installations should be expected as a result of implementing Smart Street.

The Smart Street method is faster to apply than traditional reinforcement, supports accelerated LCT connection and reduces network reinforcement costs (research workstream).

The Weezap and Lynx devices are both retrofit solutions and as such can be installed much faster than any reinforcement work. Installation of the LV capacitors is more involved but again is still easier than a full cable overlay or distribution transformer replacement. The installation of OLTCs requires the transformer to be replaced, however benefits can be achieved by adjusting the off-load tap changer to a more suitable position.

The Smart Street method facilitates the prioritisation of the range of solutions across differing LCT adoption scenarios based on a cost benefit analysis to accommodate customers' uptake of LCTs (research workstream).

From the outcomes of the analysis of the data it has been possible for Electricity North West to create a set of scenarios and understand the optimum combination of equipment to provide the most benefit. From the data it is apparent that the benefits of OLTCs and interconnection are universal across the network conditions encountered.

The Smart Street method will deliver a reduction in overall losses through network configuration and voltage optimisation (research workstream).

The data generated by the project has shown that even when the system is optimising the network to reduce the energy consumption of the LV network there is a concurrent reduction in HV losses. The system has been shown to offer reductions in losses of up to 15%.

The Smart Street method facilitates real time control of a portfolio of LV network solutions, using retrofit technologies with application combined or in isolation (technology workstream).

All the devices installed as part of the project were linked into the SP5 system and were shown to be controllable from this point.

5.1 Customer engagement and feedback

Communicating with customers in the trial area

This activity was successful in establishing an ECP consisting of three groups of customers, with the objective of exploring the most effective method of communicating Smart Street to customers in the trial regions. The panel influenced the design and evaluated modifications to a leaflet which was sent to customers on Smart Street trial circuits.

Monitoring the effects of the Smart Street trials on customers (ECPs)

This activity was successful in engaging with domestic and industrial and commercial (I&C) customers on Smart Street trial circuits. An ECP was convened to participate in qualitative research which explored the hypothesis that customers would not perceive any changes in their electricity supply as a result of Smart Street. This hypothesis was proven via a two stage approach, which involved a series of focus groups, held mid-way through the trial period and at the end of the trial period, to monitor any changes in customers' perception of their electricity supply. This research was successful as it provided sufficient evidence that the Smart Street method had no adverse effects on customers' perceptions of power quality thus supporting the hypothesis that *Customers within the Smart Street trial areas will not perceive any changes in their electricity supply.*

Monitoring the effects of the Smart Street trials on customers in trial areas

This activity was successful in developing a robust framework to ensure that all enquiries and complaints received by Electricity North West, via its traditional reporting mechanisms, were monitored to highlight any power quality issues that might potentially be related to the Smart Street trials. All potential Smart Street-related enquiries were handled on an individual basis and in consultation with the customer. In parallel, power quality and voltage issues were recorded and actively managed throughout the trial period to ensure that if any such problem arose on a Smart Street circuit, it was quickly identified, irrespective of whether this was raised by a customer or generated from another source.

The absence of voltage or power quality problems that could be directly attributed to the Smart Street method supports the transferability of the method and suggests it can be applied across the wider GB network without customer impact.

5.2 Technology implementation and effectiveness

Smart Street aimed to demonstrate that by actively optimising the network it was possible to reduce LV energy consumption and reduce HV losses; and that by doing so it could deliver financial and carbon emissions savings, in addition to facilitating the installation of LCTs at customer premises.

By using a combination of retrofit technologies, existing equipment in the primary tap changers along with the newly installed apparatus, Smart Street was shown to be both cost-effective and faster than traditional reinforcement works, thus allowing faster connection of LCTs to the network.

During the initial phases of the installation work some issues were discovered with the capacitor units leading to a delay. As a consequence of this, a four-month extension to the project was agreed with Ofgem.

Further details on the installation of the equipment can be found in the installation and commissioning report.

5.3 Smart Street trials

The Smart Street test regime was developed to rigorously test the hypotheses of the project. The trials sought to prove that optimised management of voltages and configuration of the HV and LV networks can produce benefits in terms of reduced energy consumption and losses which can lead to increased headroom for the adoption of LCTs and deferment of network reinforcement. In addition to the above, the trials needed to demonstrate that the methodology did not cause any impact on customers' quality of supply.

The test regime was developed at the start of the project; however difficulties were encountered with the installation of some equipment and issues developed with the optimisation software. This led to a review of the test regime in conjunction with the universities to maximise the learning.

The test regime and trials provided the University of Manchester and Queen's University, Belfast with sufficient data to carry out a comprehensive assessment of the Smart Street techniques.

5.4 Evaluating and enabling the benefits of the Smart Street solution

The Smart Street project was developed to show how the application of innovative technology to augment the performance capabilities of existing networks can reduce energy costs for customers, improve carbon efficiency and defer reinforcement.

The three key incremental steps are the application of:

- Co-ordinated voltage control, using on-load tap changing transformers and capacitors, across EHV, HV and LV networks
- Interconnecting traditionally radial HV and LV circuits and assuming control of these networks within the control room
- Real-time co-ordinated configuration and voltage optimisation of HV and LV networks.

The Smart Street test regime was designed to prove the following trial hypotheses:

- Smart Street will deliver a reduction in customers' energy consumption
- Smart Street will have no adverse effects on customers' internal installations or appliances
- Smart Street is faster to apply than traditional reinforcement, supports accelerated LCT connection and reduces network reinforcement costs
- Smart Street facilitates the prioritisation of the range of solutions across differing LCT adoption scenarios based on a cost benefit analysis to accommodate customers' uptake of LCTs

- Smart Street will deliver a reduction in overall losses through network configuration and voltage optimisation.

Following assessment of the trial data the following benefits have been found:

- Energy consumption can be reduced by around 5 – 8% through the use of optimised voltage control and network configuration
- If global setpoints are applied to the LV network, and not adapted as demand and generation changes, the energy consumption reduction is around 1 – 4%. Therefore greater benefits are realised when optimising the voltages
- The use of on-load tap changers provides the majority of the benefit
- Analysis showed that the use of interconnection particularly can have a positive effect on the majority of power quality metrics. There can be a negative effect on fault level but it is not shown to increase beyond design levels – this should be monitored as the demand and generation change on the network
- The LV network is more robust than previously thought. The monitoring and analysis has shown that headroom does already exist to cater for the adoption of some LCTs but as this adoption increases, the use of voltage control and interconnection can provide even more headroom, thereby reducing the need for reinforcement
- Customers benefit from energy savings. The analysis showed annual economic savings up to £70 per customer from Smart Street deployment
- Smart Street can save £44m across Electricity North West and £519m across GB by deferment of reinforcement
- Smart Street can deliver up to 15% reduction in losses depending on the network type, amount of generation and levels of demand. The use of on-load tap changers and interconnection provide the greatest benefit for losses
- The total carbon savings to GB from the application of all the Smart Street techniques could be as much as 400 $MtCO_2e$ over the 2016 to 2060 period for GB. The majority of the savings comes from reduced energy consumption.

6. REQUIRED MODIFICATIONS TO THE PLANNED APPROACH DURING THE COURSE OF THE PROJECT

6.1 Customer engagement and feedback

No fundamental changes were required to the planned approach; however, a number of minor modifications were made to the planned approach:

Communicating with customers in the trial area

Customers on the trial networks who participated in the ECP

The original Smart Street customer research proposal followed a similar methodology to that deployed in the CLASS project which affected 485,000 customers served by 60 primary substations. This research involved robust quantitative surveys, which aligned with the CLASS testing regime and involved repeated engagement with 1,300 customers across the trial period.

CLASS research provided considerable customer insight and confirmed that customers are not affected by voltage control techniques. On this basis and as the Smart Street technique was designed to ensure that power quality and supply voltage is maintained well within statutory limits, Ofgem determined that a comparatively extensive piece of customer research was unnecessary.

As such, research to prove the hypothesis that *Customers within the Smart Street trial areas will not perceive any changes in their electricity supply* was limited to a smaller qualitative study with a representative sample of customers from across the trial region. This research involved direct customer consultation with an ECP in a series of focus groups held mid- and post-trial.

A further project commitment was made to conduct more detailed analysis of the survey and technical data from the three substations common to both projects, to determine if customers involved in the Smart Street trials were more, less or representative of the survey population across all the CLASS primary substations in terms of sensitivity. Detailed analysis of this nature was not required as no customer sensitivity was noted among customers on Smart Street circuits.

For the same reason, it was not necessary to examine possible variations relating to distance of households from the substations (which was originally identified as a potential issue specific to the Smart Street trials).

While there were notable differences in the research methodology, the findings demonstrate that customers in Smart Street regions were representative of the CLASS trial population in having observed no detriment to power quality. On this basis, it can be concluded that, in common with the CLASS method, the application of Smart Street techniques is indiscernible to customers. These findings indicate that Electricity North West can be confident that any future implementation of Smart Street across the wider GB network could be applied without detrimental customer impact.

Customers on the trial networks who may have experienced short duration interruptions

A project commitment was made to inform all customers, in the trial locations, of a theoretical risk of an increase in SDIs, due to the interconnected configurations to LV networks. It had been intended to communicate this information through project awareness materials. However, the initial ECP, which had been specifically convened to evaluate communication materials, believed that this information was negative and confusing as it contradicted positive messages about network and customer benefits of Smart Street. The ECP also perceived that there would be little if any discernible customer impact of Smart Street. On the basis of this feedback, the project team anticipated that it would be unable to explain the theoretical increase in SDIs sufficiently well in a concise customer leaflet, without causing unnecessary confusion or introducing disproportional concern among the intended recipients. Therefore information about SDIs was omitted. This modification met the undertaking set out in the CEP to consider feedback and '*revise plans going forward in order to continually improve the customer engagement strategy'*. This modification benefitted the project and the customer experience overall.

In addition to the two minor modifications outlined above, a number of enhancements were made to the planned approach to ensure that the project team was as transparent as possible in all activities that had the potential to cause customer impact. The following measures were implemented to provide the best possible service for customers on trial circuits.

Testing the effectiveness of the customer leaflet

Following distribution of the Smart Street leaflet to customers on trial circuits, a small-scale piece of quantitative research was undertaken to assess the effectiveness of the leafleting campaign. This study was not a required modification but was conducted to enhance learning from the activity, specifically to ascertain customer reaction to the leaflet and gauge the return on investment of a general awareness campaign of this nature.

Over a third of customers surveyed recalled receiving the leaflet and it was generally well received and understood, fulfilling its objectives. There was a low level of awareness about Electricity North West as a company and its role and responsibilities in the electricity industry and this remains a significant barrier to reaching customers through printed materials.

Communicating with customers about street furniture installation

Approximately 1,500 advisory letters were sent to customers with properties in sight of new enabling technologies and those likely to be subject to short-term inconvenience associated with construction work. Early and proactive engagement with these customers was critical in achieving customer acceptance. This mitigated the risk of complaints and provided sufficient opportunity to modify the technical design, most economically, in circumstances where public discord necessitated compromise in the positioning of new technology. A total of 37 customer enquiries (23 directly attributable to the installation of new street furniture) were received and amicably resolved during the period by committing to remove the equipment post-trial.

Removal of street furniture

A number of technical specification issues, which could not have been foreseen at the outset of the project, will prevent utilisation of the enabling technologies as a BAU solution and arrangements are in place to decommission the equipment. The project team committed to remove any cabinets that generated customer complaints; however, it is considered inappropriate to retain redundant street cubicles, once technologies have been decommissioned. Consequently, all street furniture installed to house capacitors and end-point monitors are scheduled to be removed.

The resistance to new street furniture, in certain regions, was reinforced by follow-up enquiries received towards the end of the project from customers requiring reassurance that it remained the intention to remove cabinets, post trial.

6.2 Technology implementation and effectiveness

All the equipment installed during the project operated successfully during the trials, however a number of design issues were uncovered that would require a more polished solution for BAU than that utilised during the trials.

During the project the contactors used to control the LV capacitors were found to be overly susceptible to corrosion due to the environment which meant that annual maintenance, and the replacement of several sets, was required. While this was acceptable during the trials to prove the efficacy of the units, a more robust design would be required for a BAU solution.

A number of the sites used during the trials had issues with maintaining communications due to the signal strength of the 3G network. As part of the trials, high gain aerials were installed with some success but for a BAU approach other solutions, such as roaming SIMs or NarrowBand-Internet of Things, should be considered to maximise the availability of the equipment for optimisation.

The Lynx devices had additional communications issues, due to their location in a subterranean pit, which was resolved by the addition of an aerial pillar external to the installation. Subsequently a number of the sites began to suffer from water ingress issues. The resulting investigations identified that this situation was due to the aerial cable not being sealed, which provided an escape route for air. Once this was rectified by a temporary solution there was no reoccurrence of the issue. Following discussions with the manufacturer the bell housing which encloses these devices is being redesigned to incorporate an IP68-rated connection point for the aerial cable.

Due to the location of some of the Lynx devices it was found that a hot spot within the device could rise in temperature to a level where the electronics were automatically depowered to protect them against damage. For the trials these sites had a fan retrofitted to reduce the hot spot temperature as a temporary measure. However, for BAU devices the electronics will be constructed with higher rated components to remove this requirement.

As part of the capacitor installation it was found that existing switchgear installed on the network was not rated to break capacitive currents. As such an interlocking system was installed on the ground-mounted units to ensure employee safety. This required the local capacitor circuit breaker to be operated first to disconnect the unit.

Additionally the HV capacitors were housed inside glass reinforced plastic (GRP) enclosures to provide additional security for the installations. Due to the required internal clearances these housings were quite substantial and required planning consents to be installed as they could not be sited within the grounds of existing substations. These were granted on the understanding that the equipment would be removed on completion of the trials.

6.3 Smart Street trials

During the installation phase there were safety-related issues with some of the equipment which led to modifications and a subsequent delay in commissioning these assets. Data was collected when these devices were inhibited; therefore the devices were enabled every time optimisation was active. This represented a slight deviation from the trial regime proposed at the beginning of the project.

During the trials issues arose with the Spectrum software and its optimisation algorithm which led to erroneous setpoints being sent to some devices. After a period of consultation with Siemens and their resulting investigations it became apparent that some of the base parameters needed to be altered. This meant that there could have been issues comparing data collected later in the project, with data collected before the parameters were changed. In order to maximise the learning following this change Electricity North West worked with its academic partners to devise a new trial regime.

In the new regime Wigton was used as a ‘control’ area. In the other areas different devices were enabled on different weeks to understand the effects of the different combinations. This regime continued until the end of the trials in December 2017.

6.4 Evaluating and enabling the benefits of the Smart Street solution

There was no change to the planned approach.

Figure: 6.1: Significant variance in expected costs

£000s Cost Category	Total Forecast	Budget	Variance	Reasons for >10% variance
HV & LV network management and interconnection – labour	319	305	5%	
Network configuration & voltage optimisation – labour	450	431	4%	
Project management, planning, policy and training – labour	1,204	1,152	5%	
Data preparation – equipment	204	285	-29%	Use of the SP5 system to store data as opposed to a separate system
HV & LV network management & interconnection – equipment	2,265	2,229	2%	
HV & LV voltage control – equipment	811	721	13%	Additional costs associated with modifications to equipment
Customer engagement & survey – contractors	109	110	-1%	
HV & LV voltage control – contractors	368	350	5%	
LV Network management & interconnection – contractors	162	161	1%	
Network configuration & voltage optimisation – contractors	356	381	-7%	
Peer reviews, support & customer research – contractors	115	142	-19%	Efficiencies in the review process led to savings on TNEI time
Research – technical – contractors	651	626	4%	
Research – CBA & CIA – contractors	145	189	-24%	Correction of a misallocation between lines on the original budget
Network configuration & voltage optimisation – IT	1,098	1,090	1%	
HV & LV network management & interconnection – contingency	0	272	-100%	Not required
HV voltage control – contingency	64	426	-85%	Spend to cover extra project management following project extension
Dissemination, policy, training & trials – contingency	0	82	-100%	Not required
Network configuration & voltage optimisation – contingency	0	235	-100%	Not required

£000s Cost Category	Total Forecast	Budget	Variance	Reasons for >10% variance
Decommissioning	111	39	184%	Issues with the equipment lead to more being removed than anticipated
Technology build and trial data – other	25	87	-71%	Use of free to access data meant the allowance for purchase of data sets was not required
Learning & dissemination – other	137	133	4%	
Accommodation – other	103	103	1%	

7. UPDATED BUSINESS CASE AND LESSONS LEARNED

7.1 Customer benefits

Customers benefit from reduced energy consumption, which results in savings from market imports, balancing services, transmission charges, distribution charges and taxes. The trend at both LV and HV levels are consistent, ie, greater energy savings and benefits for customers are expected in scenarios with higher demand growth, eg, increased EV and HP uptake. However, if the savings are normalised per customer, it is evident that applications of Smart Street at LV tends to be more beneficial for customers.

The average savings per customer was estimated for different strategies applied to the selected dense urban, rural and urban networks and are shown in Figures 7.1 and 7.2. These also demonstrate the average savings per customer for a typical Electricity North West and GB network, based on the relevant network composition obtained from the Transform model. Assuming that the selected LV and HV networks provide a reasonable representation of the relevant types of networks throughout the country, the results can be scaled to a region and Electricity North West or GB levels by scaling the results by the number of networks or network composition.

Figure 7.1: Average savings per customer connected to the LV network

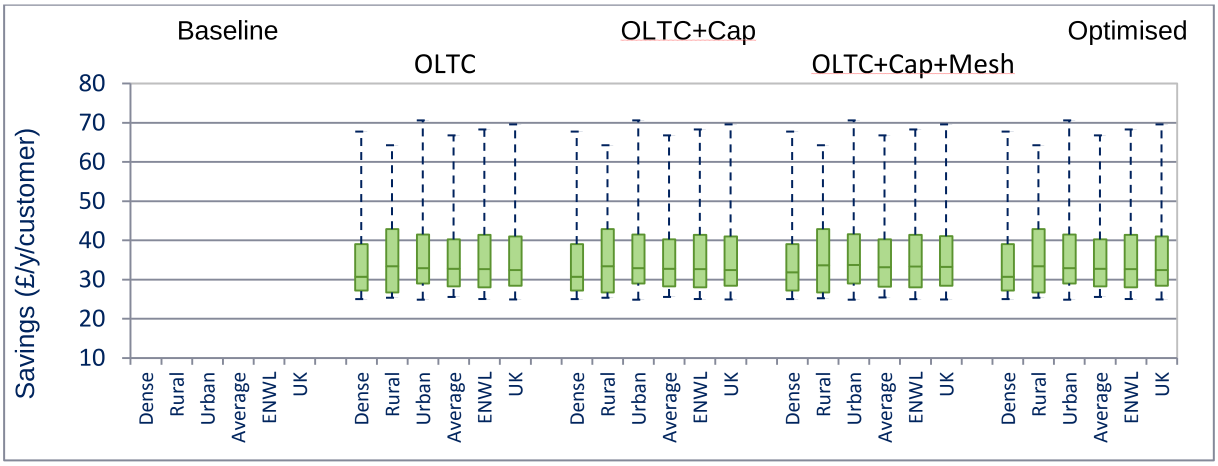
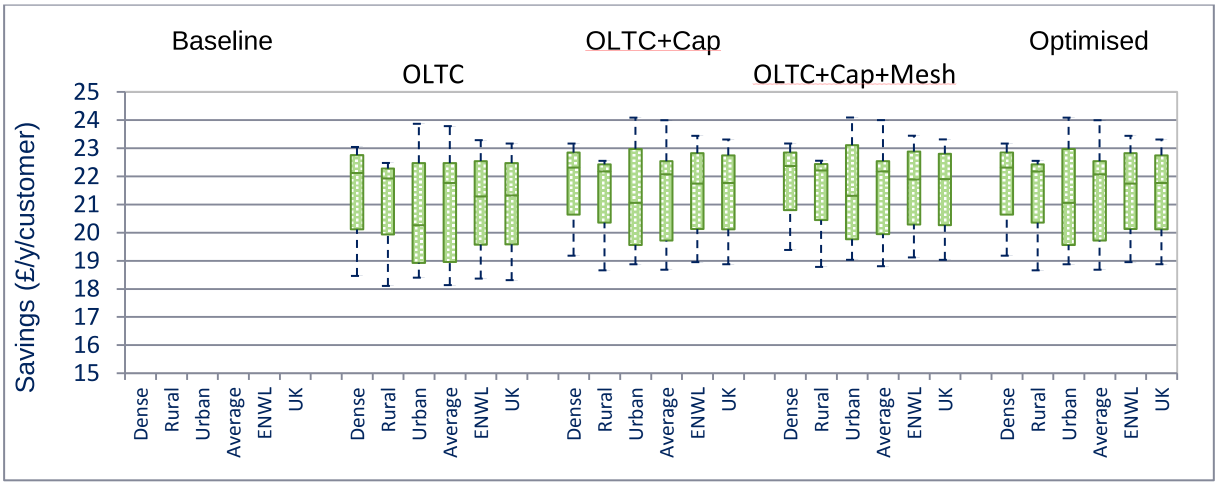


Figure 7.2: Average savings per customer connected to the HV network



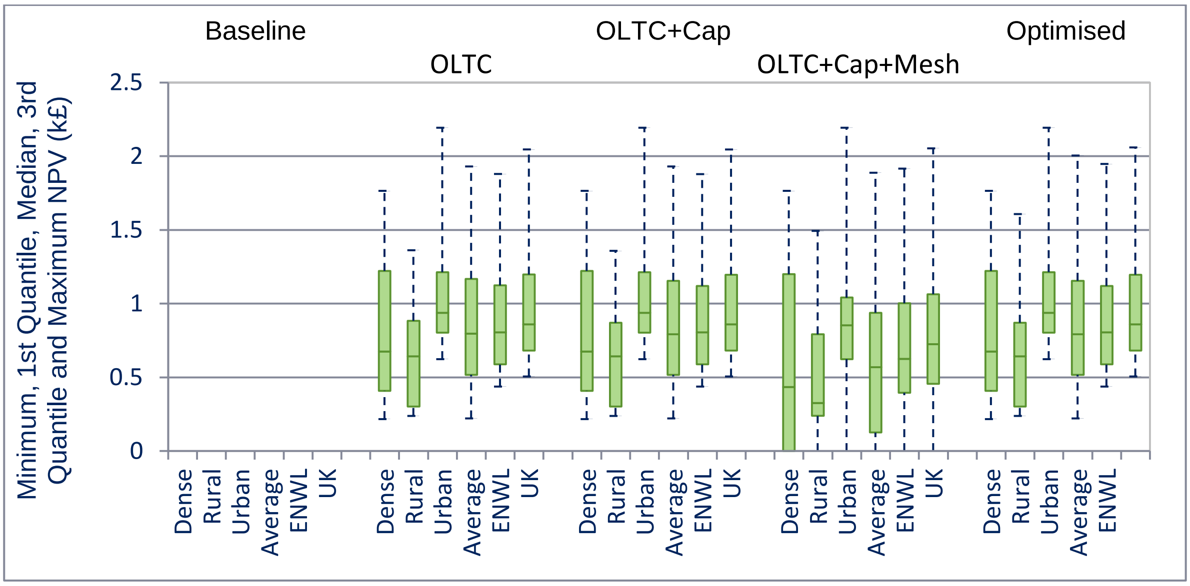
The results highlight that the value per customer does not change significantly in different networks. It is also clear that Smart Street leads to more customer benefits when applied at the LV level. This is reasonable considering that more Smart Street technologies are applicable to LV networks (eg Weezaps and Lynx). The results show annual economic savings of up to £70.

7.2 Financial benefits

The Smart Street financial analysis was carried out by the University of Manchester using the Ofgem CBA as a basis.

The Net Present Value (NPV) was calculated on a per network basis out to 2060 and Figure 7.3 shows the benefit per network and optimisation type.

Figure 7.3: NPV per network type



This graph shows a benefit of around £800 per LV network. In the full submission Electricity North West stated that Smart Street is applicable to 64% of its network and 72% of GB networks.

Using this benefit per network and scaling to 64% and 72% for Electricity North West and GB respectively, results in savings of £44m and £519m out to 2060 in deferred reinforcement. The Ofgem CBA is based on deferment of reinforcement only and not avoidance. If using Smart Street completely avoided the need for reinforcement the benefits would be greater than those discussed here.

It should be noted that the financial benefits have been calculated based on the current cost to purchase the individual items. In the case of equipment such as distribution transformers with on-load tap changers, these are relatively new items to the market and as such are currently quite costly. As the use of this type of equipment increases, it is expected that the cost will reduce and therefore increase the financial benefits of Smart Street.

7.3 Carbon benefits

Smart Street offers the potential for wider system benefits than reducing network carbon emissions through lower energy losses and avoided asset reinforcement, by reducing electricity consumed by customers. Voltage management allows the possibility to save customers electricity while providing the same end use energy services. This reduction in overall electricity consumption is Smart Street's greatest contribution to emissions reduction at the system level. The change in electricity consumption by customers accounts for ~99% of the change in the emissions between the Smart Street interventions and the BAU case over the 2016 to 2060 timeframe.

Figure 7.4: Summary of greenhouse gas emissions savings (MtCO2e) potential with full Smart Street rollout across Electricity North West area over 2016-2060 period

Scenario		HV	LV Low	LV High
Two degrees	OLTC	5.13	7.24	10.84
	OLTC + Cap	5.11	7.07	10.81
	OLTC + Cap + Mesh	5.11	7.13	10.78
Slow progress	OLTC	6.3	8.91	13.33
	OLTC + Cap	6.28	8.74	13.26
	OLTC + Cap + Mesh	6.28	8.79	13.26
Steady state	OLTC	15.14	21.45	32.06
	OLTC + Cap	15.11	21.28	31.99
	OLTC + Cap + Mesh	15.11	21.3	31.93
Consumer power	OLTC	8.09	11.43	17.12
	OLTC + Cap	8.08	11.28	17.05
	OLTC + Cap + Mesh	8.08	11.31	17.05

Figure 7.5: Summary of greenhouse gas emissions savings (MtCO2e) potential with full Smart Street rollout across GB over 2016-2060 period

Scenario		HV	LV Low	LV High
Two degrees	OLTC	64.17	90.51	135.54
	OLTC + Cap	63.94	88.42	135.13
	OLTC + Cap + Mesh	63.94	89.15	134.73
Slow progress	OLTC	78.81	111.39	166.63
	OLTC + Cap	78.52	109.26	165.8
	OLTC + Cap + Mesh	78.52	109.93	165.8
Steady state	OLTC	189.2	268.15	400.73
	OLTC + Cap	188.84	266	399.93
	OLTC + Cap + Mesh	188.84	266.27	399.13
Consumer power	OLTC	101.15	142.92	214.02
	OLTC + Cap	100.95	141.05	213.16
	OLTC + Cap + Mesh	100.95	141.34	213.16

The results of the carbon impact assessment show that overall electricity system emissions reductions of ~5% may be possible, assuming a full application of Smart Street with OLTCs at HV level, and 7 – 10% savings maybe possible where applied at LV level.

The greatest savings were identified at the LV level interventions. Even without LCT uptake on the network, as in the steady state scenario, savings in order of 400 MtCO2e may be possible over the 2016 to 2060 period for GB. Where climate change mitigation strategies are pursued most rigorously (two degrees), through reduced grid emissions and LCT uptake, LV level savings of 90 MtCO2e to 135 MtCO2e may be achieved.

7.4 Non-quantified benefits

While the Smart Street method demonstrates significant potential financial and carbon saving benefits, there are also a number of non-quantifiable benefits that should be noted. The first of these is how the solution will inform RIIO-ED2 discussions on potential incentives and obligations on energy companies for increasing customers' energy efficiency to assist the UK's carbon targets.

The Smart Street method allows a customer's appliances to operate more efficiently which can extend the life of the equipment as well as the more immediate benefit in reduced operating costs.

The learning from this project could be used to quantify future incentive structures in energy efficiency and social obligations.

The Smart Street project demonstrates innovation in the novel use of dynamic voltage regulation techniques to drive the greater utilisation of existing assets. In common with previous Second Tier projects, C_2C and CLASS, Smart Street follows the strategy of generating additional value for customers and stakeholders from maximising the use of existing assets.

The Kelvatek Weezap and Lynx devices can provide added benefits for fault response. The reclosing feature of the Weezap can be used in the event of a transient fault to restore supplies. Additionally the devices record data during a fault which can be used by the Fault Support Centre (developed under an Electricity North West IFI project) to provide fault locations. This visibility provides significant network and customer benefit by reducing customer minutes lost as the fault can be traced and repaired far quicker than using traditional fault location techniques. These devices record data continuously and when analysed may be able to predict a developing fault allowing proactive fault repairs before there are any customer interruptions.

All of the devices deployed in Smart Street and the data recorded by them have provided Electricity North West with new insight into the operation of the LV networks. This data has shown that the longstanding planning policy of applying a global 7% voltage drop to all LV feeders may not be correct and it may be more beneficial to have some more granular rules for planning. This issue will need discussion both at a company and industry level to understand and agree a way forward.

8. LESSONS LEARNED FOR FUTURE INNOVATION PROJECTS

8.1 Customer engagement and feedback

Communicating with customers in the trial area

Do not have pre-conceived ideas about customer information preferences

Due to the success of the ECP activity in influencing a customer communications strategy in C_2C, an identical approach was adopted in the subsequent Second Tier project, CLASS. However, while the process undertaken was the same, the outcome of the CLASS ECP was quite different as participants preferred to be furnished with more information about the CLASS project. Likewise, the Smart Street panel was clear from the outset that it was important to provide customers in the trial regions with quite detailed information about the project and potential impacts. Nevertheless, previous learning has shown that pre-conceived ideas need to be tested given that each project is perceived differently by customers who tend to focus primarily on the personal risks and benefits of a proposal.

Future projects should share multiple versions of detailed and abridged communication materials, designed to provide the same information in a variety of different formats, tone, focus and graphics.

Communicating with customers about street furniture installation

Proactive customer engagement is required, in addition to general awareness material, where new enabling technology is installed in sight of properties

Background

Customers are unlikely to welcome new street furniture in sight of their property. A degree of resistance had been anticipated in some residential areas to the installation of new enabling technologies. These were LV capacitors and end-point monitors housed in metal cabinets in the public footpath. A comprehensive planning exercise, including on-site surveys, established not only connection feasibility and compliance with Smart Street technical design criteria, but ensured each new piece of street furniture was installed in the least obtrusive position for customers.

Cabinets housing LV capacitors and end-point monitors are generally visible to between four and six residents. These customers received the general customer awareness leaflet, distributed in October 2014, but Electricity North West recognised the importance of additional customer engagement with those most directly impacted. It was not feasible or practical to consult with property owners on an individual basis, therefore before construction began on site, letters were sent to customers whose homes and business premises were in the immediate vicinity or in sight of Smart Street enabling technology.

To ensure any customer concerns were addressed quickly, efficiently and sensitively a complaints process was embedded and each enquiry was handled on a case by case basis by a designated member of the Smart Street customer workstream. This process allowed customer objections to be resolved appropriately, before installation work began. This proactive customer strategy was successful in fully engaging with all customers directly impacted by new technology installation work. It reduced the number of anticipated enquiries. It also maintained a good relationship and facilitated an amicable resolution in cases where customers raised concerns or objections. This allowed sufficient time to modify the technical design, where appropriate, and importantly facilitated a redesign before the start of installation work, thereby negating costly post-construction relocation costs.

Learning outcome

Early and proactive engagement with those customers most directly affected by the installation of new street furniture is critical in achieving customer acceptance. It mitigates the risk and impact of complaints and provides sufficient opportunity to modify the technical design, most economically, in circumstances where public discord necessitates compromise in the location of new technology. Early and proactive customer engagement also maximises the opportunity to reach appropriate resolutions without adversely impacting on construction timescales.

Resolution of customer installation enquiries/complaints

Background

A total of 27 customer enquiries were received following distribution of the targeted advisory letter to properties in sight of new street furniture, 23 of which were expressions of concern from domestic customers. As could reasonably have been anticipated, socio economic factors appear influential in public resistance to new street furniture and public opposition was largely from the more affluent residential trial areas. Objections fell into the following categories:

- General visual amenity
- Perceived risk of anti-social behaviour, where residents considered street furniture might pose a potential congregation point for young people
- Concerns about impaired access to property.

Because of the electrically dependent position of new technologies to meet the project's technical design criteria, alternative locations and redesign options were limited. Customers were generally found to be accepting of new street furniture once the project's objectives had been explained.

Learning outcome

All practicable alternatives were considered to reach a mutually agreeable resolution to objections, which addressed customer concerns and the design criteria. Where existing network configuration permitted, street furniture was installed in an alternative position. Five cabinets were repositioned which involved moving equipment only a few metres from the position originally proposed. It was not possible to relocate apparatus in the case of every objection; however, there was no requirement to abandon any proposed installations on the grounds of a customer complaint.

While the project design provided some limited flexibility to accommodate customer-related issues, the large scale redesign of networks, on the grounds of objection to new equipment, would be impractical in future BAU construction projects involving new street furniture installed under permitted development.

Sloping lids were constructed and retrofitted onto the original flat tops of three cabinets in areas where anti-social behaviour concerns were raised. This was done to prevent the units being used by young people as a seating area or a climbing aid.

8.2 Technology implementation and effectiveness

The integration of the stand-alone SP5 system into Electricity North West's existing CRMS led to an overly complicated design, especially given the split of field devices into switching and voltage control sets. For a BAU solution the optimisation software would be an integral part of the new NMS currently being installed.

8.3 Smart Street trials

Smart Street produced a large quantity of one-minute resolution data over the two years of the trial. It was important to ensure that the data was reviewed for availability and accuracy during the course of the trials. Having this review highlighted when the software started to show some issues and allowed Electricity North West and Siemens to take corrective action to minimise the effect on the trials.

Electricity North West experienced response issues from some of the project partners in the latter stages. It may be prudent in future to hold back final payment until all project support is complete.

8.4 Evaluating and enabling the benefits of the Smart Street solution

Smart Street had a number of different researchers working on different elements of the analysis independently which led to differences in the terminology used to describe the various scenarios being modelled. In future projects it is important to define any terminology early in the process and ensure all parties consistently use these terms which will make comparison of the analysis easier.

9. PROJECT REPLICATION

9.1 Customer engagement and feedback

Requirements for replication of customer research with an ECP, to develop communications materials and elicit perception of impact, are outlined in the ECP interim reports published in December 2014 and March 2017 along with the ECP final report, dated April 2018. These documents provide guidance on the discussion framework and stimulus materials required for research of this nature, in addition to customer consent requirements. Section 11.11 of the initial document, published in 2014, specifies the physical components required to replicate a focus group meeting with an ECP.

9.2 Technology implementation and effectiveness

To replicate the outcomes of this project other DNOs will require commercially available devices which should be installed on the HV and LV networks and communicate with the central control system. A list of the items required and their approximate cost is contained in Figure 9.1 and a description of how to use the devices is given below.

Figure 9.1: Devices required to replicate Smart Street

	Details	Approximate BAU Cost
1	Primary transformer on-load tap changer	N/A – already part of existing transformers
2	Automated HV switches/circuit breakers	Installed as per BAU practice
3	Ground-mounted HV capacitors	£43,000 p.u.
4	Pole-mounted HV capacitors	£12.700 p.u.
5	Distribution transformers with on-load tap changer	£22,000 p.u.
6	LV circuit breaker with remote control	£4,500 p.u. + £1,250 per site
7	LV switch with remote control	£3,500 p.u. + £1,250 per site
8	LV ground-mounted capacitors	£5,250 p.u.
9	LV end point monitoring	£2,205 p.u.
10	Volt/VAr optimisation algorithm for central control system*	£1,275,000 p.u.

** Costs here reflect standalone system rather than an add-on module*

Primary transformer on-load tap changer

These devices are standard on primary transformers. The optimisation software, depending on the set-up, can send either a change in voltage setpoint or tap-up/tap-down commands.

Automated HV switches/circuit breakers

These automated switching points are used to change the configuration of the HV network. DNOs have already invested in automation on their HV networks for fault restoration so these devices may already exist at the appropriate locations on the system.

Ground-mounted HV capacitors

Electricity North West has produced a specification and operational procedure for these devices which are available on request. The HV capacitors should be set up to respond to voltage rather than power factor and the optimisation software, depending on the set-up, can send either a change in voltage setpoint or switch-in/switch-out commands. The optimal location will depend on the network parameters therefore network studies should be carried out to assess the effect in different locations to choose the most appropriate one.

Pole-mounted HV capacitors

Electricity North West has produced a specification, installation and operational procedure for these devices which are available on request. The HV capacitors should be set up to respond to voltage rather than power factor and the optimisation software, depending on the set-up, can send either a change in voltage setpoint or switch-in/switch-out commands. The optimal location will depend on the network parameters therefore network studies should be carried out to assess the effect in different locations to choose the most appropriate one.

Distribution transformers with on-load tap changer

The tap changer chosen by Electricity North West was -8% to +8% in steps of 2%. Following the results of the project this tap changer has been included as an option in the Electricity North West distribution transformer specification. The optimisation software, depending on the set-up, can send either a change in voltage setpoint or tap-up/tap-down commands.

These items are currently expensive but it is anticipated that as the requirements for them increase the price will come down.

For the project these units were programmes with a ‘safe’ setpoint of 245V in the event of a communications loss. The consequence of this was that the voltage remained at 245V until the optimisation amended it which could have been up to 30 minutes later. This can result in a loss of benefits. For BAU this ‘safe’ setpoint would probably be set much lower at around 230V.

LV circuit breaker with remote control

For the Smart Street project the Kelvatek Weezap was chosen to fulfil this functionality. This device fits in a standard LV fuseway and can be operated from the central control system. It allows reconfiguration of the LV network as well as providing monitoring data as inputs to the control system. Additionally, the Weezap has the capability of reclosing up to five times following a trip which can assist with fault restoration.

LV switch with remote control

For the Smart Street project the Kelvatek Lynx was chosen to fulfil this functionality. This device fits in an LV link box and can be operated from the central control system. It allows reconfiguration of the LV network as well as providing monitoring data as inputs to the control system.

LV ground-mounted capacitors

Electricity North West has produced a specification and operational procedure for these devices which are available on request. The LV capacitors should be set up to respond to voltage rather than power factor and the optimisation software, depending on the set-up, can send either a change in voltage setpoint or switch-in/switch-out commands. The optimal location will depend on the network parameters therefore network studies should be carried out to assess the effect in different locations to choose the most appropriate one.

LV end-point monitoring

These are voltage monitoring points at the most electrically remote point from the substation. The data from these are inputs to the control system and allow the system to ensure the most remote point stays within statutory limits. Electricity North West has a specification and installation procedure for these monitoring cabinets which is available on request.

Volt/VAr optimisation algorithm for central control system

The Volt/VAr algorithm was a standard bolt-on to a standard NMS system and is available to all DNOs. The model used for the algorithm will need modifying before any BAU rollout as issues experienced with the software appeared to be from the fact that the model was a single wire model which 'averages' the three LV phases. To cater for the unbalanced nature of an LV network this model should be a full four-wire model for any BAU rollout.

Communications

The data was transferred from the numerous devices to the central server using the Vodafone 4G network. As it was relying on one network it was subject to intermittent outages which resulted in the loss of some data. For BAU a more robust method of communication should be used including the use of roaming SIMs, radio and NarrowBand-Internet of Things (NB-IoT).

10. PLANNED IMPLEMENTATION

Using the analysis of the trials data Electricity North West have developed a strategy for the management of LCT clusters. This suggests a phased approach to the installation of Smart Street technology, building up to a fully optimised LV network. This document has been published on the project website.

Some of the equipment utilised during the project requires further refinements to the design before it is suitable for use in a BAU scenario. The integrated implementation of the optimisation software would require it to be installed on the Electricity North West NMS system rather than a separate stand-alone system as this simplifies the design.

Electricity North West have updated their internal specifications to cover the equipment used during the project so it can be installed where appropriate. Proposals have also been made for amendments to national standard documentation.

At present the additional loads expected to accompany the increased penetration of EV and HP have not materialised and as such the capacitors are of limited use, especially those sited in the urban and dense urban areas. As loads increase it is expected that the installation of capacitors will become more beneficial.

11. LEARNING DISSEMINATION

This closedown report is a key element of the dissemination approach to ensuring the sharing of project learning.

The report has been structured around four key learning activities in order to facilitate easy access to specific content from a variety of different stakeholders:

- Customer engagement and feedback
- Technology implementation and effectiveness
- Smart Street trials
- Evaluating and enabling the benefits of the Smart Street solution.

A peer review of the closedown report was completed by Scottish and Southern Energy. Suggested improvements and recommendations that would ease the understanding of Smart Street by other DNOs and enable them to replicate the system were received and incorporated into the closedown report accordingly.

In addition a summary of the project and its outcomes have been presented at the following events:

- Smart Street webinars – July 2014 and April 2015
- Smart Street learning event – October 2015
- Innovation event – July 2017
- LCNI conferences – 2014, 2015, 2016 and 2017
- Smart Street workshop – February 2017
- Smart Street closedown event – February 2018.

All knowledge dissemination material is available on the dissemination page of the project website and key stakeholders advised on how to access it.

12. KEY PROJECT LEARNING DOCUMENTS

Project progress reports and key learning documents are tabulated below. A more extensive range of project-related key documentation can be found in the project library.

12.1 Project progress reports

Title	Date	Website link
Project progress report no 1	19 June 2014	Progress report no 1
Project progress report no 2	18 December 2014	Progress report no 2
Project progress report no 3	12 June 2015	Progress report no 3
Project progress report no 4	18 December 2015	Progress report no 4
Project progress report no 5	17 June 2016	Progress report no 5
Project progress report no 6	19 December 2016	Progress report no 6
Project progress report no 7	19 June 2017	Progress report no 5
Project progress report no 8	19 December 2017	Progress report no 6

12.2 Key learning documents

Title	Date	Summary
Technology		
LV network management protocols	Jun 2015	Draft policy for the LV network management applicable to Smart Street installation
Equipment specification and installation report	Jan 2016	Review of the specification, installation and configuration of the technology deployed as part of the Smart Street project
Commissioning and installation report	Jan 2016	Describes the interface between the existing control room management system (CRMS) and the Siemens Spectrum Power 5 (SP5) system
Trials		
Site selection	Jul 2014	Describes the methodology and the process for selecting the circuits that will be investigated as part of the trials
Network design	Jul 2014	Describes the methodology that was used for designing the Smart Street trial circuits
Trial and test regimes	Jan 2016	Describes the Smart Street trial methodology and resulting test regimes
Trial overview	Apr 2018	Provides a summary of the trials carried out as part of the project and an overview of the results generated
Research		
Final voltage and configuration optimisation	Apr 2018	Describes the methodology, simulation work and analysis of trial data to quantify the effects of conservation voltage reduction

Title	Date	Summary
Final design of interconnected LV networks	Apr 2018	Describes the methodology and simulation work carried out to assess the impact of interconnecting the low voltage network
Final cost benefit assessment study	Apr 2018	Methodology used to develop a techno-economic model, a business case model and a CBA framework, to evaluate the cost benefits of Smart Street
Final report on carbon accounting	Feb 2018	Final evaluation of the potential carbon savings of the Smart Street method produced by the University of Manchester
Optimisation implementation strategy	Feb 2018	Describes the means by which a communications network, required to run Smart Street, can be established and the settings used during the trial phase
Customer engagement		
ECP lessons learned	Oct 2014	Research with an engaged customer panel undertaken to help formulate an effective awareness campaign
First ECP interim report	Dec 2014	First phase of research with engaged customer panels held to develop effective communications
Second ECP interim report	Mar 2017	Findings from engaged customer panels held in early 2017 to ascertain customer reactions to Smart Street
Final ECP report	Apr 2018	Final report on findings from engaged customer panels held at the end of the Smart Street trials

13. CONTACT DETAILS

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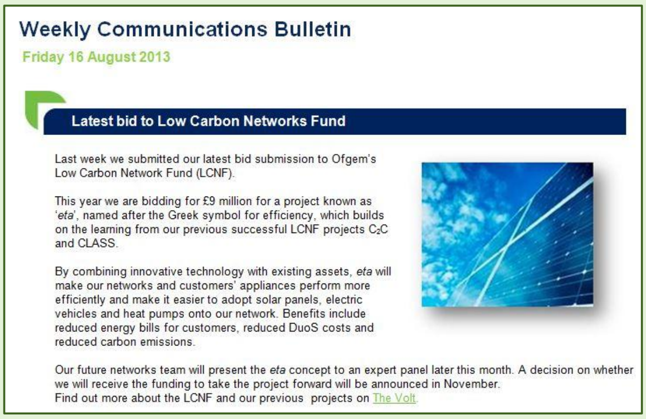
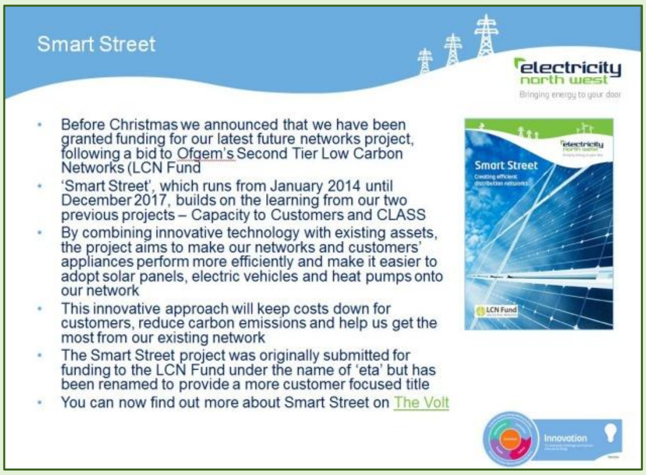
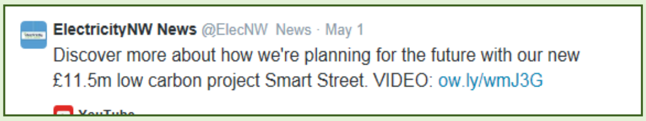
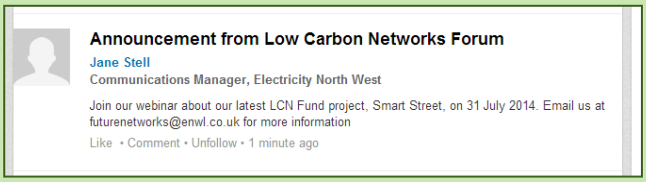
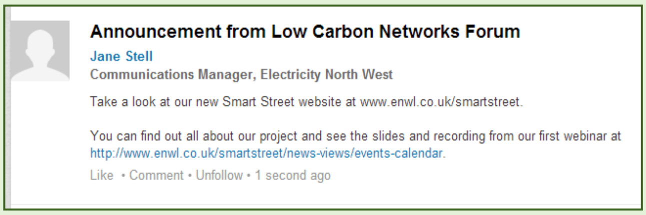
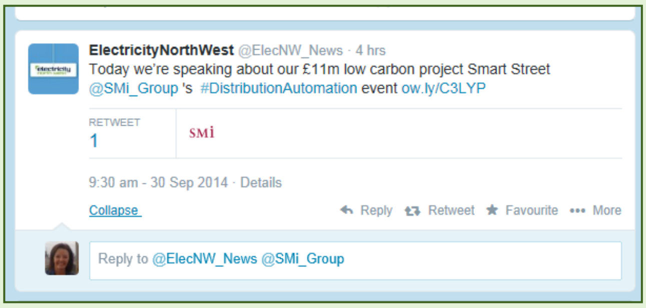
14. APPENDICES

A: Smart Street learning and dissemination activities

Date	Activity	Audience	Evidence
Aug 2013	Project proposal video on YouTube	All stakeholders	You Tube
Aug 2013	Internal announcement on proposed project in weekly ebulletin	All employees	 Weekly Communications Bulletin Friday 16 August 2013 Latest bid to Low Carbon Networks Fund Last week we submitted our latest bid submission to Ofgem's Low Carbon Network Fund (LCNF). This year we are bidding for £9 million for a project known as '*eta*', named after the Greek symbol for efficiency, which builds on the learning from our previous successful LCNF projects C_2C and CLASS. By combining innovative technology with existing assets, *eta* will make our networks and customers' appliances perform more efficiently and make it easier to adopt solar panels, electric vehicles and heat pumps onto our network. Benefits include reduced energy bills for customers, reduced DuoS costs and reduced carbon emissions. Our future networks team will present the *eta* concept to an expert panel later this month. A decision on whether we will receive the funding to take the project forward will be announced in November. Find out more about the LCNF and our previous projects on The Volt.
Nov 2013	Smart Street funding press release	All external stakeholders	Press release
Nov 2013	Smart Street funding announced	Twitter	 ElectricityNorthWest @ElectricityNW · Nov 29 £11.5 million 'Smart Street' trial set for North West power network... ow.ly/ri9YK 4 2
Nov 2013	Internal announcement about funding in weekly ebulletin	All employees	 electricity north west Bringing energy to your door Weekly Communications Bulletin Friday 29 November 2013 PERFORMANCE VALUE NOV-DEC 2013 Green light for £11.5 million low carbon project We are delighted to announce that we have been granted funding for our latest future networks project, following a bid to Ofgem's Second Tier Low Carbon Networks (LCN Fund. 'Smart Street', which runs from January 2014 until December 2017, builds on the learning from our two previous projects – Capacity to Customers and CLASS. By combining innovative technology with existing assets, the project aims to make our networks and customers' appliances perform more efficiently and make it easier to adopt solar panels, electric vehicles and heat pumps onto our network. This innovative approach will keep costs down for customers, reduce carbon emissions and help us get the most from our existing network. The Smart Street project was originally submitted for funding to the LCN Fund under the name of 'eta' but has been renamed to provide a more customer focused title. Find out more about the LCN Fund and our other projects on our website.
Dec 2013	Funding announced in internal magazine, NewsWire	All employees	

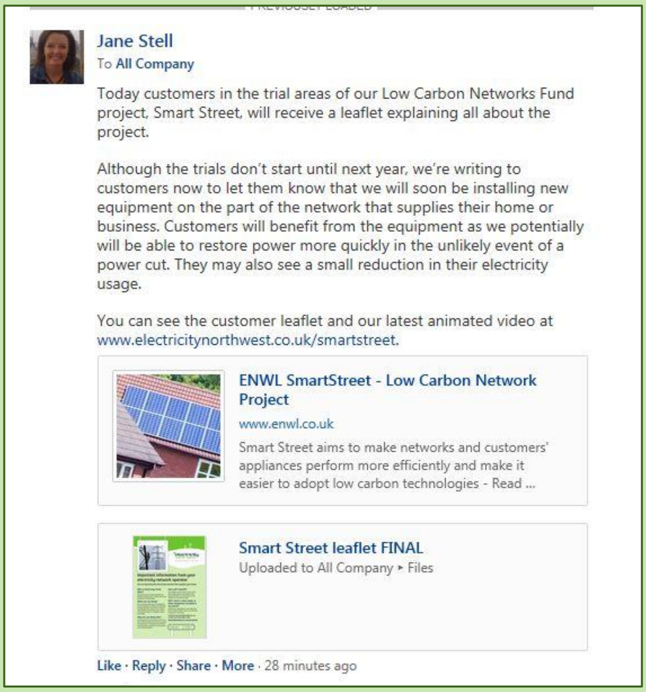
Date	Activity	Audience	Evidence
Jan 2014	Employee overview on The Volt intranet	All employees	
Jan 2014	Employee overview in company team brief	All employees	
Mar 2014	Smart Street web page	All stakeholders	Smart Street website
Mar 2014	Smart Street video updated on You Tube	All stakeholders	You Tube
Mar 2014	Project update in internal magazine NewsWire	All employees	
May 2014	Smart Street video promoted on Twitter	All stakeholders	
May/ June 2014	Smart Street project partner events	MOSI event	Event slides
July 2014	Smart Street advertorial in E&T magazine	All stakeholders	E&T magazine ad
July 2014	Smart Street webinar promoted on LinkedIn	All stakeholders	

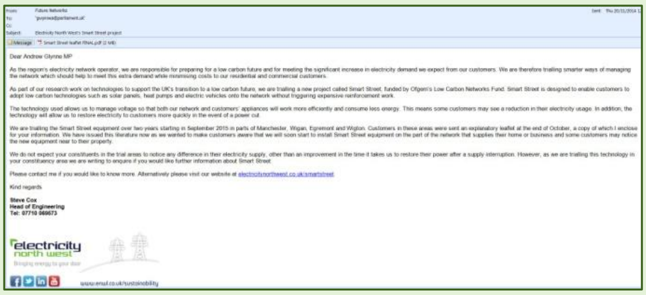
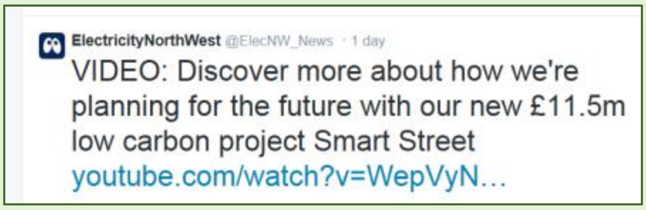
Date	Activity	Audience	Evidence
July 2014	Smart Street webinar promoted on Twitter	Twitter	
July 2014	Smart Street webinar on Twitter	All stakeholders	
July 2014	Launch of Smart Street microsite	All stakeholders	 Smart Street website
July 2014	Smart Street webinar	All stakeholders	 Webinar recording Webinar slides
Aug 2014	Website launch and webinar promoted on LinkedIn	All stakeholders	
Aug 2014	Project website promoted on Twitter	All stakeholders	

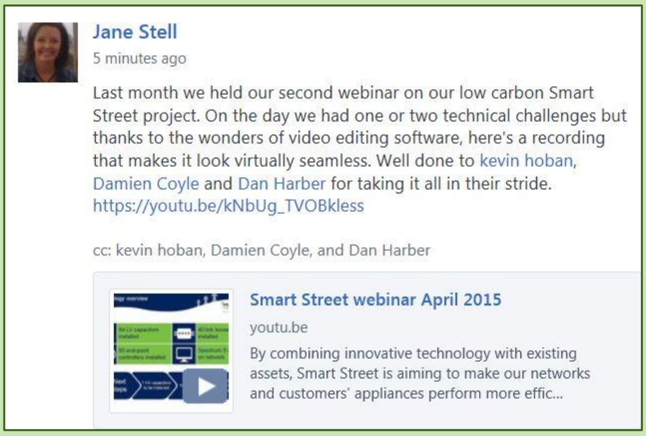
Date	Activity	Audience	Evidence
Aug 2014	Webinar promoted on Twitter	All stakeholders	
Sep 2014	Project website promoted on Twitter	All stakeholders	
Sep 2014	Smart Street project update story on company intranet and internal e-bulletin	All employees	
Sep 2014	Smart Street presentation to Infuse event promoted on Yammer	All employees	
Sep 2014	Tweet about presentation at external event	All stakeholders	

Date	Activity	Audience	Evidence
Sep/ Oct 2014	Engaged customer panels	All stakeholders	Engaged customer panel lessons learned
Oct 2014	Mailing to 67,000 customers in trial areas	Customers on trial circuits	 Smart Street customer leaflet
Oct 2014	Presentation on Smart Street at LCNI conference	Industry stakeholders	Presentation slides
Oct 2014	New Smart Street video – a day in the life of Smart Street on You Tube and project website	All stakeholders	 You Tube
Oct 2014	Smart Street video promoted on Twitter	All stakeholders	

Date	Activity	Audience	Evidence
Oct 2014	Smart Street video promoted on Yammer	All employees	 Jane Stell To Future Networks As part of the materials we put together for this year's LCNI conference, we've developed an animated video on A Day in the Life of Smart Street. Smart Street is our most recent LCN Fund tier 2 project. You can watch the video here: www.electricitynorthwest.co.uk/smartstreet  ENWL SmartStreet - Low Carbon Network Project www.electricitynorthwest.co.uk Smart Street aims to make networks and customers' appliances perform more efficiently and make it easier to adopt low carbon technologies - Read ...
Oct 2014	Leaflet and video in internal ebulletin	All employees	electricity north west Bringing energy to your door connect the weekly bulletin for our people Edition 21 Friday 24 October 2014 Latest news... **Smart Street customer leaflets sent out this week**  Today we're sending a leaflet to 19,500 customers in the trial areas of our Low Carbon Networks Fund project, Smart Street. Although the trials don't start until next year, we're writing to customers now to let them know that we will soon be installing new equipment on the part of the network that supplies their home or business. Customers will benefit from the equipment as we potentially will be able to restore power more quickly in the unlikely event of a power cut. They may also see a small reduction in their electricity usage. By introducing new technology Smart Street will balance voltage so that our network and customers' appliances perform more efficiently. It will also be much easier to adopt new low carbon technologies (such as solar panels, electric vehicles and heat pumps) onto the electricity network. This innovative approach will help to keep costs down for customers, get the most from the existing network and reduce carbon emissions. You can see the customer leaflet and our latest animated video on our website here.
Oct 2014	Smart Street leaflet and video promoted on LinkedIn	All stakeholders	 **Smart Street leaflet issued to customers** Jane Stell Communications Manager, Electricity North West Today customers in the trial areas of our Low Carbon Networks Fund project, Smart Street, will receive a leaflet explaining all about the project. Although the trials don't start until next year, we're writing to customers now to let them know that we will soon be installing new equipment on the part of the network that supplies their home or business. Customers will benefit from the equipment as we potentially will be able to restore power more quickly in the unlikely event of a power cut. They may also see a small reduction in their electricity usage. By introducing new technology Smart Street will balance voltage so that our network and customers' appliances perform more efficiently. It will also be much easier to adopt new low carbon technologies (such as solar panels, electric vehicles and heat pumps) onto the electricity network. This innovative approach will help to keep costs down for customers, get the most from the existing network and reduce carbon emissions. You can see the customer leaflet and our latest animated video at www.enwl.co.uk/smartstreet.

Date	Activity	Audience	Evidence
Oct 2014	Smart Street leaflet promoted on Yammer	All employees	
Oct 2014	Smart Street leaflet promoted on Twitter	All stakeholders	
Oct 2014	LCNI conference promoted on Twitter	All stakeholders	
Oct 2014	Engaged customer panel lessons learned	All stakeholders	ECP lessons learned

Date	Activity	Audience	Evidence
Nov 2014	Article in internal magazine	All employees	 Smart Street **Our most recent LCN Fund project is the £11.5 million Smart Street trial. Smart Street will trial innovative voltage control techniques to optimise network voltage while maintaining voltages within statutory limits. The aim is to make our networks and customers' appliances perform more efficiently and to make it easier to adopt low carbon technologies onto the electricity network.** Since funding was awarded back in November 2013, the project has moved on in leaps and bounds. Project manager Kevin Hoban told NewsWire, "We've already achieved a number of key milestones. The project team was established earlier this year. Since then we have awarded contracts to our key suppliers, selected the circuits we will use on the trial and completed our design methodology. "To make sure we engage fully with the customers in the trial area and our other stakeholders, we've produced a customer engagement plan which has been approved by Ofgem. Some of the engagement activities in the plan include a website which went live in June, a webinar held in July and 'engaged customer panels' held in September and October." The trial area covers six primary substations in the Manchester, Wigan, Egremont and Wigton areas. These sites were chosen as they are representative of our geographic area and our different customers. A leaflet explaining the project to the 67,000 customers in the trial areas was sent out in October. The future networks team are now working with colleagues in operations to install the Smart Street technology on the network ahead of live trials starting next year. Smart Street will run until December 2017.
Nov 2014	Email to MPs in primary substation areas	MPs	 Subject: Electricity North West's Smart Street project Smart Street leaflet FINAL.pdf Dear Andrew Gwynne MP As the region's electricity network operator, we are responsible for preparing for a low carbon future and for meeting the significant increase in electricity demand we expect from our customers. We are therefore trialling smarter ways of managing the network which should help to meet this extra demand while minimising costs to our residential and commercial customers. As part of our research work on technologies to support the UK's transition to a low carbon future, we are trialling a new project called Smart Street, funded by Ofgem's Low Carbon Networks Fund. Smart Street is designed to enable customers to adopt low carbon technologies such as solar panels, heat pumps and electric vehicles onto the network without triggering expensive reinforcement work. The technology used allows us to manage voltage so that both our network and customers' appliances will work more efficiently and consume less energy. This means some customers may see a reduction in their electricity usage. In addition, the technology will allow us to restore electricity to customers more quickly in the event of a power cut. We are trialling the Smart Street equipment over two years starting in September 2015 in parts of Manchester, Wigan, Egremont and Wigton. Customers in these areas were sent an explanatory leaflet at the end of October, a copy of which I enclose for your information. We have issued this literature now as we wanted to make customers aware that we will soon start to install Smart Street equipment on the part of the network that supplies their home or business and some customers may notice the new equipment near to their property. We do not expect your constituents in the trial areas to notice any difference in their electricity supply, other than an improvement in the time it takes us to restore their power after a supply interruption. However, as we are trialling this technology in your constituency area we are writing to enquire if you would like further information about Smart Street. Please contact me if you would like to know more. Alternatively please visit our website at electricitynorthwest.co.uk/smartstreet Kind regards **Steve Cox** **Head of Engineering** **Tel: 07710 069673** electricity north west www.enwl.co.uk/sustainability
Jan – Feb 2015	Letters to customers affected by technology installation	Customers in trials areas	[Copy of letter]
Feb 2015	Smart Street video promoted on Twitter	All stakeholders	 ElectricityNorthWest @ElecNW_News · 1 day VIDEO: Discover more about how we're planning for the future with our new £11.5m low carbon project Smart Street youtube.com/watch?v=WepVyN...
Feb/ Mar 2015	Internal briefings	Operational employees	[Operations briefing]
April 2015	Smart Street video promoted on Twitter	All stakeholders	 ElectricityNorthWest @ElecNW_News · Apr 7 Watch our animated video to learn more about our low carbon #SmartStreet project... youtube.com/watch?v=ezCvpe...
April 2015	Smart Street webinar promoted on Twitter	All stakeholders	 ElectricityNorthWest @ElecNW_News · 9 mins Discover more about our low carbon #SmartStreet project by signing up to our webinar on 30 April. Register here: eventbrite.co.uk/e/smart-street...
April 2015	Smart Street webinar promoted on LinkedIn	All stakeholders	 Electricity North West shared: Following · 10m Discover more about our low carbon Smart Street project by signing up to our webinar on 30 April. Register here: https://lnkd.in/dpqvwjx
April 2015	Smart Street webinar promoted on LinkedIn via Low Carbon Networks Forum	All stakeholders	 **Electricity North West's Smart Street webinar – 30th April** Jane Stell Communications Manager, Electricity North West Later this month we are holding our next learning and dissemination webinar on our Low Carbon Networks Fund project – Smart Street. Smart Street builds on the learning from our two previous projects – Capacity to Customers and CLASS. By ... Like (2) · Comment · Unfollow · 7 days ago

Date	Activity	Audience	Evidence
April 2015	Smart Street webinar recording on LinkedIn and Twitter	All stakeholders	 
April 2015	Smart Street webinar recording on Yammer	All employees	
April 2015	Smart Street webinar	All stakeholders	Slide presentation Webinar recording
June 2015	Smart Street advertorial	All stakeholders	E&T magazine ad
June 2015	Internal comms update in weekly ebulletin	Employees	
July 2015	Contact centre briefing	Customer-facing employees	Contact centre presentation
July 2015	Stakeholder update	All stakeholders	Stakeholder newsletter
Sep 2015	Learning event promoted on Twitter	All stakeholders	

Date	Activity	Audience	Evidence
Sep 2015	Learning event promoted on LinkedIn	All stakeholders	
Sep 2015	Smart Street video promoted on Twitter	All stakeholders	
Oct 2015	Presentation on Smart Street at Infuse event	Kelvatek's Infuse event delegates	
Oct 2015	Learning event	All stakeholders	Event slides
Oct 2015	Learning event on Twitter	All stakeholders	
Oct 2015	Learning event on LinkedIn	All stakeholders	
Nov 2015	Presentation at annual LCNI conference	Industry stakeholders	 Conference slides

<table>
<tr><th>Date</th><th>Activity</th><th>Audience</th><th>Evidence</th></tr>
<tr><td>Nov 2015</td><td>Supplier letter</td><td>Electricity supply companies</td><td>Letter to suppliers</td></tr>
<tr><td>Jan 2016</td><td>Stakeholder update</td><td>All stakeholders</td><td>Stakeholder newsletter</td></tr>
<tr><td>Jan 2016</td><td>Start of live trials</td><td>All stakeholders</td><td>Published on website homepage

Latest updates

Smart Street goes live! 29 January 2016

Following a challenging installation programme the Smart Street technologies have been commissioned and the project trials are under way.

See our key documents page for the latest project updates.</td></tr>
<tr><td>Feb 2016</td><td>Internal comms update in weekly ebulletin</td><td>All employees</td><td>electricity north west
Bringing energy to your door
connect
the weekly bulletin for our people
Edition 85 Friday 12 February 2016
Latest news...

Smart Street briefings

Following a challenging installation programme the £11.5 million Smart Street project is now live and the team are holding a series of meetings to update you on the technology installation and the project trials.

Smart Street is trialling innovative voltage control techniques to make our networks and customers' appliances perform more efficiently and make it easier to adopt low carbon technologies onto the electricity network. It's the first demonstration in Great Britain of a fully centralised, low voltage network management and automation system.

The trials will take place over a two-year period using a two-week-on / two-week-off test regime. This will enable us to compare one year's worth of Smart Street data with normal network operation, so we can calculate the overall benefits of Smart Street and understand any impact on the 67,000 customers served by the trial circuits in Manchester, Wigan, Wigton and Egremont.

During the technology build we have installed a range of new devices including Weezaps and Lynx, end-point monitors, low voltage capacitors, high voltage capacitors and on-load tap changing transformers. All of this equipment has been integrated into our network management system and is controlled by bespoke Spectrum 5 software developed by Siemens.

The briefings will last about an hour and will take place between 8:30AM and 12:30PM at the following dates and locations:
• Borron Street boardroom: Wednesday 24 February 2016
• Broadway meeting room: Chadderton, Monday 29 February 2016
• Conference room, Whitebirk: Tuesday 1 March 2016
• Ground floor office, Hilltop: Thursday 3 March 2016

You can find out more about Smart Street and our other low carbon projects at www.enwl.co.uk/thefuture or you can email the Future Networks team.</td></tr>
<tr><td>Feb 2016</td><td>Advertorial</td><td>All stakeholders</td><td>E&T magazine ad</td></tr>
<tr><td>April 2016</td><td>Raw monitoring data</td><td>All stakeholders</td><td>Smart Street trial data

As part of the Smart Street project we need to collect and analyse a varied and significant amount of trial data so that we can share our findings with the rest of the industry. This includes information on voltage and power quality so that we can quantify the effects of Smart Street on the regional and national electricity networks and our service to customers.

The most recent month's data is available below. For previous months' data, please contact us.

April 2016
<table>
<tr><td>1 April 2016</td><td>7 April 2016</td><td>13 April 2016</td><td>19 April 2016</td><td>25 April 2016</td><td></td></tr>
<tr><td>2 April 2016</td><td>8 April 2016</td><td>14 April 2016</td><td>20 April 2016</td><td>26 April 2016</td><td></td></tr>
<tr><td>3 April 2016</td><td>9 April 2016</td><td>15 April 2016</td><td>21 April 2016</td><td>27 April 2016</td><td></td></tr>
<tr><td>4 April 2016</td><td>10 April 2016</td><td>16 April 2016</td><td>22 April 2016</td><td>28 April 2016</td><td></td></tr>
<tr><td>5 April 2016</td><td>11 April 2016</td><td>17 April 2016</td><td>23 April 2016</td><td>29 April 2016</td><td></td></tr>
<tr><td>6 April 2016</td><td>12 April 2016</td><td>18 April 2016</td><td>24 April 2016</td><td>30 April 2016</td><td></td></tr>
</table>

Webpage</td></tr>
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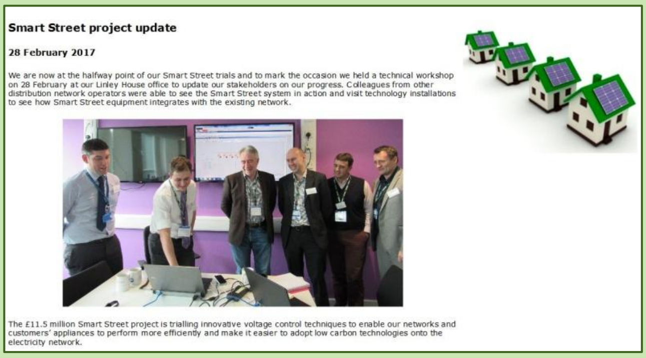
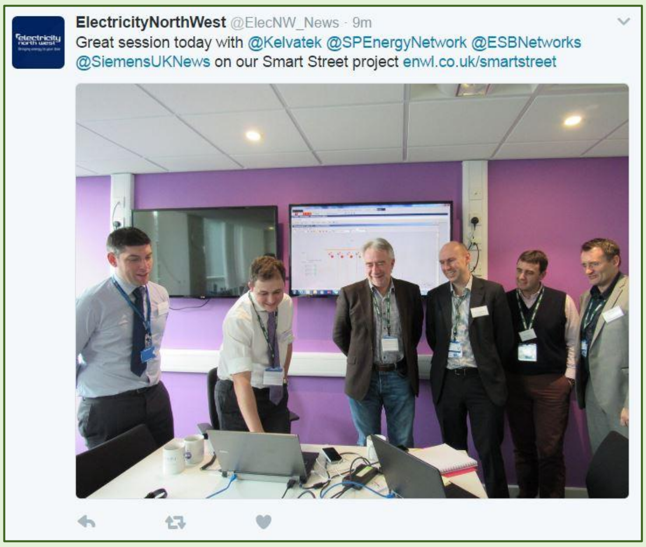
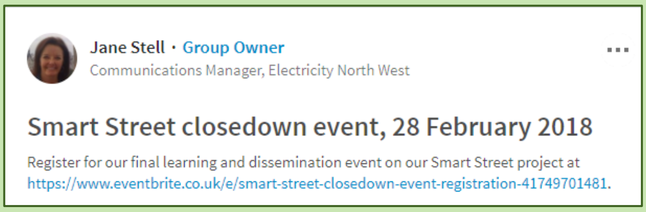
Date	Activity	Audience	Evidence
May 2016	Smart Street video promoted on Twitter	All stakeholders	
May 2016	Presentation at Utility Week Live, Birmingham	All stakeholders	Conference slides *Yammer* 
July 2016	Stakeholder update	All stakeholders	Stakeholder newsletter
Oct 2016	LCNI conference	Industry stakeholders	Slide presentation
Oct 2016	Promotion of LCNI conference in internal magazine and Connect e-bulletin	All employees	

Date	Activity	Audience	Evidence
Nov 2016	Briefing at Manchester Electrical Energy and Power Systems workshop	Industry stakeholders	Presentation slides
Jan 2017	Innovation roadshow	All employees	
Feb 2017	Industry newsletter	All stakeholders	Newsletter page
Feb 2017	Advertorial	All stakeholders	E&T magazine ad
Feb 2017	Smart Street workshop	Industry stakeholders	Slide presentation
Feb 2017	Internal comms update in weekly ebulletin	All employees	 **Smart Street project update** **28 February 2017** We are now at the halfway point of our Smart Street trials and to mark the occasion we held a technical workshop on 28 February at our Linley House office to update our stakeholders on our progress. Colleagues from other distribution network operators were able to see the Smart Street system in action and visit technology installations to see how Smart Street equipment integrates with the existing network. The £11.5 million Smart Street project is trialling innovative voltage control techniques to enable our networks and customers' appliances to perform more efficiently and make it easier to adopt low carbon technologies onto the electricity network.
Feb 2017	Workshop promoted on Twitter	All stakeholders	 ElectricityNorthWest @ElecNW_News · 9m Great session today with @Kelvatek @SPEnergyNetwork @ESBNetworks @SiemensUKNews on our Smart Street project enwl.co.uk/smartstreet

Date	Activity	Audience	Evidence
Feb 2017	Workshop promoted on Yammer	All employees	
April 2017	Smart Street learning installations	All stakeholders	
Apr 2017	IET event	IET	Slide presentation
Apr 2017	IET presentation on Twitter	IET	
Jul 2017	Innovation learning event on social media	All stakeholders	

Date	Activity	Audience	Evidence
Jul 2017	Innovation learning event on social media	All stakeholders	
Jul 2017	Innovation learning event on social media	All stakeholders	
Jul 2017	Innovation learning event	All stakeholders	[Slide presentation and survey results](#)
Jul 2017	Smart Street promoted on Twitter	All stakeholders	
Nov 2017	IET.TV consultation	All stakeholders	Recording of consultation
Dec 2017	University of Manchester Chilean seminar	Academic stakeholders	Slide presentation
Dec 2017	LCNI conference	Industry stakeholders	Slide presentation
Jan 2018	Industry newsletter	All stakeholders	Newsletter page

Date	Activity	Audience	Evidence
Jan 2018	Article in T&D World magazine	Industry stakeholders	 Creating Efficient Distribution Networks The UK's Electricity North West prototypes a network that responds to the challenges created by changing customer and low-carbon technologies. By Gerry George, International Editor
Jan 2018	Closedown event on LinkedIn	All stakeholders	
Feb 2018	Promoting closedown event on Twitter	All stakeholders	
Feb 2018	Learning event	All stakeholders	[Slide presentation]()
Feb 2018	Learning event on Twitter	All stakeholders	

Date	Activity	Audience	Evidence
Feb 2018	Internal comms update	All employees	 Connect The weekly bulletin for our people Stay connected... electricity north west Bringing energy to your door ISSUE 189 23 February 2018 LATEST NEWS **End of the road for Smart Street** Our £11 million innovation project is almost complete. Initial reports show that Smart Street will deliver energy savings by stabilising and reducing voltage – without affecting our customers' power quality. Using intelligent software to control smart devices installed on our low voltage network, Smart Street stabilises and lowers voltage levels, which saves money for customers by making their electrical appliances perform more efficiently. The project will also help prepare the electricity network for the expected increase in low carbon technologies such as electric vehicles, heat pumps and solar panels. The trials were carried out over a two-year period and involved a number of substations serving 67,000 customers in Manchester, Wigan, Wigton and Egremont. A series of focus groups were held with some of the customers in the trial to understand if the new system affected their electricity supply. All the customers confirmed that they hadn't noticed any changes. Project manager Ben Ingham said: "Smart Street has proved that controlling voltage on our low voltage network brings a number of benefits to customers. It can reduce their electricity bills, reduce carbon emissions and will provide more flexible solutions to help us connect low carbon technologies to the network – all without impacting power quality." Next week, stakeholders from across our industry will attend our final learning event in Manchester to hear about the results of the trials. The project closedown report and a series of detailed academic reports will be published on our website in April 2018.
Apr 2018	Advertorial	All stakeholders	Advertorial
Apr 2018	Industry newsletter	All stakeholders	Newsletter