Accelerated Electric Vehicle Investment
HVP Reopener Application – CRC 3F
May 2019

SP Distribution Plc

Application for an uncertainty mechanism reopener to allowed revenue under the RIIO-ED1 price control, May 2019 reopener window.

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1. EXECUTIVE SUMMARY

This submission requests an increase of £42.0m in 2012/13 prices to the SP Distribution (SPD) allowed levels of expenditure for the remaining of the RIIO-ED1 period.

SPEN believes there has been a material change in circumstances since the SPD ED1 submission was prepared pre-2015 due to the accelerated uptake (actual and predicted) of Electric Vehicles (EVs) and the associated necessity for charging infrastructure.

Recent UK government policy sets clear expectations for the electrification of transport. Average individual domestic demand is expected to double as customers migrate to EV alternatives and the increased load will considerably strain distribution networks.

Although the issue is emerging nationwide, Scottish government have accelerated the challenge by committing to removing the need for petrol and diesel vehicles by 2032; by contrast UK Government is to block the sale of new petrol and diesel vehicles nationally by 2040. It is the view of SP Energy Networks (SPEN), that EV uptake will impact Scotland first and this must be managed. As SPD serves 80% of Scottish customers, action cannot be delayed if ambitious government targets are to be met.

To accommodate this increase, significant reinforcement of distribution networks at all voltage levels will be required, with the most disruptive being wide-scale uprating of the LV and HV network. If significant changes in electrical network infrastructure and management are not made, networks cannot facilitate this demand. To best accommodate and enable this transition, SPEN believes wide-scale anticipatory network investment in the LV and HV system is required to enable a smooth EV transition and minimise economic disruption.

By delaying investment until thermal, voltage or fault level limits are breached (thereby justifying load related expenditure) the magnitude and rate of required investment would be so large and sudden that delivery would be significantly hindered. This would create inevitable price shocks, cause long delays through insufficient market capacity and drive inefficient business practices; inhibiting EV uptake and disadvantaging all customers.

This accelerated investment will be made strategically in two areas:

- The deployment of wide-scale monitoring of the LV network to test network constraints and enable smart charging; and,
- Accelerated reinforcement of areas of the network where innovative and smart solutions are not able to accommodate EV uptake.

The prior uncertainty and cost of reinforcement to meet the above challenges are considered by SPEN to qualify for arrangements for the recovery of uncertain costs under the High Value Project (HVP) mechanism. The summary of unforeseen accelerated expenditure is set out below.

Licence Area	Materiality Threshold (2012/13 prices)	HVP Threshold (2012/13 prices)	Total Costs (2012/13 prices)
SPD	£6.47m	£25.0m	£42.0m

SPEN has adhered to the relevant licence requirements as detailed within charge restriction condition CRC 3.F of the Licence special conditions and set out in the Regulatory Context section of this submission.

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2. REGULATORY CONTEXT

The RIIO model is a form of ex ante regulation, meaning the revenues for the price control are set at the start of the period with clearly defined outputs from the DNOs.

The DNO's allowed revenue comprises:

- Base revenue – the core amount of money that a network company can earn on its regulated business in order to recover the efficient costs of carrying out its activities;
- Incentive rewards or penalties for over- or under-delivery of the outputs it must deliver;
- Uncertainty mechanisms – mechanisms for funding elements that could not be set up front.

Reopeners are one form of the uncertainty mechanisms under the RIIO model. They are applicable when provisions to re-set the revenue allowances for qualifying costs at a specific date and upon crossing a specified threshold are required.

This document proves the existence of factors outside the company's control, which could not have been foreseen and/or quantified prior to the start of RIIO-ED1. They also affect and will continue to significantly affect SPD's investment plan. Hence this document proposes an anticipatory investment in SPD to accommodate Electric Vehicles in RIIO-ED1.

This submission has been prepared in accordance with Charge Restriction Condition CRC 3F, provision of uncertain costs, of the SPD licence.

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3. NEEDS CASE

3.1 Background

SPEN believes there has been a material change in circumstances since the SPD ED1 submission was prepared pre-2015 due to the accelerated uptake (actual and predicted) in Electric Vehicles (EVs)[1] and the necessity for associated charging infrastructure.

The key driver for the change in circumstances is the change in government policy, particularly in Scotland, which has introduced vastly more ambitious targets for the uptake of EVs. These policies are supported by an acceleration in EV manufacturing and availability, development in charging technologies (particularly increased power levels) and changes in consumer trends.

Our assertion is that the current SPD network and ED1 strategy is insufficient to enable SPD to deliver the charging capability necessary to meet future need and an adjustment in the allowed spending on related network assets is required. Section 3.3 details the EV uptake forecast and limitations of the current spending strategy.

The strategy for deploying solutions to the outlined issues in a targeted and cost efficient manner is described in section 4.2 of this submission.

3.2 Changing Circumstances

3.2.1 Government Policies Stimulating EV Uptake

In July 2017, UK Government outlined a ban on the sale of new petrol and diesel vehicles from 2040. In July 2018, UK government launched the Road to Zero[2] strategy, with challenging objectives; 50% of new vehicles to be ultra-low emission vehicles (ULEV) by 2030 and 100% of new vehicle registrations to be ULEV by 2040. A £400m Charging Infrastructure Investment Fund is to be made available by 2020 to accelerate the roll-out of charging infrastructure by funding companies that produce and install charge points. This funding neglects the cost of required network reinforcements.

In addition, UK government grants established in 2016, awarded through the Office for Low Emission Vehicles (OLEV) are also encouraging the electrification of transport: The Electric Vehicle Home Charging Scheme, Workplace Charging Scheme, On-street Residential Chargepoint Scheme and Ultra Low Emission Taxi Infrastructure Scheme are available to customers, businesses and councils[3].

UK government is taking powers through the Automated and Electric Vehicles Bill (2018)[4] to ensure charge points are easily accessed and used across the UK. Other recent political uncertainty around diesel emissions and air quality is increasingly encouraging customers to adopt EVs above lower band forecasts.

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[1] Throughout this submission the term Electric Vehicle is defined as vehicles driven solely from a battery, i.e. Battery Electric Vehicles (BEVs). Plug-In-Hybrid Electric Vehicles (PHEVs) are not considered as they are in a transitory phase in EV adoption and have much lower demand than BEVs.
[2] HM Government, "The Road to Zero", Jul 2018: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/739460/road-to-zero.pdf
[3] Grant schemes for electric vehicle charging infrastructure: https://www.gov.uk/government/collections/government-grants-for-low-emission-vehicles
[4] Automated and Electric Vehicles Act 2018: https://services.parliament.uk/bills/2017-19/automatedandelectricvehicles.html

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Scottish Government have accelerated this challenge and in September 2017 outlined a commitment to phase out the need for petrol and diesel vehicles by 2032[5]. This has been further reinforced in Scottish Government Vision for Scotland's Gas and Electricity Networks to 2030[6] published in March 2019.

Scottish Government will legislate to reduce greenhouse gas emissions to net-zero by 2045[7], five years ahead of the UK as a whole, based on the advice from the independent Committee on Climate Change (CCC)[8].

Scottish Government is offering additional incentives; the Energy Saving Trust can provide £300 funding towards the cost of a 32amp home charge point installation. This is in addition to the £500 provided by the Office for Low Emission Vehicles (OLEV). Transport Scotland offers a 6yr interest-free loan up to £35,000 for qualifying ULEV purchases[9]. Interest-free loans of up to £120,000, funded by Transport Scotland, are also available to Scottish businesses to help lower their transport and travel costs[10].

The introduction of low emission zones to Scotland's largest cities and associated access restrictions will further incentivise drivers to switch to lower emission options; in addition Edinburgh and Glasgow have committed to become the UK's first "net zero" cities within the next 10 years[11]. An expansion of the Switched on Towns and Cities initiative[12] will also help create new "electric towns" by 2025 to support local communities to increase electric vehicle uptake.

3.2.2 EV Ownership and Market Changes

The EV market has also changed significantly since 2015 and will further accelerate the uptake of EVs. In a recent report[13], Deloitte highlighted a global change in attitudes to EVs– from governments, consumers and manufacturers. Sales approximately doubled between 2017 and 2018 with similar trends expected out to 2030.

Deloitte's projection determined that the annual cost of EV ownership in the UK will breakeven with an internal combustion engine car by 2021/2022 (this could be earlier in Scotland based on additional incentives). The report highlights that 2022 is the likely

[5] Scottish Government, "Delivering for Today, Investing for Tomorrow, The Government's Programme for Scotland 2018-19", Sep 2018: https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2018/09/delivering-today-investing-tomorrow-governments-programme-scotland-2018-19/documents/00539972-pdf/00539972-pdf/govscot%3Adocument/00539972.pdf

[6] Scottish Government, "A vision for Scotland's electricity and gas networks", Mar 2019: https://www.gov.scot/publications/vision-scotlands-electricity-gas-networks-2030/

[7] Scottish First Minister net-zero announcement, May 2019: https://www.bbc.co.uk/news/uk-scotland-48123960

[8] Committee on Climate Change, "Net Zero – The UK's contribution to stopping global warming", May 2019: https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

[9] Energy Saving Trust, Electric Vehicle Loan: http://www.energysavingtrust.org.uk/scotland/grants-loans/electric-vehicle-loan

[10] Energy Saving Trust, Low Carbon Transport Business Loan: https://www.energysavingtrust.org.uk/scotland/grants-loans/low-carbon-transport-business-loan

[11] https://www.bbc.co.uk/news/uk-scotland-48269986

[12] Transport Scotland, Switched on Towns and Cities Challenge Fund: https://www.transport.gov.scot/our-approach/environment/carbon-reduction-on-roads/switched-on-towns-and-cities-challenge-fund/

[13] Deloitte, "New Market. New Entrants. New Challenges. Battery Electric Vehicles", Jan 2019: https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/manufacturing/deloitte-uk-battery-electric-vehicles.pdf

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tipping point where EV uptake will accelerate significantly. BloombergNEF analysis[14] also identifies 2022 as a crossover point in terms of cost of ownership.

This is supported by an upsurge in manufacturing capacity, with both new market entrants and established car manufacturers providing EV options. The Deloitte report highlights that supply is now greater than demand; reducing barriers to EV ownership.

These global trends are reflected in Scotland where the registration figures, for new battery electric and plug-in hybrid electric vehicles, have grown by 46% over the past year, compared to 33% in the rest of the UK[15]. Current EV ownership is around 10,000.

3.2.3 Growing Charging Infrastructure

With a clear policy drive from UK and Scottish Governments towards encouraging the uptake of ULEV, it is expected the installation of charging infrastructure will also grow as the availability of charging infrastructure is statistically linked to the EV uptake[16].

However, there is uncertainty around the volumes of charging infrastructure installed at different locations and this is likely to be a phased development. The EV charging infrastructure and different charging profiles are presented in Appendix A.

Scottish Government has developed the ChargePlace Scotland network[17], shown in Figure 1. This network currently has 1,662 chargers with a further planned investment of £15m[18]. This will add an additional 1,500 new charge points in homes, businesses and local authority land, including 150 new public charge points. The continued growth in the volume or both public and domestic chargers, as shown in Figure 2, is evidence of this policy implementation and growing adoption of EVs.

Figure 3 also highlights the capacity and utilisation of public chargers, with the total installed load and energy used more than doubling each year.

[14] BloombergNEF, "Electric Car Price Tag Shrinks Along With Battery Cost", Apr 2019: https://www.bloomberg.com/opinion/articles/2019-04-12/electric-vehicle-battery-shrinks-and-so-does-the-total-cost

[15] Scottish Government, Statistics on the number of electric vehicles in Scotland: FOI release, Feb 2019: https://www.gov.scot/publications/foi-19-00181/

[16] The International Council on Clean Transportation, "Emerging Best Practice for Electric Vehicle Charging Infrastructure", pg. 36, Oct 2017: https://www.theicct.org/sites/default/files/publications/EV-charging-best-practices_ICCT-white-paper_04102017_vF.pdf

[17] ChargePlace Scotland, a national network of publicly available EV charge points across Scotland: https://chargeplacescotland.org/

[18] Scottish Government, Green transport funding pledge, Sep 2018: https://news.gov.scot/news/green-transport-funding-pledge

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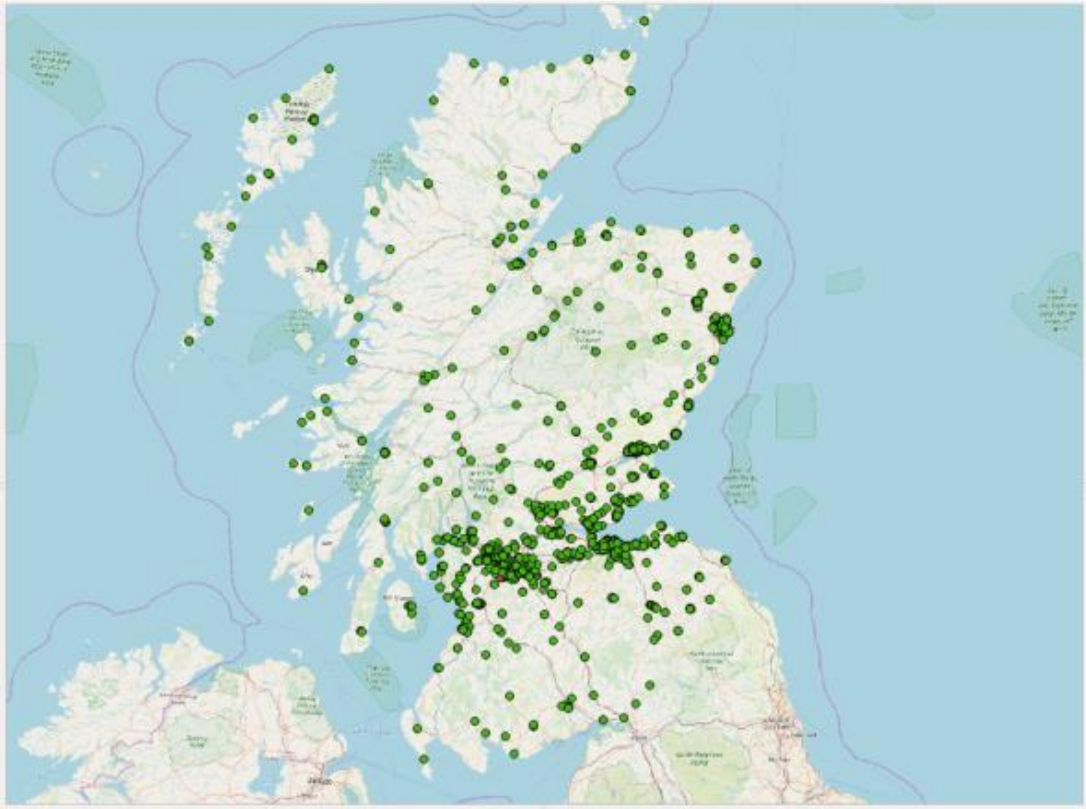

Figure 1. ChargePlace Scotland network

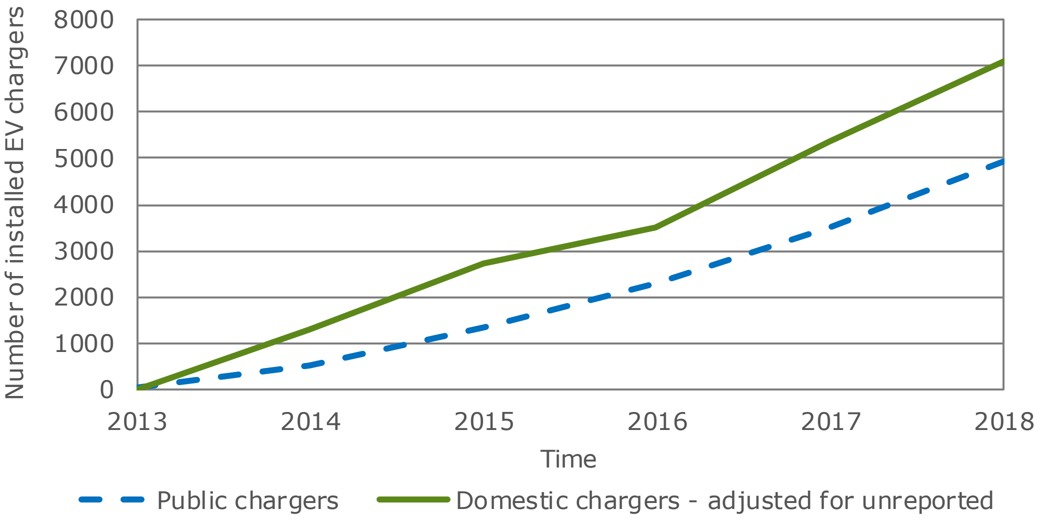

Figure 2. Number of public and domestic chargers installed in the SPD area

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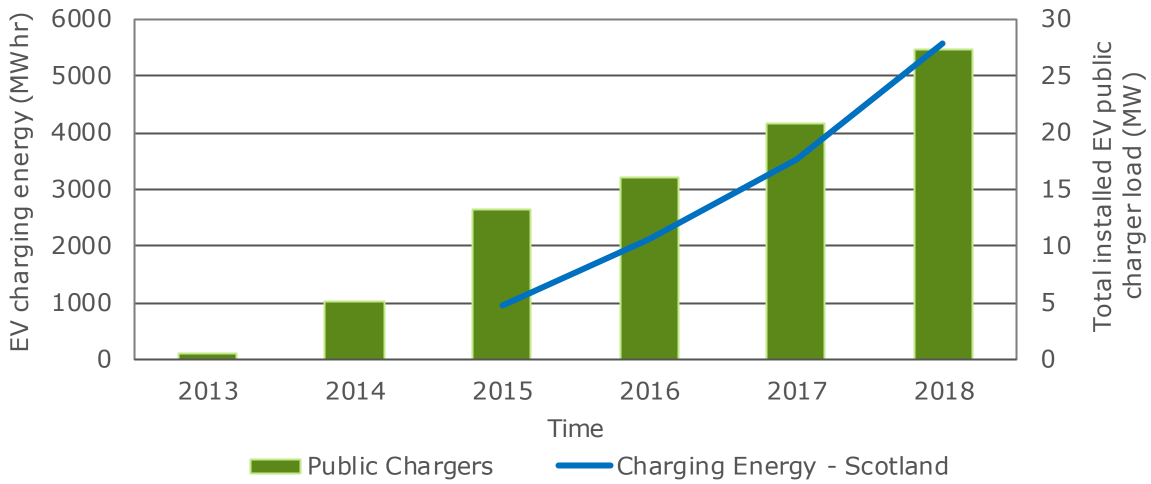

Figure 3. Installed capacity of public charge points and charging energy in Scotland

3.3 EV Uptake Forecast and Limitations of Current ED1 Strategy

3.3.1 EV Uptake Forecast

EV uptake is increasing although there is still uncertainty over the speed and style of uptake. The pace of technology take-up and cost variations are difficult to forecast, which is reflected in the range of EV uptake forecasts.

The experience of Photovoltaics uptake in the UK[19] serves as a reminder that the uptake of other new low carbon technologies can follow a similar pattern as costs reduce and public acceptance increases.

This rapid and uncontrolled increase in solar adoption has impacted the ability of the local distribution networks to maintain system security and on the UK System Operator to balance demand and generation on the UK network.

Whilst the EV uptake forecast varies widely, in all scenarios there is a significant impact on GB electricity networks[20]. Figure 4 shows a number of EV uptake forecast models, including the SPD EV forecast upon which this submission is based. A total of five forecasts are presented. These include:

- A Norway growth model based on the uptake percentage rate between 2011 and 2019 (applied to new car sales in Scotland from 2018 onwards);
- The National Grid FES 2017 Two Degrees scenario for EV uptake;
- The National Grid FES 2018 Two Degrees scenario for EV uptake;
- The SPD 2019 EV uptake forecast; and,
- The National Grid FES 2014 Two Degrees scenario for EV uptake.

Based on the drivers highlighted in section 3.2, the SPD 2019 EV uptake forecast has been aligned with the FES Two Degrees 2018 scenarios. The SPD forecast results in similar EV volumes for 2023 (end of ED1 period) and 2028 (end of ED2 period).

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[19] Ofgem, "Ofgem's Future Insights Series", p.9, 2016: https://www.ofgem.gov.uk/system/files/docs/2016/10/future_insights_overview_paper.pdf
[20] NGSO, "Future Energy Scenarios", Jul 2018: http://fes.nationalgrid.com/media/1363/fes-interactive-version-final.pdf

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SPD's predictions also factor in a higher uptake from 2021 as cost of ownership reaches parity. Based on SPEN's predictions, around a third of cars in the SPD licence area will be EVs by 2032, the time at which the government targets to phase out the need for internal combustion engine (ICE) vehicles.

The Norway model serves as an example that uptake can be more rapid than anticipated. Growth in Norway is heavily fuelled by government incentives (above those currently on offer from Scottish Government), but with a trend of reducing cost of ownership, equivalent or greater uptake is viable without the same level of incentive.

The pre-ED1 forecast (the FES Two Degrees 2014 scenarios) shows that the current forecast is significantly higher than previously predicted.

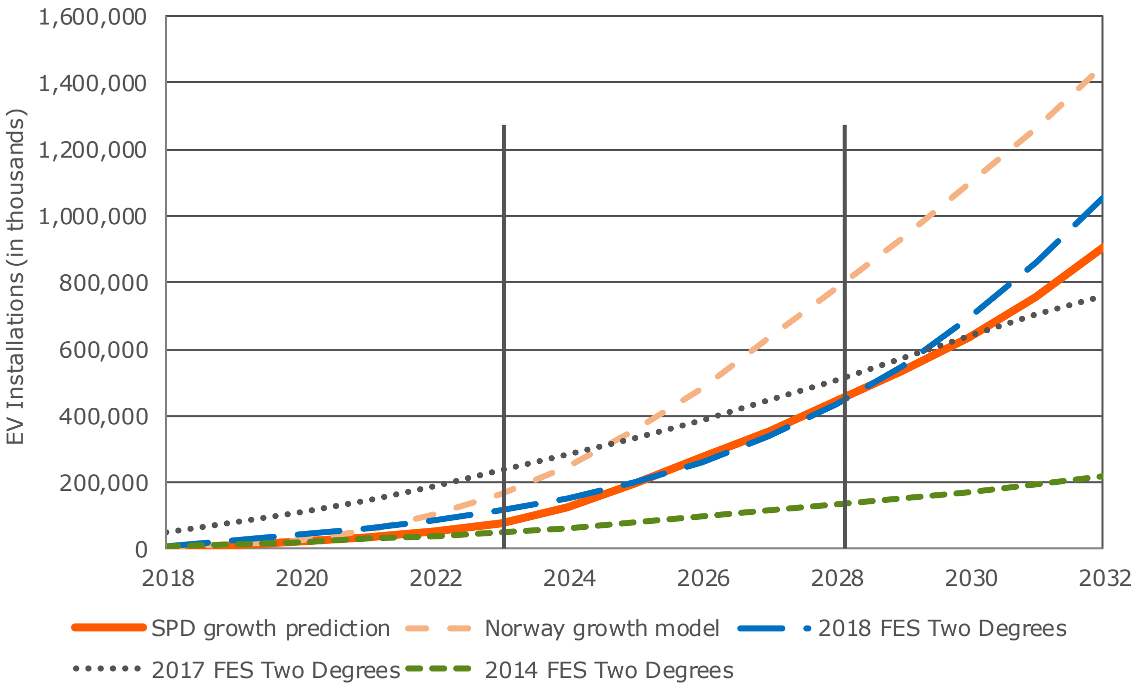

Figure 4. Forecast EV installations in SPD

The SPD EV growth prediction from Figure 4 considers uptake volumes of 80,000 EVs by the end of ED1 and 450,000 EVs by the end of ED2. ED2 will therefore see significantly greater volume of EVs coming on to the network. The rate of increase will rise from between 6,000 – 10,000 EVs expected to be added to the network this year to around 85,000 EVs in the final year of ED2.

This step change in EV uptake, coupled with the inevitable need to provide additional charging capacity, will pose significant technical and logistical challenges for SPD. To accommodate the increased demand, in addition to smart solutions, significant conventional reinforcement will be required at all voltage levels, with the most disruptive being wide-scale uprating of the LV and HV network.

If networks are not prepared for this level of load increase, rather than accommodating and enabling environmental and transport policy to achieve UK carbon targets, networks will obstruct and inhibit them.

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3.3.2 Network Capacity and Impact of Constraint Driven Reinforcement on EV Uptake

The current SPD price control settlement does not include arrangement to undertake anticipatory investment to accommodate an impending increase in demand. Load related allowance is inaccessible where system constraints have not yet been breached.

By delaying investment until thermal, voltage or fault level limits are breached (constraint driven reinforcement) the magnitude and rate of required investment would be so large and sudden that delivery would be significantly hindered. This would create inevitable price shocks, long delays through insufficient market capacity and drive inefficient business practices; inhibiting EV uptake and disadvantage all customers.

Currently on the SPD network, 5% of secondary substations are loaded to over 90%. EV uptake will increase this to 19% by end of ED2. Coupled with the impact on LV feeders (with phase imbalance issues likely to occur first), this represents a significant volume of assets with limited spare capacity for the additional load EV uptake will bring. The My Electric Avenue[21] project found that one third of LV networks will need reinforcement at between 40 – 70% EV penetrations based on based on 3.5kW (16amp) charging.

Reduced spare capacity in the existing distribution network limits the number of uncontrollable EV charging points which can be accommodated.

Due to different local city ambitions, there will be regional variations in the profile of investment required to fulfil Government aspirations. Clustering impacts from EV charging also depends on local customer demographics and charging patterns. Home charging will predominately impact distribution networks in residential areas, whilst on-street, destination and en-route charging will impact distribution networks in industrial urban contexts and highways in rural locations.

Whilst it is clear reinforcement is necessary, the existing ED1 reinforcement mechanism is ineffective for delivering this reinforcement. The mechanism is appropriate where load growth is slow and predictable, but not rapid or localised as reinforcements are only planned and delivered once the need has arisen.

Given reinforcement timescales, waiting for network capacity to be breached will delay the roll-out of charging points. This is concerning as the findings of network innovation projects and existing EV data have repeatedly shown that the ability to readily access charging infrastructure is a key consideration of potential EV owners.

Where charging facilities are not available and there is insufficient capacity to connect, long delays will hamper uptake and delay the transition to electrified transport.

This highlights the need to make anticipatory investments to upgrade electricity networks to enable the connection of charging facilities (echoed by the recent Net Zero report by the Committee on Climate Change[22]).

3.3.3 Network Visibility and Smart Solutions

Ground mounted transformer substations in the SPD licence area are equipped with basic maximum demand indicators (MDIs); these do not provide information on voltage,

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[21] SHEPD, "My Electric Avenue Summary Report", Mar 2016: http://myelectricavenue.info/sites/default/files/Summary%20report.pdf

[22] Committee on Climate Change, "Net Zero - The UK's contribution to stopping global warming", May 2019: www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

timing, duration, or frequency of peak demand. They also require manual reading with measurements taken annually. MDIs can give a false reading of the substation loading if they are not reset after network alteration or fault activity. For these reasons, they have limited use for network planning.

Accordingly, SPD does not have full visibility of the existing spare capacity within the LV network and cannot manage and deploy innovative/smart solutions optimally where networks are approaching design limits. Any reinforcement or procurement of smart services will be blunt and non-optimal, reducing customer benefit.

A low volume of secondary substation monitors are being rolled out as part of the ED1 price control. SPEN believes the speed and volume of the roll-out is insufficient to enable effective planning for the future volume of EVs. Monitors must be in-situ for a number of years to gather meaningful information or they can drive non-optimal network reinforcement.

In parallel, the development of "smart" solutions that provide rapid, incremental network capacity increases (in comparison to traditional reinforcement) will require additional monitoring to observe and manage capacity.

Flexible Networks[23] demonstrated that enhanced monitoring offers an average of 8% (39.2kVA average per substation) of network capacity can be released based on the ability to better utilise assets.

Smart Meter data, together with the secondary substation monitoring, will enable enhanced network monitoring and provide additional benefit such as aggregated feeder loadings. Smart Meter data alone can provide detail on individual customer connections but cannot be readily aggregated; the two solutions are complementary.

A high penetration of secondary substation monitoring will:

- Enable pro-active investment in interventions as required;
- Provide an enabling step towards the adoption of smart charging technologies;
- Inform and minimise anticipatory network investment through greater visibility of network capacity.

[23] SPEN, "Flexible Networks Closedown Report Final", Dec 2015: https://www.spenergynetworks.co.uk/userfiles/file/Flexible_Network_Closedown_Report.pdf

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4. OUTPUTS & DELIVERABLES – STRATEGY TO ENABLE EV TRANSITION

As a diligent network operator, SPEN has identified the requirement for anticipatory network investment to enable the EV transition. There is currently no specific ED1 funding associated with electric vehicles, or anticipatory investment to accommodate them. Anticipatory investment will be made strategically in two areas:

- The deployment of wide-scale monitoring of the LV network to test network constraints and enable smart charging; and,
- Reinforcement of areas of the network where smart options are not capable or cost efficient solutions to accommodate EV uptake by the end of ED2.

In both cases this is not additional expenditure, but accelerated investments that would otherwise have been required in ED2 as part of a managed network investment profile had EV uptake forecasts remained stable. Through these actions SPD will adopt a proactive strategy to efficiently minimise system risk and inconvenience for customers, utilising new monitoring and switching technologies to limit costs. The rationale for and perceived benefits of this strategy are detailed in the following sections.

4.1 Accelerated Investment

Various forecasts in section 3.3.1 highlight that EV uptake is likely to be far more significant within ED2 compared to the remainder of ED1. To deliver this investment efficiently it must be delivered linearly, beginning as quickly as possible.

SPD has conducted analysis to quantify the impact this would have on the reinforcement which will be required to support EV uptake by the end of the ED1 and ED2 periods. This analysis is based on the SPD EV growth prediction (Figure 4), maximum demand indicator data, asset ratings and EV uptake scenarios to identify inevitable reinforcements. It is recognised that smart solutions will delay or negate the need for reinforcement, and this has been factored into the analysis. It has been assumed that 25% of identified reinforcement will not be required due to the deployment of smart solutions. A deferral of 25% is optimistic given experience of previous smart solutions. Flexible Networks[24] determined that 8% of additional capacity can be released through enhanced monitoring.

Table 1 shows the rate of reinforcement will be significantly higher in ED2 compared to ED1 (20 times as much for LV cable and secondary substation). This demonstrates the challenge arising from the current constraint driven reinforcement mechanism.

Activity	ED1 volumes / per year	ED1 volumes	ED2 volumes / per year	ED2 volumes
LV cable (km)	18	63	69	345
LV service joint	1,109	3,880	4,304	21,520
Secondary substation	18	63	167	837
LV reconfiguration point – link box	19	67	179	893
LV reconfiguration point – pillar	5	16	45	224

Table 1. Forecast reinforcement required to provide capacity for SPD EV forecast

[24] SPEN, "Flexible Networks Closedown Report Final", Dec 2015: https://www.spenergynetworks.co.uk/userfiles/file/Flexible_Network_Closedown_Report.pdf

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SPD's proposal to deliver these volumes most efficiently is through anticipatory investment. This will accelerate ED2 EV related investments to maintain a steady investment profile from now until the end of ED2 across the two price control periods. Accelerating these projects to ED1 means they can be delivered gradually and efficiently, rather than reactively several years after they are needed. Delays, cost and inconvenience of constraint driven reinforcement will be exacerbated if schemes must be delivered concurrently due to the limited resources and insufficient market capacity.

The proposed adjustments to the ED1 and ED2 volumes are presented in Table 2. The volumes within Table 2 will provide SPD customers with the capacity to charge around 210,000 EVs by the end of ED1. SPD forecast predicts that this many EVs will occupy the SPD area by early 2025.

Activity	ED1 accelerated volumes / per year	ED1 accelerated volumes	Adjusted ED2 volumes / per year	Adjusted ED2 volumes
LV cable (km)	48	168	48	240
LV service joint	2,989	10,462	2,989	14,938
Secondary substation	106	371	106	529
LV reconfiguration point – link box	113	396	113	564
LV reconfiguration point – pillar	28	98	29	142

Table 2. Proposed adjustment to ED1 and ED2 volumes to enable smooth investment in network asset reinforcement

A similar approach can be applied to managing the roll-out of LV monitoring equipment. Table 3 outlines the current volumes of monitors to be deployed in ED1 and ED2; Table 4 presents the proposed adjustment. This adjustment would provide monitoring to 40% of secondary substations (≥200kVA) by the end of ED1, providing valuable planning information and enabling flexible supply options for customers.

Activity	ED1 volumes / per year	ED1 volumes	ED2 volumes / per year	ED2 volumes
LV monitoring	419	1,466	3,135	15,676

Table 3. Current LV Monitor volumes in ED1 and ED2

Activity	ED1 accelerated volumes / per year	ED1 accelerated volumes	Adjusted ED2 volumes / per year	Adjusted ED2 volumes
LV monitoring	1,959	6,857	2,057	10,285

Table 4. Proposed adjustment to LV monitoring ED1 and ED2 volumes

Adopting this approach across both monitoring and network reinforcement facilitates the timely deployment of network infrastructure and supports EV growth. It also enables smoother investment in future network asset upgrades shown to benefit the wider economy[25].

The subsequent sections provide further detail about the specific solutions which will be deployed, the criteria for their deployment and how their roll-out will be managed.

4.2 Accelerated Investment Strategy

The allocation of investment in the outlined volumes will be driven by robust analysis of needs, including socio-economic modelling and electrical network modelling, to understand areas for most effective deployment. The methodology for determining these candidate areas for investment (either monitoring or reinforcement) is detailed in Appendix C with a case study presented in Appendix D.

4.2.1 Understanding Stakeholder and Customer Needs

Whilst this submission sets out a methodology for determining potential areas for increased uptake, SPD is also engaging with a range of stakeholders to supplement, validate and improve conclusions and future processes.

1. SPD has been engaging extensively with Scottish Government, Transport Scotland and ChargePlace Scotland to understand public EV charger roll out and network implications. Coordinating the development of the public EV charging infrastructure with the development of electricity networks is critical to ensuring both are capable of supporting Government ambition.
2. The Network Innovation Competition (NIC) project CHARGE[26] is combining transport and electricity network planning for the first time to optimise the location and installation of EV charging infrastructure. Focussed in the SP Manweb area, the project will also provide learning that will be deployed in SPD and inform future investments.
3. SPEN's EV Uptake Modelling (EV-Up) Network Innovation Allowance (NIA) project[27], will enable continual refinement during the scope of reopener. EV-Up will develop data sets to improve the understanding of customers' ability to transition to EVs based on parking opportunity and demographics. This will improve visibility of increased demand areas and inform investment programmes. EV-Up will provide granular data and enable precise network investment requirements. The initial output of a parking probability study is shown in Figure 5.

[25] Turner, K., Alabi, O., Calvillo, C., Katris, A., & Figus, G., "Who Ultimately Pays for and Who Gains from the Electricity Network Upgrade for EVs?", May 2019: https://doi.org/10.17868/67741
[26] SPEN, CHARGE NIC project: https://www.ofgem.gov.uk/system/files/docs/2018/11/charge_spen_-_2018_nic_resubmission_redacted.pdf
[27] SPEN, EV-Up NIA project: https://www.smarternetworks.org/project/nia_spen_0037

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Figure 5. EV-Up Project – Initial output of parking probability perspective

4.2.2 Risk Based Deployment

Accelerated investment will be based on an assessment of the asset becoming constrained during the ED2 period. Through the proposed modelling activity, an asset's constraint risk will be categorised based on two properties. These are:

- Uptake Index – related to geographic location and an indicator of the probability EV uptake.
- Capacity Index – a measure of the remaining capacity of the asset.

These measures will be used to populate a risk matrix. Examples are shown in Table 5 and Table 6 for substations and cables respectively.

		Substation Capacity Index (Modelled EVs)			
		1 (<80%)	2 (≥80% and <95%)	3 (≥95% and <99%)	4 (≥99%)
Uptake Index	Green				
	Amber	Low Risk	Medium	Risk	High Risk
	Red				

Table 5. Risk based deployment matrix for substation assets

		Cable Capacity Index (Modelled EVs)	
		Capacity not exceeded (km)	Capacity exceeded (km)
Uptake Index	Green		
	Amber	Low Risk	High Risk
	Red		

Table 6. Risk based deployment matrix for LV cables

Figure 6 illustrates the investment strategy based on the allocation of risk. As shown, there is a focus on high risk assets for all reinforcement activity. Monitoring will be prioritised across high and medium risk assets given their potential to inform later reinforcement activity and facilitate the later adoption of smart solutions.

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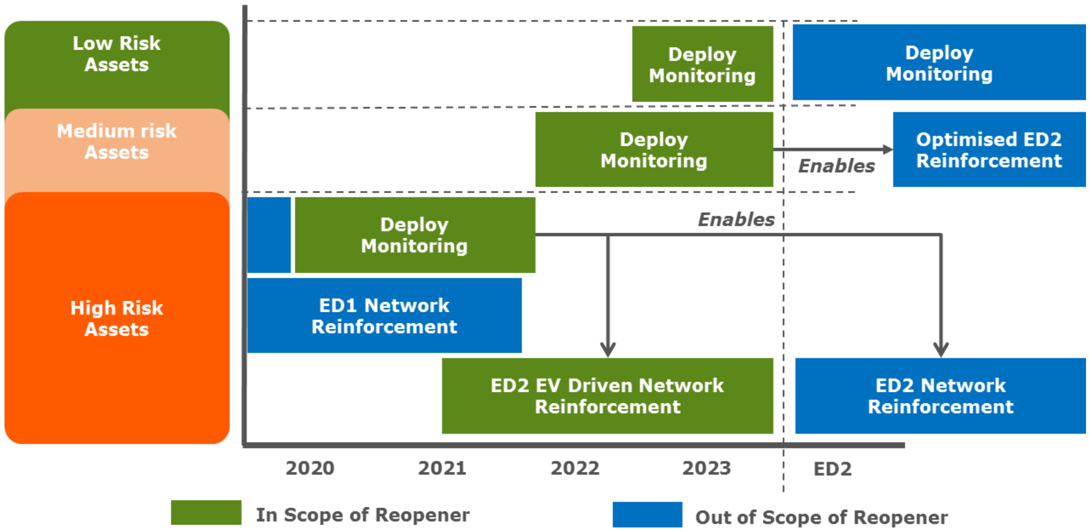

Figure 6. Accelerated investment strategy

4.3 LV Monitoring

This section describes the type and scale of LV monitor deployment:

- Section 4.3.1 outlines the proposed monitoring system;
- Section 4.3.2 details the volumes within the reopener submission; and,
- Section 4.3.3 describes the unit costs of the monitoring system.

4.3.1 Monitoring System Design

The proposal utilises the Enhanced Secondary Substation Monitoring (ESSM) system to monitor secondary substations. The ESSM system provides detailed measurements of voltage and current communicated to a central data network telecom operator's 2G/3G/4G networks. The ESSM system provides the necessary features outlined in section 3.3.3, and supports cost efficient investment in the network.

A detailed description of the proposed monitoring system architecture is presented in Appendix E.

4.3.2 Monitoring Reopener Volumes

Based on analysis from SPEN, monitoring of only substations supplying ≥200kVA provides most benefit for a given cost. Therefore, these higher power supply points will be the target of the monitoring programme roll-out.

The overall number of secondary substations (≥200kVA) is detailed in Table 7. It is anticipated that it is practicable to install monitors on 40% of these substations by the end of the ED1 whilst still deriving associated benefits. Monitors would therefore be deployed on 6,857 substations.

Secondary Substation (≥200kVA)	Volumes
Ground mounted	15,378
Pole mounted	1,764

Table 7. Secondary substations in the SPD licence area with a rating of ≥200kVA

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SPD has an allowance of £2.61m within the current ED1 agreement. This equates to 1,466 monitors based on the unit cost detailed in the following section. Table 8 details the remaining volumes on which this reopener submission is based.

Activity	Reopener volumes
Monitoring devices	5,391
Central processing infrastructure	1

Table 8. Planned monitoring volumes

4.3.3 Monitoring Unit Costs

Monitoring hardware

The below costs have been determined through engagement with suppliers and potential vendors of the enhanced monitoring unit. The remaining items are common electrical equipment items with well-established and understand constituent costs. Exact pricing will vary depending on volumes, especially for the monitoring device itself; expected variance is 10-20%, which has less than a 5-10% impact on the total installation costs.

The cost breakdown of the ESSM system is given for a single substation in Table 9.

Item description	Cost
Enhanced secondary substation monitoring unit	xxx
Substation gateway	xxx
Current Sensors (5 sets, 3 phase)	xxx
Voltage Sensors/Clamps	xxx
Mounting accessories	xxx
Wiring	xxx
Isolator/fuses	xxx
Labour charges for installation	xxx
Total Cost	**xxx**

Table 9. Cost breakdown for installation of ESSM device, £ (2012/13 prices)

For safety reasons, the installation will be carried out by a two-person team working to live-line practices. The installation is based on the 2-person team installing up to four systems per day – i.e. 4-equivalent hours per installation.

Central Data System Costs

The cost for central data storage systems and analytics are drawn from best practices adopted in previous similar projects. Breakdown for development of central data storage systems, integration with existing data base and data analytics is detailed in Table 10.

Activity description	Cost
Existing product enhancement	xxx
Data integration	xxx
Data analytics and visualisation	xxx
Total Cost	**xxx**

Table 10. Cost breakdown for central data storage systems and data analytics, £k (2012/13 prices)

4.4 Network Reinforcement

This section describes reinforcement options available as part of the proposed activities with expected volumes and costs. Structured as follows:

- Section 4.4.1 outlines the reinforcement design options;
- Section 4.4.2 details the volumes associated with the reopener submission; and,
- Section 4.4.3 describes the unit costs of the reinforcement options.

4.4.1 Reinforcement Design

A number of reinforcement design options are considered within the scope of this submission and will be applied as appropriate. These are:

- Upgrade of LV cabling (including LV service joints)
- Upgrade of a secondary substation
- LV reconfiguration point (link box or pillar)

It is assumed that if thermal limits of LV Overhead Line (OHL) services are breached, they will be undergrounded.

Further details, and alternative intervention options, are presented in Appendix B. Where network reinforcements are made, consideration of capacity requirements out to 2050 will be given to avoid revisiting investments to upgrade the capacity again (following recommendations made by the CCC[22]).

It is anticipated that HV automation will also be needed to support cost efficient EV driven network reinforcement in future. However further network information (e.g. from monitors) is required to determine where the inclusion of this functionality would be most effective. Therefore, HV automation is excluded from this reopener submission.

4.4.2 Reinforcement Reopener Volumes

The selection of reinforcement candidates will be informed by network modelling. Assets will only be considered for reinforcement where capacity has been exceeded within the considered EV uptake scenario[28] and headroom cannot be achieved through smart/flexible solutions. LV system models will enable the timely start of intervention; supplemented by monitoring data as this becomes available. SPD is targeting assets

[28] Hence EV uptake is the primary driver for capacity being exceeded rather than normal load growth.

where future investment is guaranteed and capacity will be well utilised, minimising the potential for stranded assets, Table 11. Connections where costs are likely to be incurred by the applicant (e.g. public chargers) are considered out of scope.

Activity	Reopener volumes
LV cable (km)	105
LV service joint	6,582
Secondary substation	308
LV reconfiguration point – link box	329
LV reconfiguration point – pillar	82

Table 11. Planned volume of network reinforcements

4.4.3 Reinforcement Unit Costs

The proposed reinforcement unit costs for three reinforcement options considered are listed in the following tables. These costs exclude design works, outage planning and delivery support activities listed in section 4.5.

Activity	Cost
Installation of 20m of HV cabling	xxx
Secondary substation transformer	xxx
LV board	xxx
Ring Main Unit	xxx
Installation of 40m LV cabling	xxx
Civil works	xxx
Total	**xxx**

Table 12. Unit cost for upgrade of a secondary substation, £k (2012/13 prices)

Activity	Cost
LV cable (km)	xxx

Table 13. Unit cost for upgrade of LV cable, £k (2012/13 prices)

Activity	Cost
LV service joint	xxx

Table 14. Unit cost for LV service joint, £k (2012/13 prices)

Activity	Cost
LV reconfiguration point – link box	xxx
LV reconfiguration point – pillar	xxx

Table 15. Unit cost for LV reconfiguration points (only one option is to be selected), £k (2012/13 prices)

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The proposed unit costs can be efficiently delivered by SPD. Benchmarking of these costs is shown in Table 16. The proposed unit cost is the SPD efficient outturn average cost for majority of the activities except:

- LV boards for which the industry outturn average costs are proposed due to previously limited LV board delivery in SPD;
- LV cable for which the industry outturn average costs are proposed due to the requirements for service breach joints when upgrading LV cable; and
- LV service joint for which the cost of £0.54k has been utilised, based on SPEN's analysis of replacement unit costs within SPD's original ED1 submission.

Activity	SPD Outturn Average Cost	Industry Outturn Average Cost	Ofgem ED1 Expert View Cost	Proposed Unit Cost
HV cable (km)	xxx	xxx	xxx	**xxx**
Secondary substation transformer	xxx	xxx	xxx	**xxx**
LV board	xxx	xxx	xxx	**xxx**
Ring Main Unit	xxx	xxx	xxx	**xxx**
Civil works	xxx	xxx	xxx	**xxx**
LV cable (km)	xxx	xxx	xxx	**xxx**
LV service joint	xxx	xxx	xxx	**xxx**
LV reconfiguration point – link box[29]	xxx	xxx	xxx	**xxx**
LV reconfiguration point – pillar	xxx	xxx	xxx	**xxx**

Table 16. Reinforcement unit cost comparison, £k (2012/13 prices)

[29] SPD outturn average cost has been selected to account for the higher anticipated cost for installing new link boxes as opposed to upgrade of the existing ones.

4.5 Project Team

A dedicated project team comprising 11.5 FTE members will be established to support delivery of accelerated EV load investment. The project team structure consists of design and delivery components under a single project manager, as shown in Figure 7:

- Specialised design resources are required to undertake detailed LV network modelling studies, including optimisation of associated LV network configuration.
- Required support at the delivery stage includes programming of work and operational network management. Significant level of support is also required for outage and system access planning purposes. Additional labour is required to monitor outputs and ensure accurate reporting.

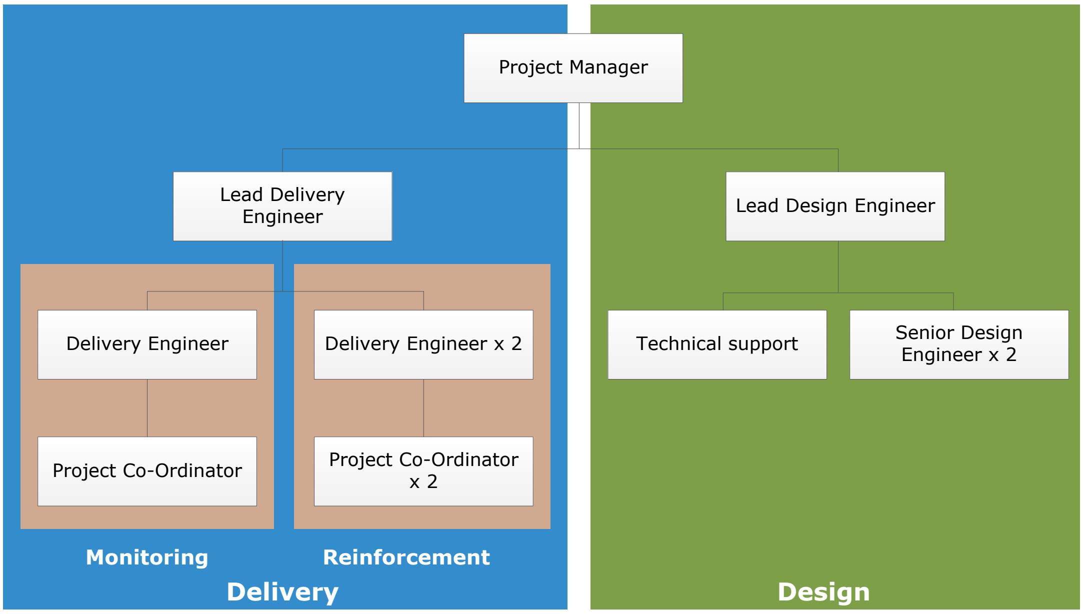

Figure 7. Project team structure

The division of labour is presented in Table 17.

Role	Delivery FTE	Design FTE
Project Manager	0.25	0.25
Lead Design Engineer	–	1
Senior Design Engineer	–	2
Technical Support	–	1
Lead Delivery Engineer	1	–
Delivery Engineer (Monitoring)	1	–
Project Co-Ordinator (Monitoring)	1	–
Delivery Engineer (Reinforcement)	2	–
Project Co-Ordinator (Reinforcement)	2	–
Total	**7.5**	**4**

Table 17. Project Team FTE

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4.6 Summary of Outputs and Deliverables

The total proposed additional volumes for the period between 2019/20 and 2022/23 are presented in Table 18 for the monitoring and in Table 19 for the reinforcement works.

Activity	Delivery volume schedule				
	2019/20	2020/21	2021/22	2022/23	RIIO-ED1
Monitoring devices	320	1,691	1,691	1,691	5,391
Central system[30]	0.4	0.6	0	0	1

Table 18. Deployment schedule for monitoring devices

Activity	Delivery volume schedule				
	2019/20	2020/21	2021/22	2022/23	RIIO-ED1
LV cable (km)	0	38	38	29	105
LV service joint	0	2,367	2,368	1,845	6,579
Secondary substation	0	109	109	90	308
LV reconfiguration point – link box	0	116	116	97	329
LV reconfiguration point – pillar	0	29	29	24	82

Table 19. Deployment schedule for reinforcement activities

4.7 Summary of HVP adjustment

SPEN's analysis estimates a requirement for £42.0m investment to be undertaken in SPD in ED1 to enable the smooth EV transition. The full strategy sets out the use of network monitoring and socio-economic models to identify the reinforcement necessary to meet the emerging and approaching EV charging requirements.

The total proposed adjustment to the RIIO-ED1 value is £42.0m (2012/13 prices) for the period between 2019/20 and 2022/23. A breakdown of these costs is given in Table 20.

Activity	2019/20	2020/21	2021/22	2022/23	RIIO-ED1
LV monitoring	xxx	xxx	xxx	xxx	xxx
Reinforcement	xxx	xxx	xxx	xxx	xxx
Labour – Delivery	xxx	xxx	xxx	xxx	xxx
Labour – Design	xxx	xxx	xxx	xxx	xxx
Grand total	**1.63**	**14.42**	**13.72**	**12.19**	**41.95**[31]

Table 20. Summary of HVP adjustment, £m (2012/13 Prices)

[30] It is anticipated that limited system functionality would be established in year one with a full system deployed within year two.
[31] Total values are correct - summation differences are due to rounding errors.

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5. SUMMARY OF COMPLIANCE AGAINST HVP LICENCE CONDITIONS

5.1 Summary of Licence Conditions

CRC 3F.8 of SPD's electricity distribution licence sets out the conditions that any HVP reopener must meet. SPEN has considered this HVP reopener submission against those requirements:

a) *Is based on information about the actual or forecast level of efficient expenditure on the uncertain cost activity that was either unavailable or did not qualify for inclusion when the licensee's Open Base Revenue Allowance was derived.*

SPEN considers that this HVP reopener submission meets this requirement as the information was unavailable when SPD's Open Base Revenue Allowance was prepared pre-2015. There has been a material change in circumstances since the SPD ED1 submission was prepared pre-2015. UK and Scottish Government policy is vastly more ambitious, supported by EV ownership and market changes, and increasing charging infrastructure as outlined in section 3.2. These policy decisions predominantly affect the SPD distribution network as ca. 80% of Scotland's customers reside within this area. SPD is facing these challenges one price control earlier than other GB distribution business.

As the level of EV investment required to meet government targets could not be foreseen during preparation of the ED1 submission and in the absence of an appropriate load related anticipatory investment mechanism, this HVP uncertain cost reopener will ensure SPD does not inhibit ambitous UK and Scottish government targets.

b) *Takes account of any relevant adjustments previously determined under this condition.*

This HVP reopener submission meets this requirement – there have been no previous relevant adjustments under this condition.

c) *For all uncertain cost activities other than High Value Project Costs, constitutes a material amount as specified for the licensee in Appendix 2, 3, 4 or 5.*

This condition is not applicable as SPEN's submission is an HVP reopener.

d) *For High Value Project Costs passes the tests set out in Appendix 1.*

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This submission meets this requirement – the below checks against the tests in Appendix 1 of CRC 3F have been completed. All values are in £m, 2012/13 Prices.

A1.2

$$(\max(TUCHVPF - TUCHVPov, TUCHVPov - TUCHVPF)) > MA + (20\%\ x\ TUCHVPov)$$

A1.3

The total adjustment must not exceed:

i) $TUCHVPF - TUCHVPov - (20\%\ x\ TUCHVPov)$

$Where\ TUCHVPF > TUCHVPov$; or

ii) $TUCHVPF - TUCHVPov + (20\%\ x\ TUCHVPov)$

$Where\ TUCHVPF < TUCHVPov$

Term	***Definition***	***SPD***
$TUCHVPov$	*Means the total opening level of allowed expenditure that is defined as High Value Project Costs as set out in Table 2 plus any additional allowed expenditure determined under previous reopeners under this condition.*	*0.00*
$TUCHVPF$	*Means the proposed revised level of allowed expenditure that is defined as High Value Project costs.*	*41.95*
MA	*Is the material amount set out for the licensee at Table 2 of this Appendix.*	*6.47*

A1.2

$$\mathbf{41.95 - 0.00 > 6.47 + (20\%\ x\ 0.00)}$$ **Passes**

A1.3

$$\mathbf{41.95 > 0.00}$$

$$\mathbf{41.95 - 0.00 - (20\%\ x\ 0.00) \leq 41.95}$$ **Passes**

e) *Relates to costs incurred or expected to be incurred after 1 April 2015.*

This HVP reopener submission meets this requirement – all costs will be incurred after 1 April 2015.

f) *Constitutes an adjustment to allowed expenditure that (excluding any Time Value of Money Adjustment) cannot be made under the provisions of any other condition of this licence.*

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SPEN considers that there is no other available funding mechanism within the licence for this programme. These works could not have been included within SPEN's ED1 business plan submissions due to their uncertain nature. As such the project qualifies for consideration under CRC 3F – arrangements for the recovery of uncertain costs.

This HVP is driven by the necessity to deliver network capacity for an emerging and foreseeable surge in EV demand for which there is no other available funding arrangement. SPD has no other provision to fund anticipatory network investment in relation to EVs or otherwise. Load related allowance is inaccessible as it is allocated specifically for constraint driven reinforcement and will only be spent in these instances.

If the costs associated with wide-scale monitoring and reinforcement imposed by the EV roll-out had been identified in advance of ED1, their inclusion within the SPD business plans would have been subject to Ofgem's final determination assessments.

The requirements of a HVP submission; a project... "reasonably forecast to cost the licensee £25 million or more (in 2012/13 prices) during the Price Control Period, and for which clear outputs, a needs case and a statement of costs have been provided to the Authority", have been met as set out in this submission.

All other uncertain cost reopener activities are not applicable and can be ruled out.

5.2 Ofgem's Principal Objective

We have considered this submission against the Ofgem's key objective of ensuring that all customers are able to access maximum value and quality of service from their energy supply. We believe there is certainty that accelerated, managed and deliverable network investment profile is in the interest of SPD customers through reduced overall costs and improved security of supply. The accelerated investment is also essential to meet government's ambitious targets.

Electric Vehicle Reopener Application – CRC 3F

6. PROPOSED OUTPUT MEASURES

Project delivery will be tracked volumetrically, shown in Table 21; this is readily measurable with full transparency and accountability. RIIO-ED1 close-out will be supported by a Performance Assessment Report with detailed analysis papers for each investment scheme demonstrating customer value.

Activity	Precedent	Unit	Proposed Adjustment
LV monitoring	CV7	Each	This submission sets a volume of secondary substations under which LV monitoring equipment will be installed under the HVP. Costs have been derived through engagement with suppliers and potential vendors of the enhanced monitoring unit. It is proposed at close-out, a review of volumes of completed sites is used to scale the allowed adjustment with respect to delivered volumes proportionally. Any over delivery adjustment should be capped to +20%.
LV Cable	CV7	km	This submission sets a volume of km of cable that must be efficiently replaced to deliver anticipatory network investment to enable the smooth EV transition. Project costs have been derived as the product of volumes and efficient unit cost. It is proposed at close-out, review of actual delivered volumes is used to apply any adjustment using the agreed unit cost.
LV service joint	CV8	Each	This submission sets a volume of LV service joints that must be efficiently replaced to deliver anticipatory network investment. Project costs have been derived as the product of volumes and efficient unit cost. It is proposed at close-out, review of actual delivered volumes is used to apply any adjustment using the agreed unit cost.
Secondary Substation	CV7	Each	This submission sets a volume of secondary substations that must be efficiently replaced to deliver anticipatory network investment. Project costs have been derived as the product of volumes and efficient unit cost. It is proposed at close-out, review of actual delivered volumes is used to apply any adjustment using the agreed unit cost.
LV reconfiguration point	CV7	Each	This submission sets a volume of LV reconfiguration points that must be efficiently replaced to deliver intervention. Project costs have been derived as the product of volumes and efficient unit cost. It is proposed at close-out, review of actual delivered volumes is used to apply any adjustment using the agreed unit cost.
Project Management, Engineering Management & Clerical Support (EMCS)	C9	£	The project team costs have been derived using SPEN's internal rates. The measure of the team's success is the full deployment of proposed LV monitoring and network reinforcement. It is proposed at closeout, allowance is reviewed against the planned volumes. Any adjustment should be compared against the % of remaining volumes from Table 8 and Table 11. Where there are 0 volumes remaining, 100% of the proposed team costs should be allowed.

Table 21. Comparable close out precedents and adjustment methodologies

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Materiality

SPEN proposes that if any adjustment required under the above metrics is less than the materiality thresholds set out in Table 2 of Appendix 1 of CRC 3F, there shall be no positive or negative adjustment to the total value presented in Table 20 of this submission.

Double-Counting

SPEN believes there is no risk of double counting under this project as all activity will be recorded against the HVP.

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APPENDIX A EV CHARGING INFRASTRUCTURE AND PROFILES

A.1 EV Charging Infrastructure

The type and location of EV chargers can have a significant influence on the load profile which it will present to the network. First considering required charging power, current EV charge points can be split into four main categories:

- Slow – 3kW or 7kW
- Fast – 11kW or 22kW
- Rapid – 50kW
- Ultra rapid – 150kW which allows for charging in around 30 minutes or 350kW[32] which will allow for charging in ca. 5-10 minutes (similar to refuelling at a conventional petrol station).

It is clear that the higher power charger types will add significant short term load to the network. Figure 8 highlights that there is an increasing volume of these chargers being installed each year.

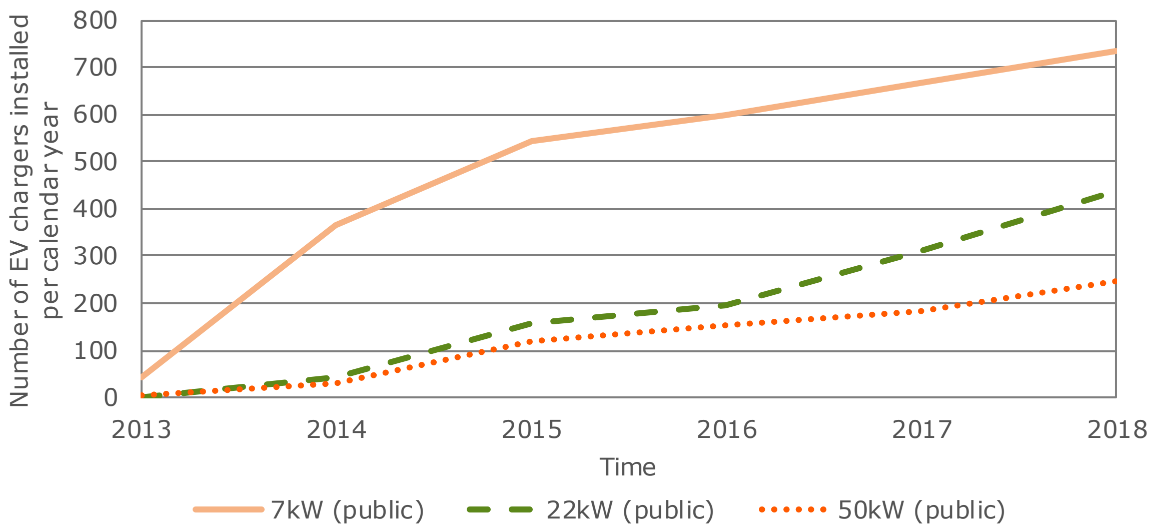

Figure 8. Public charger types installed per annum within the SPD licence area (based on figures from ChargePlace Scotland)

These different charger types tend to be associated with different locations and use cases. Four may use cases are:

- Domestic charging: charging at home where vehicle owners have their own dedicated space to park or charge their vehicle. Domestic chargers are usually rated at 3kW to 7kW.
- On-street charging: public chargers located on streets. These chargers are predominately rated at 7kW, 11kW or 22kW. The deployment of these chargers is limited by the physical practicalities of on-street parking.
- Destination charging: public or semi-public chargers installed at car parks, recreational locations (shopping centres, cinemas, leisure centres etc.), park/ride

[32] Ultra-rapid chargers with ratings of up to 400kW are being developed: https://electrek.co/2017/01/05/chargepoint-400-kw-charing-electric-vehicle-range/

locations (subway and bus connections to city centre). Destination chargers include a combination of 7kW, 11kW and 22kW, and 50kW chargers.
- En-route charging: located on the route of major roads, including motorways, similarly as existing motorway services/petrol stations. These chargers are rated at 50kW and above.

A.2 EV Charging Profiles

Charging profiles vary between the different user types and locations. While domestic charging profile usually has the peak demand in the evening, other charging models show the peak demand in the morning and throughout the day.

Domestic charging profile based on the results from the WPD Electric Nation project[33] is shown in Figure 9.

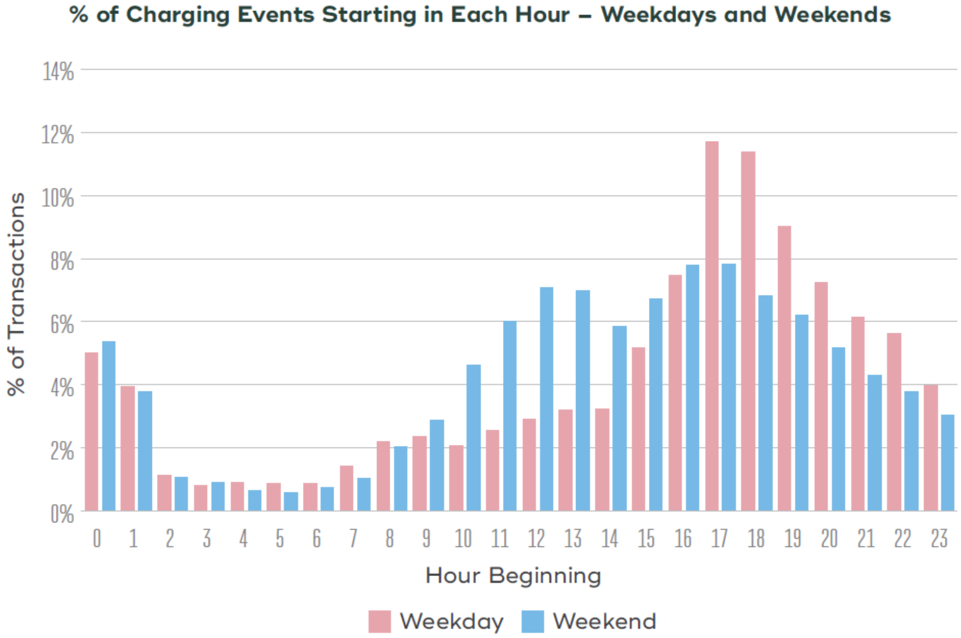

Figure 9. Domestic charging profiles (WPD, Electric Nation project)

Figure 10 shows a demand for chargers within Glasgow city locations[34]. It is clear that the charging profiles vary with the location. There is a clear peak for city centre car parks in the morning between 8am and 9am adding a large early morning demand to the network. Recreational sites have morning and evening peaks while on-street charging use is the highest during the midday.

[33] WPD, Electric Nation project, Oct 2018: http://www.electricnation.org.uk/wp-content/uploads/2018/10/Electric-Nation-What-weve-learnt-so-far-Oct18.pdf
[34] Data from ChargePlace Scotland with number of charge events based on use over a two-year period.

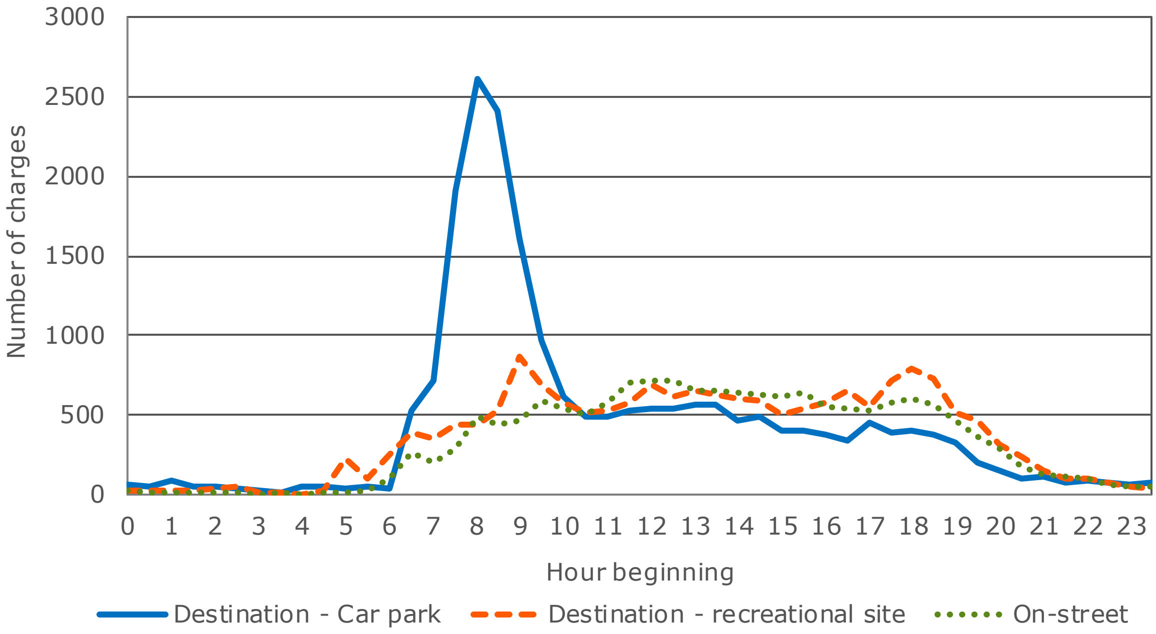

Figure 10. Charger use profiles for public chargers within Glasgow city locations

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APPENDIX B EV INTERVENTION OPTIONS

There are a range of solution options, both conventional and smart, that could be considered and combined to release capacity for EV charging.

Section B.1 summarises the conventional reinforcement solutions considered within this reopener. Section B.2 discusses smart solutions available now and in the future which will be facilitated by the inclusion of LV monitors.

B.1 Conventional Reinforcement Solutions

Conventional reinforcement solutions to provide additional EV charging capacity can be divided into two main categories:

- Asset upgrades and
- Network reconfiguration

Asset upgrade solutions increase thermal and voltage capacity and can therefore accommodate greater levels of peak load. These are:

- Upgrade of LV cabling. This simply involves the installation of cable which has a large capacity than the existing cable to meet capacity.
- Upgrade of a secondary substation. Depending on the configuration of the substation, this would typically involve the installation of a new secondary substation transformer, LV board and a ring main unit.

The main advantage of installing or upgrading a new asset is an increased network capacity and mitigation of fault level issues that may exist. However, this can come at high cost and can cause disruption (especially in dense urban areas).

Network reconfiguration can enable load on one circuit to be switched to another, potentially alleviating overload or voltage issues on one circuit. It includes the closing of normally open points or the opening of switches/circuit breakers in other parts of the network. Switching points must exist in order for the network to be capable of providing this reconfiguration. On the LV network, feeders can be split and LV underground boards or pillars can be installed to provide this capability where it does not pre-exist. The reconfiguration needs to be carefully managed to satisfy security of supply requirements.

B.2 Smart Solutions

Smart solutions enable an optimised utilisation of the grid and available energy. They present opportunities for how DNOs will manage their networks. They could be used to significantly reduce need for reinforcement and enable timely rollout of EV charging points. The level of Smart Solution deployment varies with both volumes and size of installations, a greater number of EVs gives a greater opportunity to apply technologies and the aggregate effect of these technologies and control methods will be greater.

However, this will not happen automatically and the right strategies are required to facilitate the smart integration of EVs. Smart solutions require interoperable charge points, communication protocols accessible by the DNO and customer expectations around flexibility, where DNO control would only be for network critical purposes.

There are several different approaches that could be used to defer or avoid reinforcement. These range in terms of complexity and cost to the user (and network operator) as shown in Figure 11.

In areas of high EV penetration (clustering) with high numbers of charge point penetration, it is likely that conventional reinforcement solutions will still be required given the significant increase in load. However, combining these reinforcements with smart solutions will enable SPD to adopt least cost solutions to accommodating EVs.

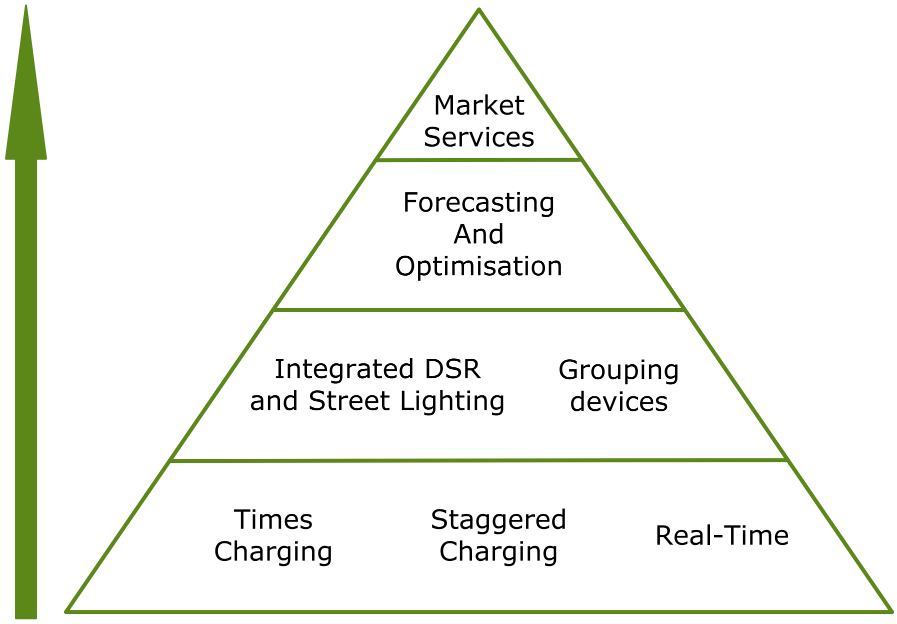

Figure 11. Smart management strategies to be trialled in the CHARGE NIC project, rising in complexity[35]

[35] SPEN, CHARGE NIC project: https://www.ofgem.gov.uk/system/files/docs/2018/11/charge_spen_-_2018_nic_resubmission_redacted.pdf

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APPENDIX C PRIORITISING MONITORING AND REINFORCEMENT

The proposed activity detailed within this submission will be justified and prioritised through detailed modelling of the LV network, with input from a range of sources. Models will be developed to examine:

- The need for charging infrastructure;
- The potential constraints on the network; and,
- The intervention options which accommodate future EV uptake.

The methodology for how these modelling activities will support investment decisions is illustrated in Figure 12. The various steps will be described in sections C.1 to C.4.

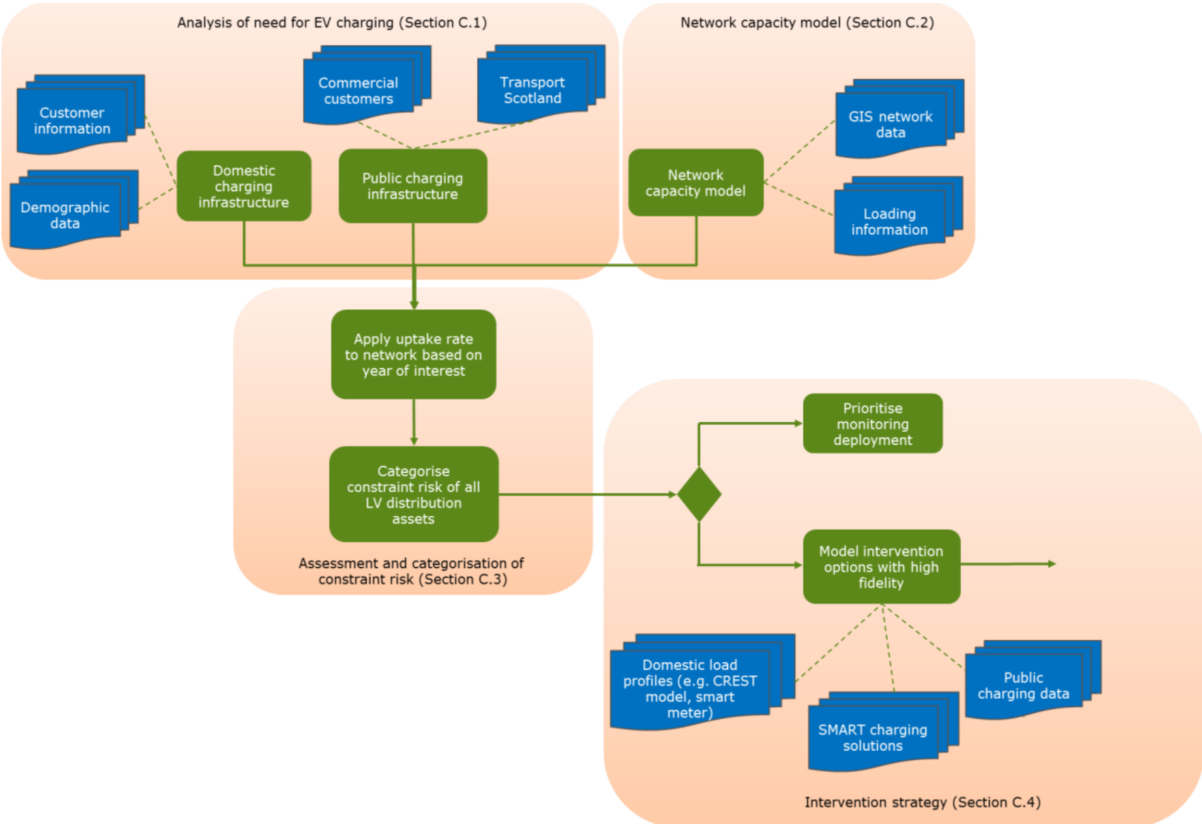

Figure 12. The prioritisation methodology will determine the risk of distribution assets becoming constrained over time

C.1 Analysis of Need for EV Charging

C.1.1 Domestic Charging Infrastructure

The need to provide network capacity for domestic charging will be based on an estimation of probability of future EV ownership.

This probability will be determined by socio-demographic information about the respective geographical zone. Zones will be categorised into red, amber and green zones based on predicted probability of EV uptake (with red being the highest). Different EV uptake profiles over time will be applied to these different zones which will reflect the higher probability of EV purchase.

The initial demographic data information used for the zone categorisation will be derived from Scotland's Census 2011[36] data. With the census, the data is presented within various datazones (up to 6,976 datazones are available, one for every 760 people in Scotland). The size of the datazones is determined by population and therefore their geographic area changes (size is a function of population density). This provides high granularity of demographic data which can be readily analysed across the whole of Scotland.

Four data points are extracted from the census for each datazone. These are:

- Car ownership;
- Property type;
- Affordability classification; and,
- Means of travelling to work.

The respective metrics for these datazones are then combined to determine a relative probability score for each zone. The relationship between scoring and classification is described in Table 22. Table 22 also presents scoring results from the assessment of Scotland's demographics and highlights that EV uptake is considered to be most prevalent in around 20% of the zones considered. An illustration of the classification map is presented in Figure 13.

Classification	Relative Score	Number of zones in Scotland	Percentage zones in Scotland
Red	≥80	1,427	20.5%
Amber	≥60 and <80	1,888	27.1%
Green	<60	3,661	52.5%

Table 22. Classification of demographic zones in Scotland

[36] Scotland's Census 2011 results, Data warehouse: https://www.scotlandscensus.gov.uk/ods-web/data-warehouse.html

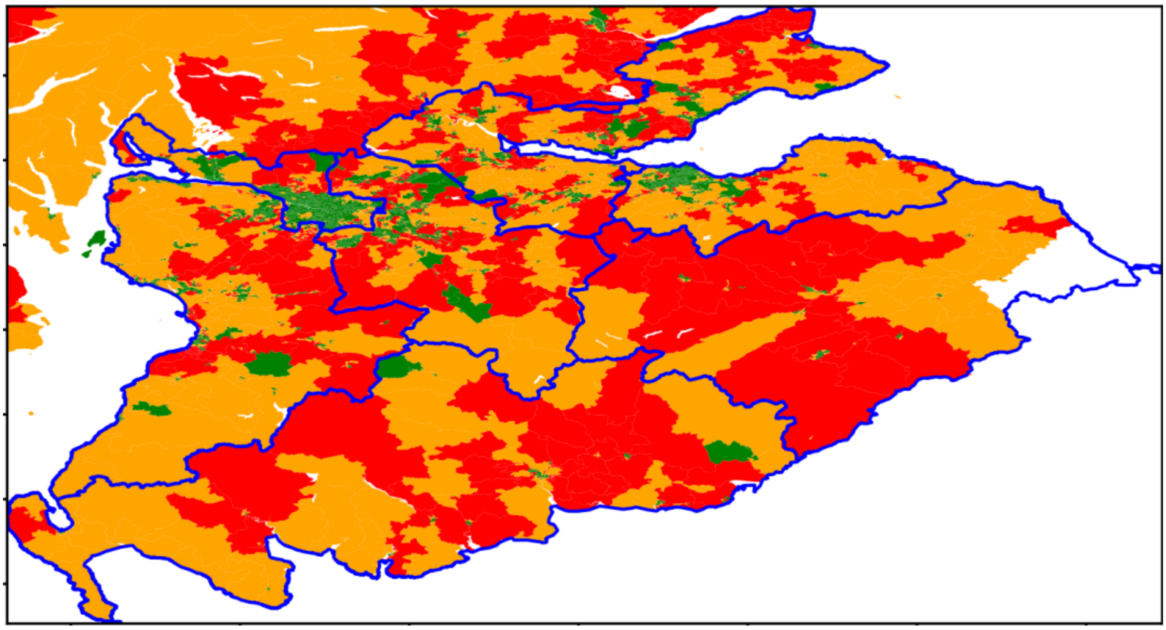

Figure 13. Demographic zone classification across the SPD licence area

Within the analysis of network constraints, different uptake scenarios will be considered for the three zone classifications. The proposed uptake rate over time for each zone is shown in Figure 14.

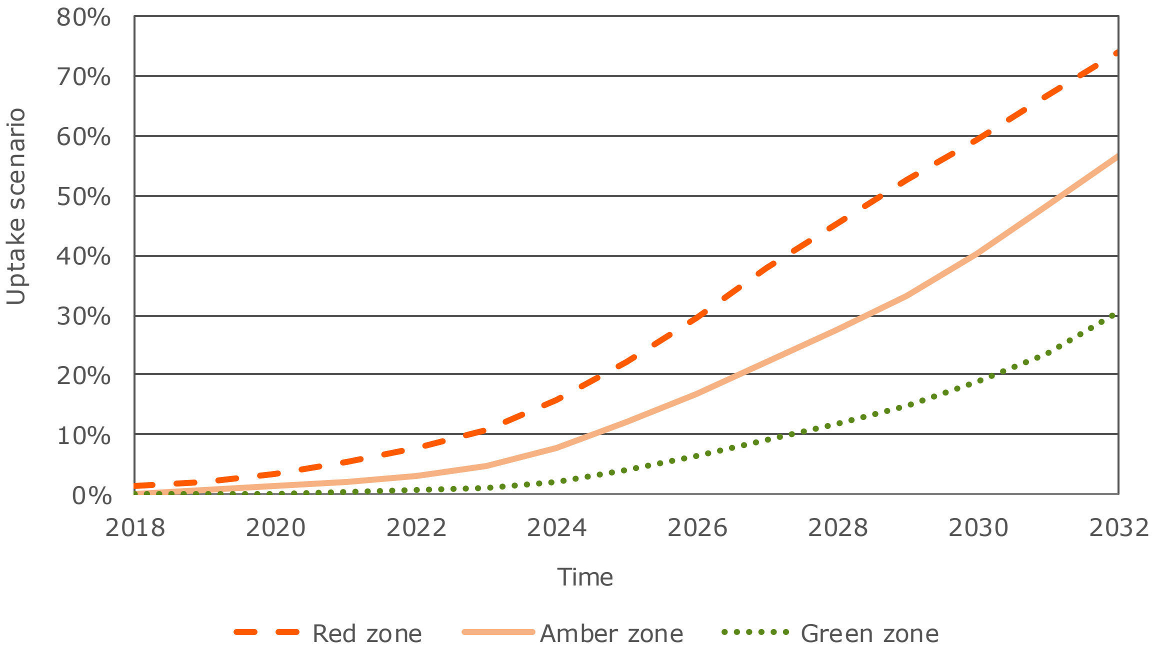

Figure 14. Modelled EV uptake percentage over time for different socio-demographic zones

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C.1.2 Public Charging Infrastructure

To date SPD has established links with a range of stakeholders, notably the Scottish Government, Transport Scotland, ChargePlace Scotland and various local councils. These links provide SPD with access to data on how current chargers are being used and enable SPD to take part in planning discussions for charge points to be rolled out in a way that does not adversely impact the distribution network.

As charger roll-out plans are developed, this will enable the likely locations of public charging points to be inserted into network models to determine their impact on the network.

It is noted that associated reinforcement costs of many public chargers would not be DUOS funded. However, it is important to understand the wider network impact of this growing charging infrastructure which will absorb available capacity.

C.2 Network Capacity Model

The Network Capacity model will be developed using the NAVI Platform. This platform was developed through the SPEN's Network Constraint Early Warning Systems (NCEWS) Network Innovation Allowance (NIA) project[37].

The NAVI Platform takes SPEN LV GIS data and, through a series of processing steps, creates a "node & edge" connectivity model. This model describes the asset attributes (e.g. rating) and allows a range of network analysis to be performed, as well as the annotation of external datasets for application to each section of LV network. The original purpose of the Platform was to allow the annotation of Smart Meter data to the LV network to better understand load flows and usage patterns on the network; however it has subsequently evolved to include modelling of the LV network. Building type classifications, derived from standard ordinance survey datasets and annotated to the LV connectivity model, is used to estimate After diversity maximum demand (ADMD) – now and in the future – to understand the impact of a range of LCT loads on the network, including EVs. According to the My Electric Avenue project[38], the ADMD for households with a 3.5kW EV charger is approximately 2kW, i.e. double the conventional demand observed. With the current standard EV domestic chargers of 7kW, the ADMD increase is higher.

The Platform has a series of Application Programme Interfaces (APIs) that allows network data to be extracted on a circuit-by-circuit basis, via automated scripts, which are fed into the EV analysis to model future network scenarios as a result of EV rollout. This approach enables analysis of the LV network at a scale not previously feasible.

Given the current capability of the NAVI platform and the available data the assessment of network constraints will be primarily based on thermal rating of electrical equipment. As the tools develop, issues such as phase imbalance will also be considered in future.

C.3 Assessment and Categorisation of Constraint Risk

An individual asset's constraint risk will be determined using the Network Capacity model. This will import and overlay the EV uptake rates on to existing loading information to support the prediction of future EV driven network constraints.

[37] SPEN, NCEWS NIA project: https://www.smarternetworks.org/project/nia_spen_034
[38] EA Technology and Southern Electric Power Distribution (SEPD) NIC project, "SSET205 – My Electric Avenue (I^2EV)", Project close-down report, Apr 2016: https://www.ofgem.gov.uk/ofgem-publications/100342

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Constraint risk will be determined through a matrix structure. This matrix will consist of an Uptake Index and a Capacity Index. The Uptake Index for a given asset will be determined by the category of the datazone within which it is located. The Capacity Index will vary depending on asset type.

The Substation Capacity Index has four levels and is modelled on a transformer load index. The Substation risk matrix with risk categorisation is shown in Table 23.

		Substation Capacity Index (Modelled EVs)			
		1 (<80%)	2 (≥80% and <95%)	3 (≥95% and <99%)	4 (≥99%)
Uptake Index	Green	Low Risk	Low Risk	Medium Risk	High Risk
	Amber	Low Risk	Medium Risk	Medium Risk	High Risk
	Red	Low Risk	Medium Risk	High Risk	High Risk

Table 23. Risk based deployment matrix for substation assets

The Cable Capacity Index is more simplistic and considers only two states not exceeded and exceeded. The Cable risk matrix with risk categorisation is shown in Table 24.

		Cable Capacity Index (Modelled EVs)	
		Capacity not exceeded (km)	Capacity exceeded (km)
Uptake Index	Green	Low Risk	High Risk
	Amber	Low Risk	High Risk
	Red	Low Risk	High Risk

Table 24. Risk based deployment matrix for LV cables

Once the steps described in sections C.1 and C.2 have been complete, the proposed implementation process is as follows:

1. Identify the socio-economic grouping that the substation from each circuit is fed from, using the substation location and datazone polygons that were imported.
2. Extract house-type classification from node data and, based on socio-economic classification of substation, apply EVs to a percentage of properties (determined by uptake input) connected to each circuit resulting in larger ADMD values for these.
3. Calculate total load on substation and categorise Substation Capacity Index.
4. Propagate load values across network, and assess if thermal limits on any cables have been breached and categorise Cable Capacity Index.
5. Create summary output with high-level statistics for each circuit – i.e. substation rating / substation loading / number of cables overloaded. Populate the asset constraint risk matrix (see Table 23 and Table 24).
6. Repeat for each scenario (e.g. year of interest).

A key feature of this approach is the "fully scripted" nature of its implementation. Software scripts have been developed in the Python language such that this process requires minimal user input. This method is therefore highly time efficient and is also scalable for use across all the SPD LV network.

Appendix D will present a demonstration of how this approach has been applied to an example SPD distribution network.

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C.4 Intervention Strategy

C.4.1 Substation Monitoring

As highlighted within section 4.3, the deployment strategy for LV monitors will prioritise high and medium risk substations with an overall target of deployment on 40% of substations ≥200kVA. The determination of constraint risk will inform this risk for each asset. This will be coupled with practical factors (such as geographical location[39]) to ensure that the installation is carried out in an efficient manner.

C.4.2 Network Reinforcement

All network assets categorised as having a high risk of being constrained at the end of ED2 will be considered for reinforcement. The determination of whether to reinforce the network will be supported by a further stage of modelling activity. Specifically, this will model circuits at higher fidelity, meaning that power profiles over time will be included as opposed to ADMD values. Appropriate profile information will be determined from sources such as CREST models[40] and Smart Meter data[41]. It is proposed that the Network Capacity model is also used to apply these profiles to assess network constraints.

The higher fidelity modelling will enable an assessment of intervention options, with a focus on identifying the most cost effective solutions, either smart or conventional reinforcement solutions as described in Appendix B. For example, this will consider whether deferred charging would relieve potential constraints on network assets as illustrated in Figure 15. Similarly options for network reconfiguration (e.g. by splitting LV feeders) will be considered as an alternative to asset upgrades given the lower associated cost.

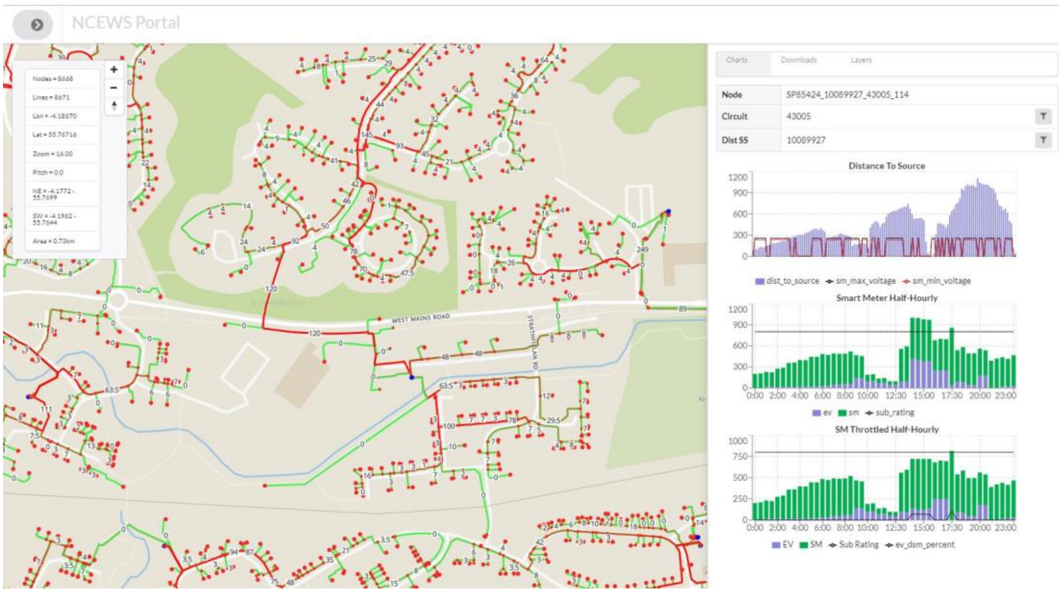

Figure 15. An example of the detailed modelling

[39] For example, it is more time efficient to install multiple monitors within the same or nearby geographical locations even if risk scores differ across these locations.
[40] Loughborough University, CREST Demand model: https://www.lboro.ac.uk/research/crest/demand-model/
[41] As substation monitors are rolled out this data may also be used.

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APPENDIX D CASE STUDY OF EV NETWORK IMPACT

An area considered as a study case is an area south of Glasgow highlighted in blue in Figure 16. This area represents a mixture of rural and urban areas and has 8,360 households and around 9,190 cars and vans.

The electricity network in this area consists of 161 secondary substations (120 substations with a rating ≥200kVA) and 266km of LV circuits.

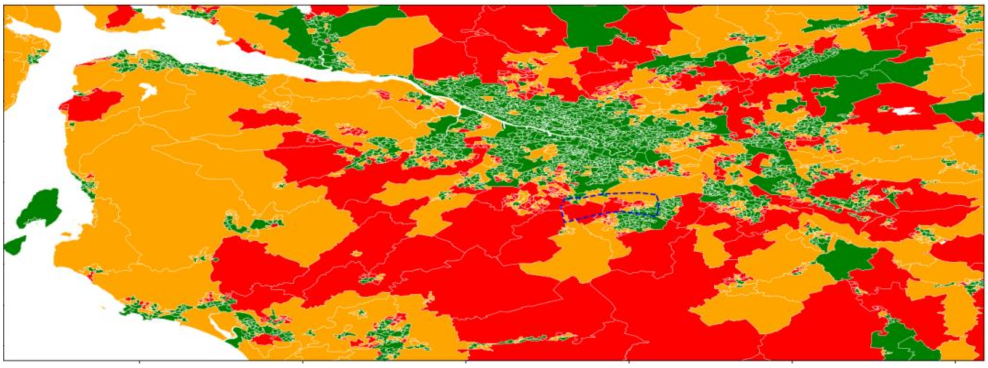

Figure 16. Uptake index of datazones across SPD with the study case highlighted in blue

The detailed Uptake Index for the studied area, developed as described in section C.1, is shown in Figure 17.

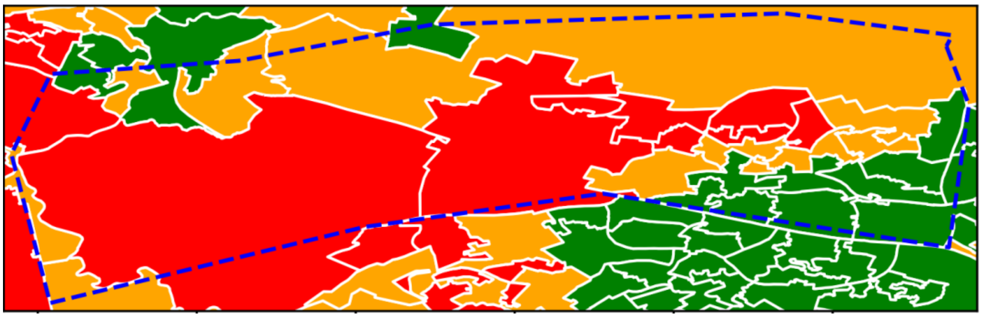

Figure 17. The Uptake Index datazones within the studied area

An individual asset's constraint risk is determined using the Network Capacity model, described in section C.2. The map of the existing Substation Capacity Index is shown in Figure 18 and the map of the existing Cable Capacity Index is shown in Figure 19.

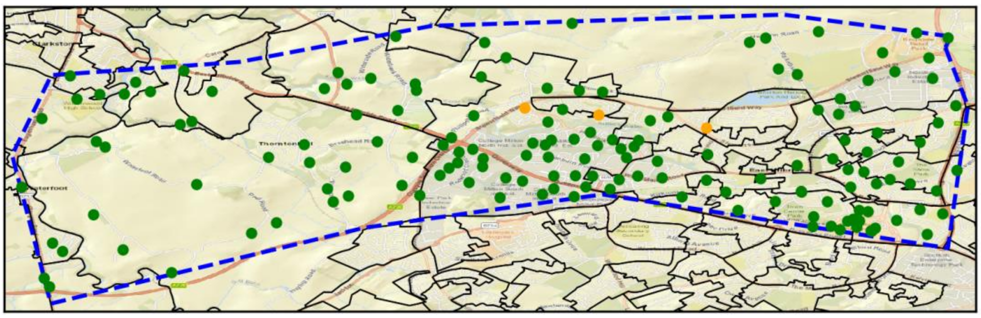

Figure 18. Existing Substation Capacity Index (green – substation capacity index 1, yellow –2, red –3, purple –4)

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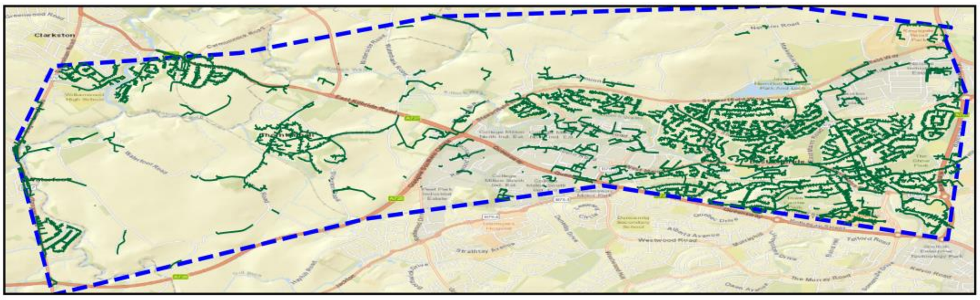

Figure 19. Existing Cable Capacity Index (green – capacity not exceeded, red – capacity exceeded)

Following the implementation process, described in section C.3, Substation Capacity Index and Cable Capacity Index are categorised for two years of interest, the end of ED1 (2023) and the end of ED2 (2028). The Substation Capacity Index for 2023 and 2028 are shown in Figure 20 and Figure 21, respectively.

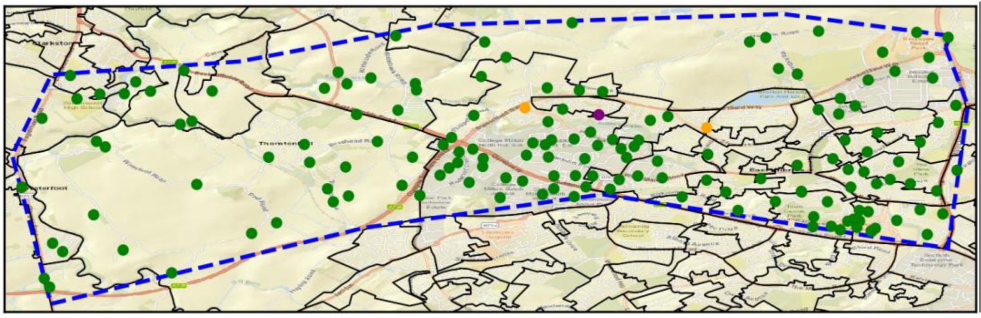

Figure 20. Substation Capacity Index 2023 (green – substation capacity index 1, yellow –2, red –3, purple –4)

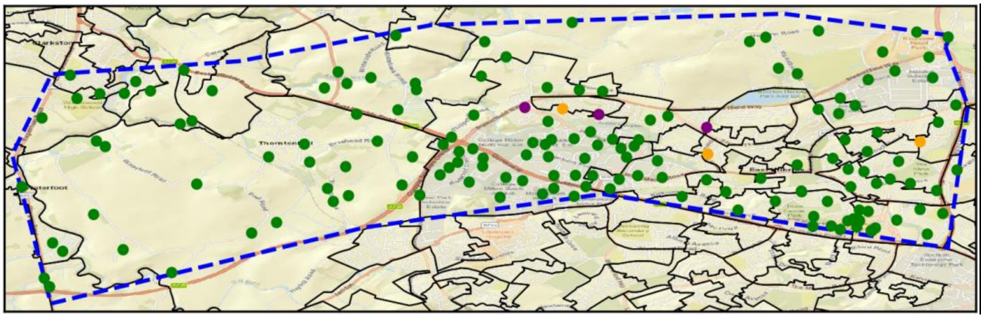

Figure 21. Substation Capacity Index 2028 (green – substation capacity index 1, yellow –2, red –3, purple –4)

The Cable Capacity Index for 2023 and 2028 are shown in Figure 22 and Figure 23, respectively.

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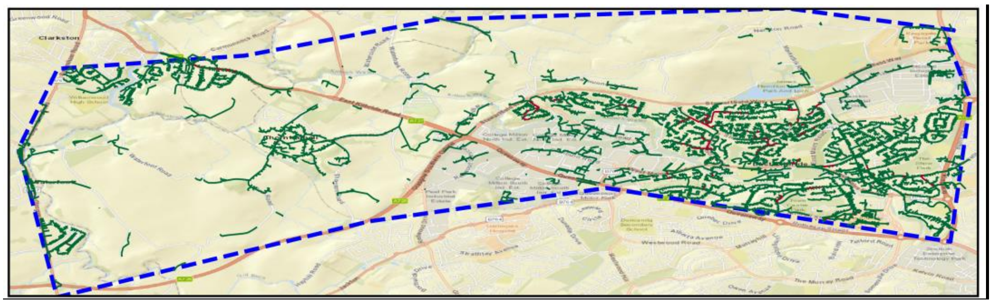

Figure 22. Cable Capacity Index 2023 (green – capacity not exceeded, red – capacity exceeded)

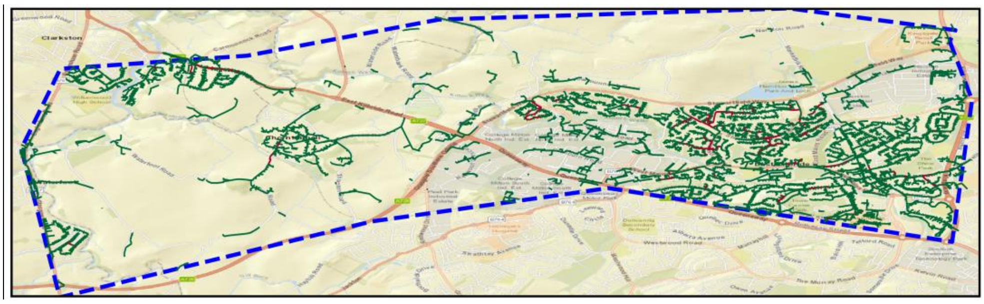

Figure 23. Cable Capacity Index 2028 (green – capacity not exceeded, red – capacity exceeded)

The constraint risk for each year is determined through a matrix structure, which consists of an Uptake Index and a Capacity Index, as described in section C.3. Table 25 and Table 26 show the substation risk based deployment matrix and the LV cable risk based deployment matrix, respectively.

		Substation Capacity Index (Modelled EVs)			
2019		**1 (<80%)**	**2 (≥80% and <95%)**	**3 (≥95% and <99%)**	**4 (≥99%)**
Uptake Index	**Green**	41	0	0	0
	Amber	42	0	0	0
	Red	73	3	0	2
2023		**1 (<80%)**	**2 (≥80% and <95%)**	**3 (≥95% and <99%)**	**4 (≥99%)**
Uptake Index	**Green**	41	0	0	0
	Amber	42	0	0	0
	Red	73	2	0	3
2028		**1 (<80%)**	**2 (≥80% and <95%)**	**3 (≥95% and <99%)**	**4 (≥99%)**
Uptake Index	**Green**	40	1	0	0
	Amber	42	0	0	0
	Red	71	2	0	5

Table 25. Case study risk based deployment matrix for substation assets for 2019, 2023 and 2028

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Cable Capacity Index (Modelled EVs)			
2019		Capacity not exceeded (km)	Capacity exceeded (km)
Uptake Index	Green	95	0
	Amber	55	0
	Red	115	0
2023		Capacity not exceeded (km)	Capacity exceeded (km)
Uptake Index	Green	93	2
	Amber	54	1
	Red	110	6
2028		Capacity not exceeded (km)	Capacity exceeded (km)
Uptake Index	Green	92	3
	Amber	53	2
	Red	108	7

Table 26. Case study risk based deployment matrix for LV cables for 2019, 2023 and 2028

As demonstrated above, with increased penetrations of EVs, the network would start to require reinforcement to accommodate the increased power flows. With clustered uptakes, or higher capacity chargers, LV circuit reinforcements would not be sufficient and an additional transformer capacity would be required.

The following intervention strategies have been identified for the case study, based on the intervention strategy described in section C.4 without detailed modelling of reinforcement and smart options:

- **Substation Monitoring**
    - 48 monitors prioritising high and medium risk assets and low risk assets with a red uptake index
- **Network Reinforcement**
    - Upgrade of 2 secondary substations
    - Upgrade of 1km of LV cable including 63 LV service joints
    - 2 LV reconfiguration point

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APPENDIX E MONITORING SYSTEM ARCHITECTURE

SPD's proposal is to utilise the Enhanced Secondary Substation Monitoring (ESSM) system to monitor secondary substations as part of this reopener submission. The proposed arrangement of an ESSM unit installed at a secondary substation to monitor both transformer loading and the five outgoing LV feeders is shown in Figure 24.

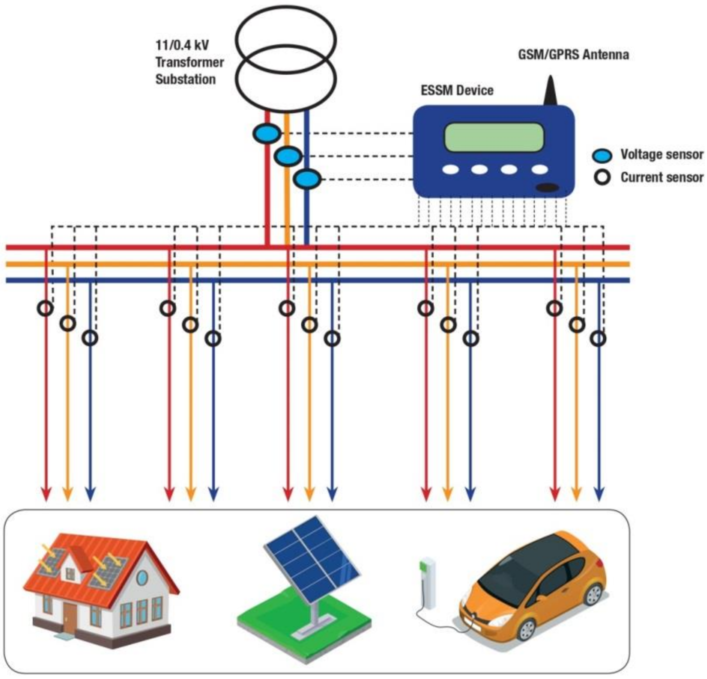

Figure 24. Arrangement of enhanced secondary substation monitoring system

The ESSM is formed of three main components:

- Monitoring hardware
- Current and voltage sensors
- Data communications and data management system

Figure 25 and Figure 26 depict the ESSM device installed in SPEN as part of the Flexible Networks project[42] in indoor and outdoor substations, respectively.

[42] SPEN, "Flexible Networks Closedown Report Final", Dec 2015: https://www.spenergynetworks.co.uk/userfiles/file/Flexible_Network_Closedown_Report.pdf

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Figure 25. ESSM device installed in SPEN indoor substation

Figure 26. ESSM device installed in SPEN outdoor substation

The monitoring device will be a single unit for the measurement of voltage and current. It will be based on open platform hardware and operating system (such as LV-CAP or equivalent) to allow third-party applications (such as a Smart MDI App or equivalent) to run on the operating system. The device will have an inbuilt GSM/GPRS modem which will enable a two-way communications functionality of sending data to a remote server in one direction and configuration settings and software upgrades in the other.

Low cost current sensors will be used to measure the LV distributor phase currents in secondary substations. The selected current sensors can be installed around existing cable cores or sections of the busbar which generally enables on-line installation without breaking the circuit. This is a key consideration for minimising the need for any circuit reconfiguration and associated DNO's interruption performance, Customers Interruptions (CI) and Customer Minutes Lost (CML).

On secondary transformers, the output phase voltages will be measured on the 415/240V busbar connections using a proven "G" clamp. With a clearly developed installation procedure and considering SPEN's health and safety guidelines, the voltage clamp can be installed directly on the live busbar which enables on-line installation without breaking the circuit. This is a key consideration for minimising the need for any circuit reconfiguration and associated CIs and CMLs.

The ESSM units will be enabled with an inbuilt SIM card based GSM/GPRS modem by which the monitored data will be transferred through the telecom operator's 2G/3G/4G communication gateway. The data will be received by the wireless logic at the SPEN's central data network and will be transferred to a new enterprise-level data management system (Siemens IP) which is being introduced for use with Smart Meter data. This enterprise service bus arrangement will enable different applications to utilize the monitored data for further processing and analysis.

An overview of the monitoring data management system architecture is illustrated in Figure 27.

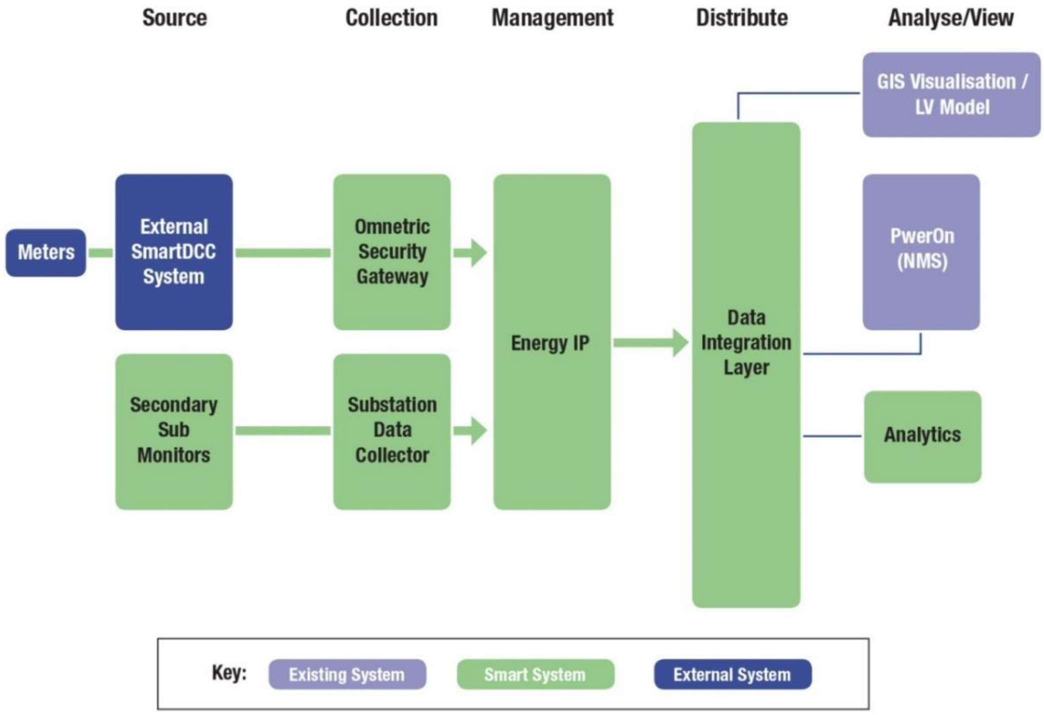

Figure 27. High level monitoring data management system architecture