RIIO-ED2 Business Plan
December 2021

Annex 4A.8:

Losses Strategy



PRINCIPAL PARTNER
UN CLIMATE CHANGE CONFERENCE UK 2021
IN PARTNERSHIP WITH ITALY

Contents

1 AN INTRODUCTION TO THIS ANNEX 5
2 PURPOSE OF OUR LOSSES STRATEGY 7
2.1 The Business and Legal Environment 7
2.2 Our Strategic Vision 8
2.3 Our Strategic Objectives 9
3 WHAT ARE LOSSES? 10
3.1 Technical Losses 10
3.2 Non-Technical Losses 11
3.3 Where are Losses in Our Networks? 12
4 WHY LOSSES WILL INCREASE IN FUTURE 13
4.1 The Drivers Affecting Losses 13
4.2 Losses Forecasts 16
5 OUR LOSSES ACTION PLAN 19
5.1 Our Losses Action Plan on a Page 19
5.2 Our Method for Selecting Losses Management Actions in RIIO-ED2 20
5.3 Our Method for Evaluating Actions 21
5.4 Stakeholder feedback 21
6 IMPROVING OUR UNDERSTANDING OF LOSSES 22
6.1 Overview 22
6.2 How We Measure Losses 22
6.3 Innovative Use of Smart Meter and Network Data 25
6.4 Enhanced Network Modelling 26
6.5 Improving our Understanding of Non-Technical Losses 27
6.6 Contact Voltage Losses on LV Networks 27
7 PROCESSES TO MANAGE TECHNICAL LOSSES 28
7.1 Overview 28
7.2 Loss Reduction Opportunities in Network Design and Construction 29
7.3 Transformer Upgrades 30
7.4 Underground Cable and Overhead Line (OHL) Upgrades 35
7.5 LV Mains Fuses 40
7.6 Voltage Uprating 40
7.7 Voltage Optimisation 41
8 PROCESSES TO MANAGE NON-TECHNICAL LOSSES 43
8.1 Overview 43
8.2 Theft and Revenue Protection 44
8.3 LV Network monitoring 44
8.4 Unmetered Connections 45
8.5 Theft in Conveyance 46

9 LOSSES INNOVATION 47
9.1 Overview 47
9.2 Mobile Asset Assessment Vehicle 47
9.3 DC Distribution 49
9.4 Active Network Configuration 50
9.5 Data Processes 52
10 COLLABORATION AND STAKEHOLDER ENGAGEMENT 53
10.1 Overview 53
10.2 Industrial Engagement 53
10.3 Distributed Generator Customer and Stakeholder Engagement 54
10.4 Losses Management through DSO Transition 54
10.5 Holistic Losses Consideration 55
10.6 Wider Community Engagement through Revenue Protection Activities 55
11 CONCLUSION 57
12 GLOSSARY 58
13 REFERENCES 60
APPENDIX 1 – SUPPLEMENTARY ANALYSIS 61
A1.1 Losses on Underground Cable Circuits 61
A1.2 Estimated Transformer Losses 63
APPENDIX 2 – REPUTATIONAL INCENTIVE PROPOSAL 64
A2.1 ODI-R Proposal 64

List of Figures

Figure 1: Resistance of 33kV Single Core unarmoured aluminium conductor by cross-sectional area 11
Figure 2: Where energy is lost in distribution networks 12
Figure 3. Network losses with (right) and without (left) generation 14
Figure 4: DFES forecast on electrification out to 2028 15
Figure 5: Example domestic daily loading profile 16
Figure 6: Example service cable losses 16
Figure 7: SPD DFES2021 demand growth 17
Figure 8: SPM DFES2021 demand growth 17
Figure 9: Forecast Losses across both SPEN licence areas 17
Figure 10: Forecast carbon emissions due to losses across both SPEN licence areas 18
Figure 11: Forecast environmental and economic cost of losses across both SPEN licence areas 18
Figure 12: Transformer Types in Our Distribution Network 30
Figure 14: SPD HV Tx Age Profile (Source: CBRM, Mar 21) 32
Figure 15: SPM HV Tx Age Profile (Source: CBRM, Mar 21) 32
Figure 16: Power Consumption by Voltage Level 42
Figure 17: Single / Parallel Transformers Losses Comparison 51

List of Tables

Table 1: Our Strategic Objectives 9
Table 2: DFES Scenarios 16
Table 3: Losses Action Plan Summary 19
Table 4: RIIO-ED1 Investment Decisions and RIIO-ED2 Applicability – proactive actions (changes to BAU) are highlighted 20
Table 5: RIIO-ED1 LDR Initiatives and RIIO-ED2 Applicability – new initiatives (changes to BAU) are highlighted 21
Table 6: Overview of Innovation Activities to Reduce Network Losses 22
Table 7: Technical Losses Reduction Initiatives Summary 28
Table 8: RIIO-ED2 Losses-Driven Primary Transformer Early Replacement 31
Table 9: RIIO-ED2 Condition-Based Grid Transformer Replacement (SPM only) 31
Table 10: RIIO-ED2 Condition-Based Primary Transformer Replacement 32
Table 11: Losses-Driven Secondary Transformer Early Replacement During RIIO-ED1 and RIIO-ED2 33
Table 12: Condition-Based Secondary Ground-Mounted Transformer Replacement During RIIO-ED2 33
Table 13: RIIO-ED2 PCB-Based Secondary Pole-Mounted Transformer Replacement 34
Table 14: HV and LV Conductor Volumes per Licence Area 37
Table 15: RIIO-ED2 HV Cable Replacement Losses Savings 38
Table 16: RIIO-ED2 LV Cable Replacement Losses Savings – estimate based on 300 mm^2 Minimum Conductor Size 39
Table 17: Losses from Uprating of 6.6kV Islands to 11kV in RIIO-ED2 41
Table 18: Non-Technical Losses Reduction Initiatives Summary 43
Table 19: RIIO-ED2 Losses Savings as a Result of Revenue Protection Inspections 44
Table 20: RIIO-ED2 Losses Savings as a Result of Increased LV Network Monitoring 45
Table 21: RIIO-ED2 Losses Savings as a Result of Theft in Conveyance Investigations 46
Table 22: Overview of Innovation Activities to Reduce Network Losses 47
Table 23: Contact Voltage Types 48
Table 24: Network Losses Savings as a Result of Contact Voltage Discovery and Repair 48
Table 25: TASS Energy Savings 52
Table 26: Overview of Collaboration and Stakeholder Activities to Raise Awareness of and Reduce Network Losses 53
Table 27: Proactive High-Loss Cable Replacement on HV Network 62
Table 28: Proactive High-Loss Cable Replacement on LV Network 62

1 An introduction to this annex

Scope

In RIIO-ED1, we set our strategic losses vision to:

Consider all reasonable measures which can be applied to reduce losses and adopt those measures which provide benefit for customers.

We will maintain this vision in RIIO-ED2. Therefore, we are reviewing our current losses strategy and updating our losses action plan.

This annex sets out our position on losses and how this will develop over RIIO-ED2. It provides details of our updated losses strategy and RIIO-ED2 losses action plan and identifies areas key where applying our strategic vision and losses action plan will mitigate increases in losses over RIIO-ED2.

Key highlights

A summary of our headline actions in RIIO-ED2 are as follows:

Continue to accelerate the replacement of high-loss assets, such as old design transformers, with more efficient new technologies.

Increase the minimum cross-sectional area of HV and LV cables and overhead lines in conjunction with other works.

Improve our knowledge and understanding of losses through:

- Applying our intelligent network algorithms to smart meter data.
- Increasing metering capabilities, particularly at secondary substations.
- Improving network modelling.

Continuation of our use of industry-leading Revenue Protection services.

Procure a Mobile Asset Assessment Vehicle (MAAV) under a Consumer Value Proposition to detect contact voltage faults and subsequent network (and customer) losses caused by these faults

Continuing our work in our flagship innovation projects investigating DC distribution use cases.

Continuing to chair the ENA Technical Losses Working Group to work collaboratively on better processes for measuring, managing, and reporting losses.

Benefits

For the UK to achieve its Net Zero ambitions for decarbonisation by 2050, we need to adopt greater levels of Electric Vehicles (EVs), Heat Pumps (HPs) and renewable Distributed Generation (DG) – this will increase levels of distribution network losses.

Widescale societal change is required. We must stop using petrol and diesel for transportation and use electric vehicles instead. We must phase out fossil fuels for heating our homes and use electric heating and high-quality insulation. Finally, we must generate electricity using large-scale renewables such as offshore wind, distributed renewable generation and small-scale generation such as domestic solar panels and community owned wind turbines.

While this transition is easy to describe, it presents significant challenges to the electricity *supply chain* in the UK. We must significantly increase network capacity; we must manage constraints more intelligently as a Distribution System Operator (DSO); and we must continue to invest in the underlying resilience and condition of the distribution network to ensure a safe, reliable, and secure supply. The evolution of the industry will be a long journey, one that will see our networks carrying more power than ever before.

Consequently, we must provide additional capacity on our networks over the coming decades. We must also act to minimise losses on our networks.

This annex sets out how, through consideration of losses across all of our RIIO-ED2 activities, we will mitigate this impact on losses compared to a 'do nothing' baseline. We calculate that our opportunistic losses savings through policy-driven, losses-informed intervention will mitigate 269GWh of losses, saving over 51,000 tCO_{2e}. Additionally, our Theft and Revenue Protection activities will mitigate a further 183GWh of losses, saving over 38,000 tCO_{2e} and our proactive, losses-driven transformer replacement activities will mitigate 36GWh of losses, saving 7,400 tCO_{2e}. Finally, we calculate that contact voltage fault detection using the MAAV will mitigate 85GWh of losses, savings over 18,000 tCO_{2e}.

Customer and stakeholder input

We have undertaken significant stakeholder engagement as part of our plan development and have sought feedback from a range of stakeholders. See Annex 3.1 – Stakeholder Engagement Annex for more information on this process. Following this engagement, we have developed the below commitments for RIIO-ED2 which are relevant to this Annex:

We will continue to implement our losses strategy to avoid an estimated 36 GWh of network losses, thereby limiting losses to a lower level than would otherwise be the case during RIIO-ED2.

Where applicable, we have also considered specific feedback from customers and stakeholders throughout this annex – namely, this feedback is on our approach to formulating our losses action plan, and on our key action to accelerate the replacement of high-loss assets.

Delivering our Plan

Our RIIO-ED2 plans in this area are consistent with our historic levels of activity and our RIIO-ED1 track record, delivery profiles have been optimised where possible to ensure maximum customer benefit. By comparing to our past performance, and considering deliverability constraints in the planning stage, we are confident the RIIO-ED2 plans set out in this annex are deliverable, realistic, and required by our customers. Programme development and deliverability assessments have been completed in parallel to ensure our business can deliver the required level of investment.

For more information on our Deliverability strategy, see Annex 6.1 – Delivering our Plan.

Signpost for Ofgem's business plan requirements

Ofgem BP Guidance No	Annex Page Number
Appendix 3	This document in our Losses Strategy. Section 5 sets out the actions we plan to undertake to manage losses in RIIO-ED2.

2 Purpose of our Losses Strategy

2.1 The Business and Legal Environment

Under the conditions of our current licence for RIIO-ED1, we must have a losses strategy. The strategy should set out how we will design, build, and operate our distribution system such that distribution network losses are as low as reasonably practicable. 'Reasonably practicable' means that the time, trouble, and cost of actions to mitigate or reduce losses is outweighed by the societal and environmental benefits of the avoided losses – in effect, where it presents value for money for our customers.

In preparation for RIIO-ED2, we are reviewing our current losses strategy [1] and updating our losses action plan. This document presents our losses strategy plans for RIIO-ED2 for our two licence areas – SP Distribution (SPD) and SP Manweb (SPM). It discusses our plans for the following areas:

- How we will develop our understanding of the volume and locations of losses in our network, and how this will develop in the transition to Net Zero.
- Our process, policies, and actions that we will take to minimise network losses (although losses on our networks will increase due to the Net Zero transition, we will reduce losses compared to the baseline or 'do nothing' case).
- Any projects and innovations that will be explored in RIIO-ED2.

This will ensure that we meet Ofgem's RIIO-ED2 business plan guidance baseline expectation [2] to:

- *"Develop and commit to implementing a strategy to efficiently manage both technical and non-technical losses on the DNO's network over the long term. This should include specific actions and performance measures to track the impact of actions in RIIO-ED2."*

Furthermore, this document also sets out how we will report on the progress of our strategy in RIIO-ED2, and also how we will continue to collaborate and share information with our peers and stakeholders.

This will ensure that we meet Ofgem's additional baseline expectations to:

- *"Commit to reporting on the progress of implementing the losses strategy and associated performance measures."*
- *"Contribute to the evidence base on the proportion of losses that network companies can influence/control."*

As part of RIIO-ED1, Ofgem launched the Losses Discretionary Reward (LDR) scheme, with the aim of incentivising Distribution Network Operators (DNO) to undertake additional actions to improve their understanding and reduction of losses in their networks. The LDR was broken down into three tranches, for which £8m, £10m and £14m of award funding was available in 2016-17, 2018-19, and 2020-21, respectively. We provided submissions for all tranches [3] [4] [5] and received the third highest award in tranche one at £770,000. No further awards were given to any DNOs in tranches two or three.

Ofgem have confirmed the LDR scheme will be discontinued in RIIO-ED2, having been effective at achieving greater understanding and collaboration in losses management across GB over the course of RIIO-ED1. Therefore, this document collates all of our ongoing initiatives into a single, consolidated plan.

2.2 Our Strategic Vision

At SP Energy Networks, in RIIO-ED1 we set ourselves a clear strategic losses vision to:

Consider all reasonable measures which can be applied to reduce losses and adopt those measures which provide benefit for customers.

We are maintaining this vision for RIIO-ED2, as we believe it has been effective at steering our policies, procedures and actions, whilst safeguarding our customers.

However, assessing improvement or even the present position on losses is not an exact science. Although we are moving closer to a comprehensive understanding with better information gathering (through network monitoring), more advanced network models, and better sharing of data (through Open Data platforms), measuring losses remains inexact and difficult.

The difficulty with measuring losses is compounded by the changing demands placed upon our networks in the transition to Net Zero, which will continue in RIIO-ED2 and beyond. This is transforming the way we build and operate our networks, and in turn this will have both positive and negative outcomes in terms of electricity losses.

To maintain the best price and service level for customers, we are innovating to make our networks work harder in the face of load growth and increased distribution connected generation. Our target therefore cannot be set to reduce losses, but rather to improve them over what would have been the case had we not adopted a proactive strategy.

Therefore, our approach has been to develop a strong culture of considering losses in every decision we take, which will continue into RIIO-ED2. We will implement losses reduction activities that are deemed cost-effective, which will have a direct benefit to our customers in reducing energy bills and over the longer term should contribute toward lower costs of energy supplied to customers.

2.3 Our Strategic Objectives

During RIIO-ED1, we defined our core strategic objectives, derived from our strategic vision. Table 1 summarises these objectives along with our performance during RIIO-ED1 and our plan for RIIO-ED2.

Table 1: Our Strategic Objectives

Area	Objective	ED1 Progress	ED2 Plan
General	Ensure compliance with all legal and regulatory requirements	Compliant	Continuation
	Optimise value for customers	Compliant Leading of TLWG[1] to drive best practice, promote information sharing, and minimise duplicated effort.	Continuation Standardisation of documentation and processes through TLWG.
	Improve recognition of technical constraints and, where possible, reduce constraints.	Increased network modelling.	Utilisation of network modelling to identify and mitigate losses hotspots.
Compliance Demonstration	Continually demonstrate that we are doing the maximum to reduce network losses.	Definition of losses policy, as part of LDR Tranche 3.	Enacting losses policy defined during LDR Tranche 3.
Continuous Improvement	Deliver the most appropriate initiatives for the period, considering all network drivers.	13 Initiatives covering all aspect of loss behaviour launched for LDR Tranche 3. Replacement of highest losses assets.	Continued replacement of high loss assets. Use *lessons learnt* from RIIO-ED1 to shape RIIO-ED2 business plan. Engage with Ofgem to propose improved regulatory mechanisms for RIIO-ED2.
	Progressively improve the quantity and quality of information available for: • Factoring losses into investment decisions. • Target setting and progress monitoring.	Algorithm development to use domestic and network metering data more effectively.	Deploy and refine algorithms, using *real* network data.
		Development of granular *bottom-up* models replacing highly-aggregated *top-down* models.	Shaping losses management processes for RIIO-ED2. Ongoing assessments of how best to use near real time network information to drive operational policy and active network management.
Reduce Technical Losses	Amend SPEN networks development and replacement policies to align with our strategic vision.	Large-scale asset replacement, driving improved network efficiency.	Continued replacement with higher efficiency assets. Engagement with transmission system operator, and embedded generation operators.
	Develop a technical losses action plan based on the strategic vision. • Quantifying expected outputs. • Defining how outputs will be monitored.	Losses strategy defined for RIIO-ED1.	Losses strategy defined for RIIO-ED2
Reduce Non-Technical Losses	Reduce and deter theft anywhere in the electricity supply chain.	Proactive policy design for best utilisation of smart meter data.	Policy implementation. Monitoring of international regulatory mechanisms.
		Algorithm development to support identification of theft.	Algorithm implementation
		Best practice sharing with partner DNOs.	Continuation
	Improve accuracy of the record of unmetered supplies.	Auditing of unmetered connections and policy development to resolve inconsistencies between load registers and observed consumption.	Continuation of auditing. Policy implementation.
	Improve accuracy of the metering energy supplied.	Continued smart meter roll out.	Continued smart meter roll out
		Algorithm development to use smart meter data effectively.	Algorithm implementation
		Algorithm development to use network monitoring data effectively.	Metering capabilities on all new distribution transformers and retrofitted to extant units.

[1] ENA Technical Losses Working Group

3 What are losses?

Distribution electrical losses are the difference between the energy entering our distribution network – from the transmission system and distributed generation – and the energy billed to end consumers. Typically, distribution network losses are in the range of 4% to 8% [6] of all units distributed. However, as the system undergoes the Net Zero transition, these volumes will increase due to increased network utilisation.

Much of these units are lost in heat and noise as part of the electricity supply process – these are referred to as technical losses. In addition, a small amount of energy is stolen or not fully recorded – these units are referred to as non-technical losses. The electricity industry settlement systems charge suppliers for network losses and therefore losses are paid for by our customers. Furthermore, because not all electricity in Great Britain is currently generated through renewable sources, there is also an environmental impact of network losses. Losses also in part drive the need for additional generation assets.

3.1 Technical Losses

Our distribution network comprises overhead lines, underground cables, switchgear, and transformers and is constructed for operation at several different voltage levels to efficiently convey power to consumers. Each of these network components generates heat or noise or both as electricity is transferred, leading to a quantity of energy being consumed. This lost energy is an unavoidable consequence of transporting electricity; though through well designed networks and components, and the use of efficient materials, the energy lost through transportation is small relative to the total energy delivered.

Technical losses are divided into fixed and variable losses.

- **Fixed Losses:** Fixed losses occur independently of electrical load. The biggest source of fixed losses in our distribution network are in standard power transformers. To keep a transformer operational, magnetising current is required to energise its core, with some energy dissipated as heat and noise. The magnetising current required is independent of electrical load. Fixed losses[2] can be reduced in transformers using improved core design and modern material selection - but they cannot be removed.

Additionally, energy is consumed by our equipment to ensure reliable network operation: in our substations, electricity is typically consumed for heating and lighting, dehumidification & cooling equipment, oil pumps, air compressors and battery chargers to maintain secure network operation and resilience. However, this usage is recorded as separate unmetered supplies and corresponding estimates of annual energy consumption are uploaded into the settlement system; therefore, this energy is accounted for.

- **Variable Losses:** Variable losses[3] increase with electrical load. All conductors – whether windings in transformers, aluminium or copper wires in overhead lines or cables and even in switchgear – have electrical resistance which causes them to heat when carrying electric current. This heat is lost to the environment. The amount of heat losses rises as the square of the current and therefore if the peak current was 10 times the minimum, that losses at peak would be 100 times as large as the losses at minimum load. Like fixed losses, they can be reduced but not removed. Variable losses can be reduced by reducing the resistance of the conductors, either through material selection or by increasing the conductor size (for example, Figure 1 overleaf shows the relationship between resistance and cross sectional area for a Nexans 33kV single core aluminium cable [7]).

[2] Fixed losses in transformers can also be called iron losses, or non-load losses.
[3] Variable losses can be called copper losses, or load losses.

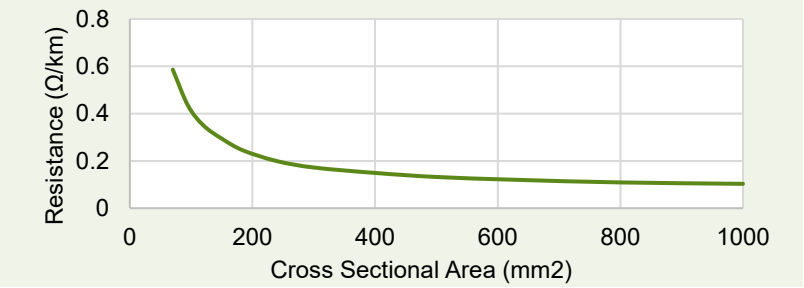


Figure 1: Resistance of 33kV Single Core unarmoured aluminium conductor by cross-sectional area

In implementing losses-savings measures, cognisance must be taken of the additional material and installation costs relative to the costs saved through the losses avoided, particularly when the equipment would not otherwise require intervention. When upsizing certain equipment such as overhead lines beyond that required for future capacity, this can often become a prohibitively expensive option if it leads to further reinforcement.

The fundamental design of distribution networks – that of a series of reducing voltages between the highest-voltage transmission system and the customers at the low-voltage (LV) end – is based on the principle that as the load to be transferred increases, so does the operating voltage. This design ensures that the electric current does not become excessive and create uneconomic levels of losses.

3.2 Non-Technical Losses

Non-technical losses primarily relate to unidentified, misallocated, and inaccurate energy flows. It is energy delivered but not billed. It is important to differentiate this from energy billed but where the bills are not paid – in that case we know who is consuming the energy. In the case of non-technical losses, the end user is unknown, or the amount of energy being consumed is uncertain.

Non-technical losses broadly fall into three categories:

- **Energy theft:** Illegal abstraction of electricity by a small number of customers, achieved through tampering with supplier meters or interference with our network assets. This remains an ongoing challenge for the electricity industry and concerted effort by a range of stakeholders will continue to be required to mitigate this problem. In addition to fraud there are serious safety aspects to be considered.
- **Unmetered supplies:** Not all customer supplies in our distribution areas are metered. Typical unmetered loads include street lighting, traffic lights and road signs, advertising hoardings and lighting in shared occupancy buildings. Such consumption is quantified by establishing accurate records for each unmetered supply and applying a representative profile to estimate consumption characteristics. Losses typically arise as a consequence of incorrect or incomplete unmetered supplies records and inaccurate estimated annual consumption information.
- **Conveyance errors – electricity delivered but not accurately recorded in energy settlements:** Situations arise where energy is consumed but is not accurately recorded in the national electricity settlement system and effectively becomes ‘lost energy’. Typical reasons for energy not being accurately recorded include missing/unregistered metering points, incorrect recording of metering point energisation and incorrect registration of metering systems which all result in inaccurate or missing consumption data.

These non-technical losses are not a loss of energy to the environment but a loss of revenue to the system, which, like technical losses, are paid for by users of the system (our customers). While theft and recording errors are undesirable, many unmetered connections do *societal work* and therefore provide public value.

Unlike technical losses, non-technical losses are avoidable and could be eliminated in principle; however, the cost of doing so would be uneconomic. In pure economic terms, we should only invest in non-technical loss recovery up to the point where the expenditure equals the value recovered. However, we believe that it is necessary to take a long-term view and that view needs to somehow value the deterrent value of our actions.

3.3 Where are Losses in Our Networks?

Losses occur in across equipment at all voltage levels, although most network losses – both technical and non-technical – occur at high-voltage (HV) and below (as depicted in Figure 2).

This breakdown also changes by network type and location: no distribution networks are exactly the same and therefore neither is the makeup of their losses. For example, urban network losses are driven by high utilisation, whereas rural network losses are driven by long feeder lengths.

A 2018 study conducted by Imperial College London [8] offered a detailed breakdown of losses in the South East which supported that losses on the Low Voltage (LV) system were comparable for urban networks as with rural networks, but the underlying drivers were different, as above. This report also demonstrated how losses are not evenly distributed across all assets. This is well exemplified by looking at what the report presents for feeder losses:

- 20% of LV feeders account for over 50% of LV network losses.
- 20% of HV feeders account for over 70% of HV network losses.

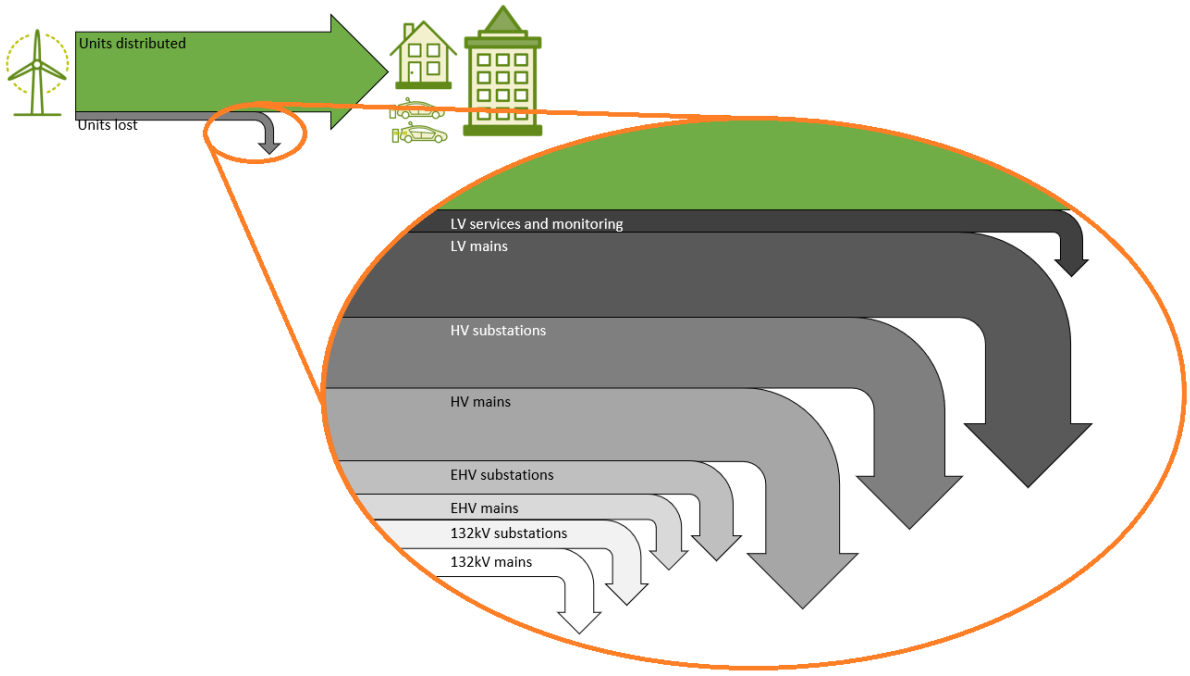


Figure 2: Where energy is lost in distribution networks

Historically, there has been insufficient network loading information to pinpoint losses within distribution networks. Without extensive system monitoring, for example, it is not possible to identify exactly which LV network assets are highly loaded (a source of technical losses), and where electricity is being illegally abstracted (non-technical losses). The amount of network monitoring has increased over RIIO-ED1 and we are planning to further deploy over 14,100 LV monitors during RIIO-ED2 (see Section 6.2.2 of this strategy, Annex 4A.3: Our DSO strategy, and Annex 4A.21: Network Visibility Strategy for further details), which should allow us to better quantify the location of losses as RIIO-ED2 progresses. Furthermore, we have made big advances in our network modelling capability, that will be used to help build more accurate losses models.

4 Why Losses Will Increase in Future

In order to meet Net Zero, use of GB distribution networks will both change and increase. As set out in our Distribution Future Energy Scenarios (DFES) document (Annex 4A.6), to achieve Net Zero carbon emissions, our networks will experience higher utilisation of electric heating combined with increased penetration of EVs and increased distributed generation (DG) connections. To manage this increased utilisation of the network, our system will also operate in different ways, using flexible demand and generation connections, and active network management solutions. This transition is part of our Distribution System Operator (DSO) strategy (Annex 4A.3).

This will have two effects that will become more visible over the course of RIIO-ED2 and future regulatory periods:

- Losses will increase, due to higher network utilisation; and
- The locations of losses may change, due to re-routed power flows and new technologies within the network.

In a WSP study [9] commissioned by Energy Networks Association (ENA) Technical Losses Working Group (TLWG), which we convened and chair, it was found that losses are highly likely to increase. At maximum levels of penetration, low-carbon technologies could increase losses by up to 350%. The drivers for this increase are discussed in more detail in this section.

4.1 The Drivers Affecting Losses

The Climate Change Act 2008 legally binds the UK to an 100% reduction in carbon emissions relative to 1990 levels, to be achieved by 2050. In 2019, secondary legislation extended that target to *at-least* 100%[4] in England and Wales. The Scottish Government has set out a plan to do the same by 2045[5]. To achieve this magnitude of decarbonisation, several sweeping infrastructure changes are required to incorporate Low Carbon Technologies (LCTs), as follows.

4.1.1 Distributed Low Carbon Generation

In the past, generation connected to the National Transmission System and entered the distribution system at grid supply points. To meet Net Zero targets, there will be increasing penetration of smaller, renewable DG connecting into the distribution networks at all voltage levels – from wind-farms connecting at 132kV down to solar panels on roofs connecting at LV.

Intuitively, as moving generation closer to the point of demand reduces the distance for electricity to travel, this may be considered to reduce losses in transportation. Small penetrations of DG can have a holistic benefit for losses, primarily a reduction in transmission losses. However, high penetration of DG has the opposite effect.

[4] https://www.legislation.gov.uk/uksi/2019/1056/contents/made
[5] https://www.gov.scot/news/reaching-net-zero-1/

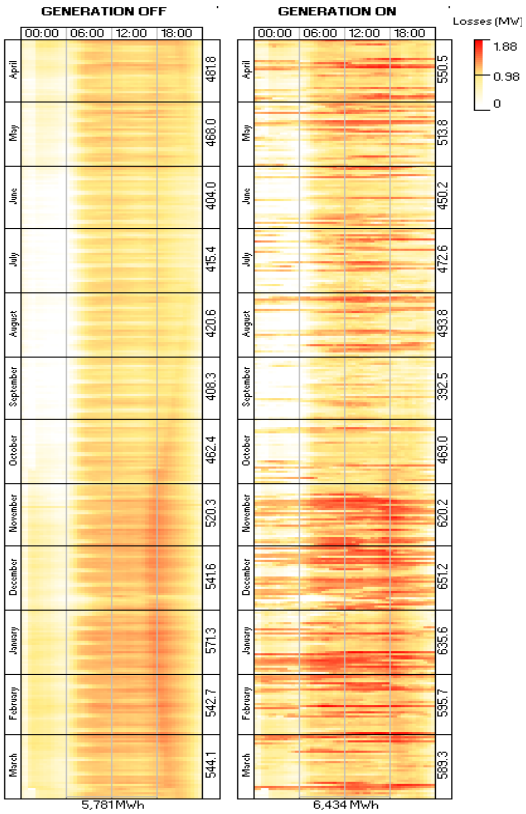


Figure 3. Network losses with (right) and without (left) generation

Our new 'bottom-up' modelling approach developed in RIIO-ED1 (see Section 6.4) has been used to assess the impact of distributed generation on losses in our networks. An example sensitivity analysis was conducted for a CIRED 2019 paper as follows.

Considering both a heavily interconnected substation group, common to SPM, and a radial 33kV network, common to SPD, we simulated network flows with and without DG connected. The SPM network includes around 70MW of embedded generation, the SPD network around 60MW, both predominantly wind.

On a case by case basis (highly dependent on network configuration), there were some periods in the year when losses were reduced as a result of increased embedded generation. However, both cases predominantly saw an increase in losses throughout the year with generation on. The losses with generation connected to the network were also found to be highly stochastic, reaching up to 200% during typically high-demand periods such as the winter months.

See Figure 3 for an example of the losses modelled with generation off (left) and generation on (right), where the deeper the red, the higher the losses.

4.1.2 Transportation

Petrol and diesel engine vehicles have been ubiquitous over the last century. However, such engines are inefficient and cause carbon emissions (as well as air quality pollution in populated environments). EVs are becoming an ever-more-popular alternative, and the market share is expected to grow significantly in light of new government plans to outlaw the sale of new petrol and diesel in the UK by 2030[6].

EVs simultaneously create technical issues and potential future benefits from a networks' perspective:

Mass deployment of EVs will create an unprecedented *step change* in demand, pushing LV networks beyond their existing capacity (in particular the service cables that carry electricity the last step between the LV mains and our homes). However, EVs may also provide a solution to changing demand and generation patterns though supply / demand balancing – their batteries could in future be used to absorb excess power output at low demand and provide *peak clipping* during high demand periods.

However, both of these factors drive up losses – through increasing utilisation, and also through energy storage losses, as batteries have a round-trip[7] efficiency of approximately 80%.

Furthermore, to compete with the convenience of petrol and diesel cars that can be refilled quickly and easily at filling stations, faster chargers are being developed, increasing peak current through the network (when connected at the same voltage level).

[6] https://www.gov.uk/government/news/government-takes-historic-step-towards-net-zero-with-end-of-sale-of-new-petrol-and-diesel-cars-by-2030

[7] Round-trip efficiency is the percentage of electricity put into storage that is later retrieved. U.S. Energy Information Administration (EIA), in 2019, the U.S. utility-scale battery fleet operated with an average monthly round-trip efficiency of 82%, and pumped-storage facilities operated with an average monthly round-trip efficiency of 79%, https://www.eia.gov/todayinenergy/detail.php?id=46756

4.1.3 Electric Heating

Natural gas is the dominant fuel source for domestic heating and cooking in the UK, and there are 1.7 million gas boilers installed in the UK each year. The 2020 UK Energy White Paper outlines the aim of all newly installed heating systems to be low-carbon by the mid-2030s [10]. Electric heating will play a significant role in this restructuring, along with heat pumps, hydrogen, *green gas,* and shared heat networks. In its Future Homes Standard consultation[8], the government set out its expectations for heat pumps to become the primary heating technology for new and off-gas-grid homes.

Like EVs, heat pumps are expected to drive a significant demand increase in RIIO-ED2 and beyond. To highlight the scale of the challenge, the UK Digest of United Kingdom Energy Statistics (DUKES) 2020 report detailed that in 2019 [11], domestic gas consumption was approximately 300 TWh, compared to domestic electricity consumption of approximately 104 TWh.



	Electric vehicles	Heat pumps	Generation
Now	ca. 20,000	ca. 1,000	4.8GW
2028	0.7-1m	0.3-0.8m	+4.9-6.4GW

Figure 4: DFES forecast on electrification out to 2028

4.1.4 Load and Generation Balancing

Customer load patterns are also undergoing a period of change with general energy efficiency reductions overlaid with increases in the electrification of heat and transport. Various technologies such as sophisticated energy management systems, embedded generation, and energy storage at a range of scales mean that customers can interact more dynamically with the electricity network.

Load and generation balancing – e.g. flexibility and demand-side management schemes – are a 'double-edged sword' when it comes to network losses. On the one hand, moving electricity consumption to less busy times of the day to reduce peak loading does reduce the theoretical maximum current that would flow through the network. This may even reduce losses in the shorter term. However, the driver for these new network tools is to reduce the overall network impact of rapid load and generation growth and, therefore, the requirement for traditional network interventions (such as new or upsized conductors). The overall effect, therefore, is that these tools drive an increase in network utilisation. In the longer term, losses are expected to increase as a result of these tools.

For example, see the demand-side management example in Figure 5 and Figure 6. Compared to a generic loading example (Figure 5 scenario 1), the same demand uniformly spread throughout the day (Figure 5 scenario 2) results in significantly fewer losses in the cables supplying the house (Figure 6). However, just a small increase in household load (e.g. scenario 3 – 10%) returns losses back to the pre-demand-smoothing levels.

[8] https://www.gov.uk/government/consultations/the-future-homes-standard-changes-to-part-l-and-part-f-of-the-building-regulations-for-new-dwellings

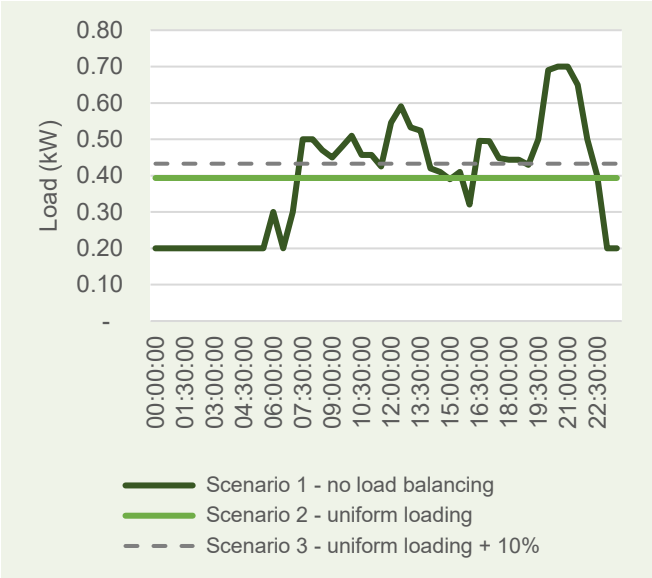


Figure 5: Example domestic daily loading profile

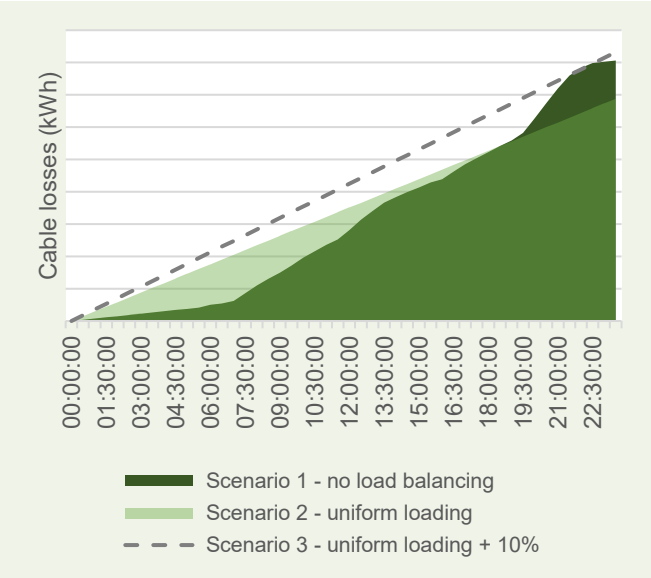


Figure 6: Example service cable losses

4.2 Losses Forecasts

For the reasons summarised previously, the electrical loads on GB distribution networks will increase in the Net Zero transition. In our DFES work, we have projected these increases in load out to 2050 over a range of possible scenarios – a brief description of the key social, political and technological drivers behind the different scenarios is given in Table 2. The subsequent range in load growth is shown in Figure 7 and Figure 8.

Table 2: DFES Scenarios

Steady Progression (SP)	Consumer Transformation (CT):
Progress is slower than in the other scenarios. While home insulation improves, there is **still heavy reliance on natural gas, particularly for domestic heating**. Electric vehicle take-up grows more slowly than in other sectors. This scenario still has significant annual carbon emissions but is some way short of the Net Zero target.	Net Zero target is **met with measures that have a greater impact on consumers**. Heat pumps will be prevalent and most of electricity demand will be smartly controlled to provide flexibility to the system. The system will have higher peak electricity demands that will be managed with flexible technologies including energy storage, demand side response and smart energy management.
System Transformation (ST)	**Leading the Way (LW)**
Net Zero target is met, following a pathway that has the least consumer impact to do so. **This scenario includes a high use of hydrogen for heating and other energy demands**. More of the significant changes in the energy system happen on the supply side, away from the consumer. Hydrogen boilers and fuel cell vehicles will be prevalent.	Rapid decarbonisation with high levels of investment in world-leading decarbonisation technologies. **Consumers are highly engaged in acting to reduce and manage their own energy consumption**. This scenario includes the highest and fastest improvements in energy efficiency to drive down energy demand. Hydrogen is used to decarbonise some of the most challenging areas of society, with this hydrogen produced solely from electrolysis powered by renewable electricity.

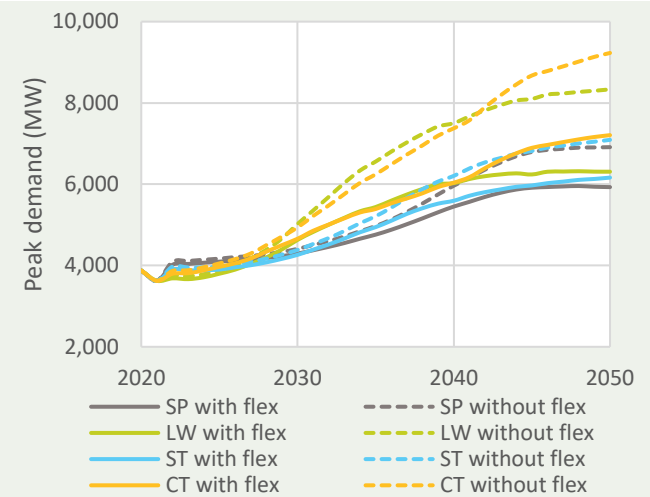


Figure 7: SPD DFES2021 demand growth

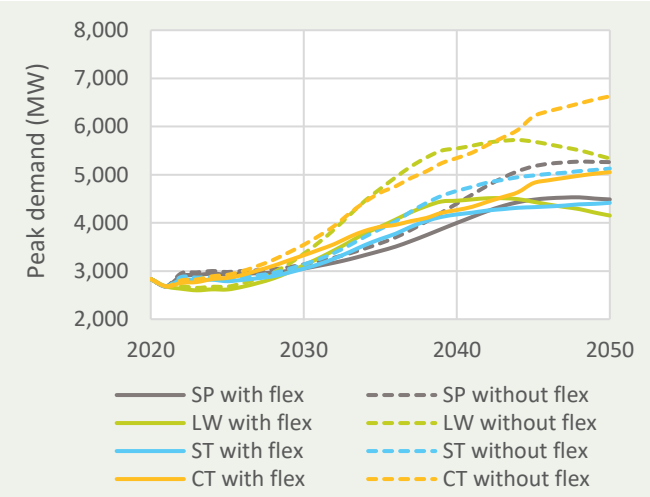


Figure 8: SPM DFES2021 demand growth

Losses increase with high utilisation, and as such peak losses occur in line with peak demand. Peak demand is seen to increase in all scenarios, but particularly in CT and LW scenarios, that rely upon significant consumer behaviour changes. In order to meet Net Zero, we will need to meet the levels of decarbonisation seen by these two scenarios. The dashed lines show that without flexibility, the peak load increases significantly further still.

We have used the range of load growth forecasts to forecast the effect on losses for the next ~15 years out to 2036, as shown in Figure 9.

- The darker green lines cover the scenarios in which traditional reinforcement methods are relied upon to meet increases in demand, particularly Steady Progression but possibly applicable to System Transformation also. In these scenarios, the losses 'as a percentage of units distributed' stays relatively similar to today's levels (~7%) as network utilisation stays the same. The solid line covers a low load-growth scenario, and shows losses increasing by approximately 15% by the end of RIIO-ED2. This is considered to be the minimum credible volume of losses in future.

- The lighter green lines cover the scenarios in which load and/or generation balancing technologies are used to push our networks harder, increasing utilisation to meet increases in demand. This has a compound effect on losses as, although utilisation increases, this does work to bring the peak loading down (as seen in Figure 7 and Figure 8). The dashed line covers a high load-growth scenario, driven by large volumes of heat pumps and electric vehicles. This could be a credible growth scenario, but it is possible this can be brought down somewhat by losses-inclusive operation of demand-side flexibility.

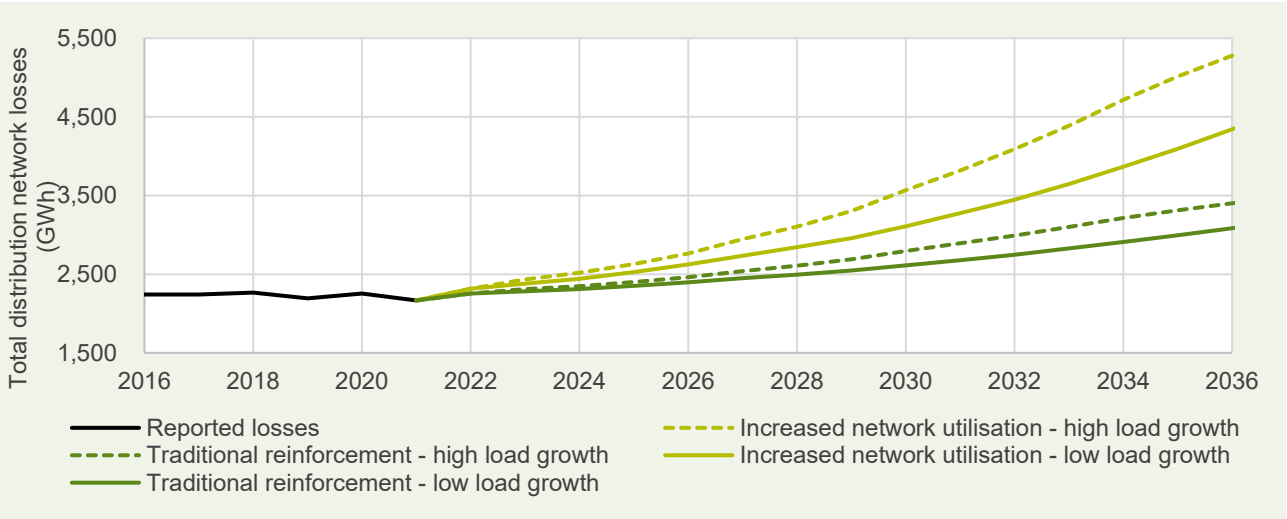


Figure 9: Forecast Losses across both SPEN licence areas

It can be seen from Figure 9 that, depending on the influence of external social, political and technological drivers, losses may be affected in different ways. **In all scenarios, however, losses are set to increase.** Any absolute reduction in losses in future would require significant investment – quickly going beyond the measures that are reasonably practicable. However, a focus to maximise losses savings compared to the baseline will now become more important than ever to ensure maximum value for money for our customers. Where reinforcements and asset replacements are planned there will be opportunities to offset these increases by installation of new lower loss network infrastructure where economically justified by cost-benefit analysis.

4.2.1 The Cost of Losses

Due to increases in renewable generation and the removal of fossil-fuel generation from the GB generation mix, the carbon intensity of losses will decrease significantly over the next few business periods, reducing the carbon emissions due to losses across SPEN – as shown in Figure 10.

However, despite this significant reduction, there are still factors keeping the potential cost of losses high. Firstly, the cost of carbon (£/tCO_{2e}) will increase sharply to drive emissions reductions across the whole GB economy. Additionally, there is the economic cost of losses, driven by the wholesale cost of generating the electricity in the first place. This cost in fact dominates the total cost of losses. There is uncertainty in how the economic cost will change, as this is linked to future energy prices. Using the current value of losses in 2020/2021 prices of £58/MWh, the potential cost of losses will increase over the next few business periods as shown in Figure 11.

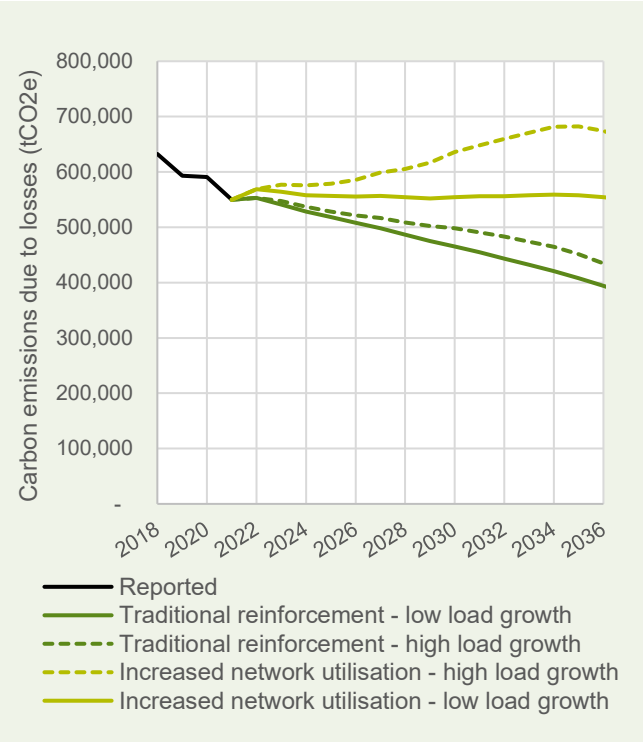


Figure 10: Forecast carbon emissions due to losses across both SPEN licence areas

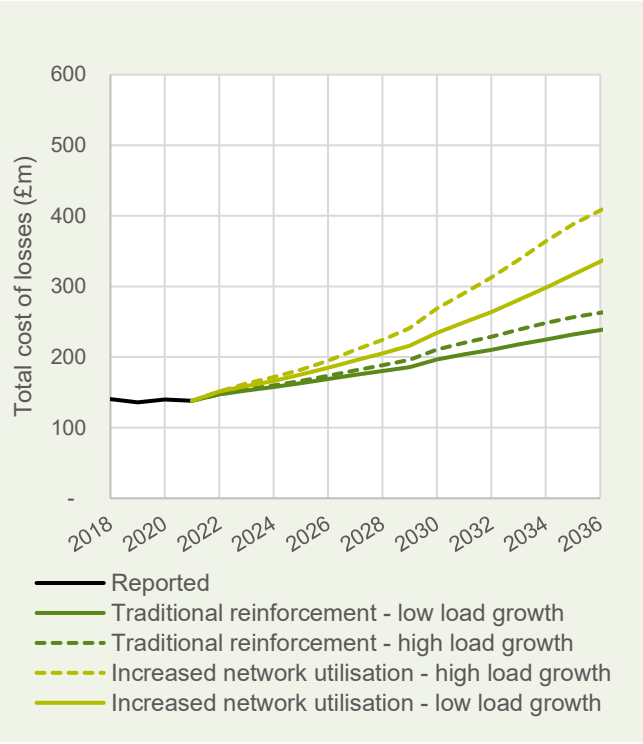


Figure 11: Forecast environmental and economic cost of losses across both SPEN licence areas

5 Our Losses Action Plan

5.1 Our Losses Action Plan on a Page

Table 3: Losses Action Plan Summary

	Activity	Technical or non-technical losses	Losses Reduction over ED2 period		Section
			GWh	tCO_{2e}	
Improve understanding	Better ways to measure total network losses	*Both*	*Enabling action*		*6.2*
	Innovative Use of Smart Meter and Network Data	*Both*	*Enabling action*		*6.3*
	Enhanced Network Modelling	*Both*	*Enabling action*		*6.4*
	Improving our Understanding of Non-Technical Losses	*Non-technical*	*Enabling action*		*6.5*
	Contact Voltage Detection	*Both*	*Enabling action*		*6.6*
Processes to reduce losses	Proactively replace 4 primary transformers in SPD	*Technical*	*4.2**	*856*	*7.3.1*
	Opportunistic losses reduction through replacement of 10 grid transformers in SPM	*Technical*	*9.8*	*1,937*	*7.3.1*
	Opportunistic losses reduction through replacement of 104 primary transformers.	*Technical*	*17.0*	*3,510*	*7.3.1*
	Proactively replace 795 ground mounted secondary transformers	*Technical*	*31.8**	*6,547*	*7.3.2*
	Opportunistic losses reduction through replacement of 414 ground mounted secondary transformers	*Technical*	*15.4*	*3,146*	*7.3.2*
	Opportunistic losses reduction through replacement of 8,620 pole mounted secondary transformers	*Technical*	*28.2*	*5,757*	*7.3.2*
	Increase minimum size of OHL conductor for HV main line new build and offline rebuilds	*Technical*	*Analysis ongoing*		*7.4.2*
	Increase minimum size of HV UG conductor for all condition-based overlay and cable reinforcement	*Technical*	*18.7*	*3,800*	*7.4.3*
	Increase minimum size of LV UG conductor for all condition-based overlay and cable reinforcement	*Technical*	*125.6*	*25,556*	*7.4.3*
	Blown LV Fuse Detection	*Technical*	*Analysis ongoing*		*7.5*
	Convert 6.6kV islands to 11kV operation – 3 in SPD, 5 in SPM	*Technical*	*17.0*	*4,192*	*7.6*
	Voltage Optimisation	*Technical*	*Analysis ongoing*		*7.7*
	Theft and Revenue Protection	*Non-technical*	*160.3*	*33,950*	*8.2*
	LV monitoring roll-out	*Non-technical*	*36.8*	*3,718*	*8.3*
	Better understanding and therefore management of non-technical losses through unmetered supply inaccuracies.	*Non-technical*	*Enabling action*		*8.4*
	Theft in Conveyance	*Non-technical*	*22.9*	*4,842*	*8.5*
Losses innovation	Mobile Asset Assessment Vehicle (MAAV)	*Both*	*85.5*	*18,169*	*9.2*
	DC Distribution	*Technical*	*Analysis ongoing*		*9.3*
	Active Network Configuration	*Technical*	*Analysis ongoing*		*9.4*
	Data Processes	*Both*	*Enabling action*		*9.5*
Stakeholder engagement	Technical Losses Working Group	*Both*	*Enabling action*		*10.2*
	Early Loss Adjustment Factors	*Technical*	*Enabling action*		*10.3*
	Losses Management through DSO Transition	*Technical*	*Enabling action*		*10.4*
	Holistic Consideration of Losses	*Technical*	*Enabling action*		*10.5*
	Community Engagement though Revenue Protection Activities	*Non-technical*	*Enabling action*		*10.6*
Total			***573.2***	***115,980***	*11*

**These GWh savings form our RIIO-ED2 commitment (#78) on Losses reduction.*

5.2 Our Method for Selecting Losses Management Actions in RIIO-ED2

To develop our RIIO-ED2 action plan, we have collated the programmes of activity from the following schemes:

- Maintained successful activities and programmes from our current losses strategy [1] and revisited key ***Investment Decisions*** across asset management, design policy and operational process (as set out in Table 3) in the context of Net Zero.
- Reviewed all ***Initiatives*** from our LDR programme [5] (as set out in Table 5), identified those that are now Business As Usual (BAU) and carried forward those which are successful and ongoing.
- Looked at wider industry ***Innovation and Best Practice***, to supplement our existing activities.

Where necessary, we have refreshed Cost-Benefit Analyses (CBAs) to support our plan, in line with methods in Section 5.3 below.

Table 4: RIIO-ED1 Investment Decisions and RIIO-ED2 Applicability – proactive actions (changes to BAU) are highlighted

#	RIIO-ED1 Strategy Investment Decision	ED1 Decision	RIIO-ED2 Applicability
1	Should we replace or refurbish grid and primary transformers?	Not efficient to replace where loss reduction is the primary driver	Efficient to replace some primary transformers where loss reduction is the primary driver
2	Should we move to procurement of Tier 2 ground mounted secondary transformers immediately instead of waiting until 2021?	Continue to procure Tier 1 units in line with the EU Regulations	All transformer procurement will comply with Eco Tier 2 as minimum standard.
3	Should we replace or refurbish ground mounted secondary (HV) transformers?	There is a losses-based case for bringing forward replacement of high-loss units	There is a losses-based case for bringing forward replacement of high-loss units
4	Should we proactively replace HV pole mounted transformers?	Maintain ongoing policy to replace on failure	Maintain ongoing policy to replace on failure
5	Should we increase cross-sectional area of overhead line conductors at EHV / 132kV to reduce network losses?	Increasing conductor size is to be considered on a case-by-case basis	Increasing conductor size is to be considered on a case-by-case basis
6	Should we increase cross-sectional area of overhead line conductors at HV to reduce network losses?	New and rebuilt HV mains will be constructed using 100mm^2 conductor	Continued assessment – maintain or increase minimum standards
7	Should we increase cross-sectional area of underground cables at EHV or above to reduce network losses?	Increasing conductor size is to be considered on a case-by-case basis	Increasing conductor size is to be considered on a case-by-case basis
8	Should we increase cross-sectional area of underground cables at HV or LV to reduce network losses?	No increase to minimum conductor size, but decision kept under review	Continued assessment – increase minimum standards
9	Should we increase cross-sectional area of LV service cables to reduce network losses?	No increase to minimum conductor size, but decision kept under review	Continued assessment – increase minimum standards
10	Should we rationalise voltage in legacy areas of 6.6kV to 11kV?	The programmed work to upgrade the 6.6kV islands to 11kV will continue	The programmed work to upgrade the 6.6kV islands to 11kV will continue

Table 5: RIIO-ED1 LDR Initiatives and RIIO-ED2 Applicability – new initiatives (changes to BAU) are highlighted

#	RIIO-ED1 LDR Initiative	ED1 Progress	RIIO-ED2 Applicability
1	**Initiative 1 –** Smart Meter Data Analysis Systems to Reduce Non-technical Losses	Awaiting smart meter data	Continued modelling improvements using data as it becomes available
2	**Initiative 2 –** Smart Meter Data Analysis Systems to Reduce Technical Losses		
3	**Initiative 3 –** Voltage Optimisation to Improve Network Losses and Load	Awaiting smart meter data	Awaiting smart meter data
4	**Initiative 4 –** Improved Modelling of Complex Networks to Reduce Losses	BAU	Continued assessment of Seasonal Normal Open Points
5	**Initiative 5 –** Improved Modelling of Rural Networks to Reduce Losses	BAU	BAU
6	**Initiative 6 –** Assessment of Power Factor to Improve GB Losses	Continued engagement with NGET	Continued engagement with NGET
7	**Initiative 7 –** Improved Detection of Theft through Revenue Protection	BAU	Continued Revenue Protection Activities
8	**Initiative 8 –** Improved Network Loading by Stakeholder Engagement	Continued stakeholder engagement	Continued stakeholder engagement
9	**Initiative 9 –** Substation Efficiency – Alternative Uses for Waste Heat	Not pursued due to lack of business case	Not pursued due to lack of business case
10	**Initiative 10** – Substation Efficiency – Monitoring and Self-Sufficiency	Not pursued due to lack of business case	Not pursued due to lack of business case
11	**Initiative 11 –** Consider Case for Mobile Asset Assessment Vehicle (MAAV)	Not pursued due to lack of funding	Applied for Consumer Value Proposition (CVP) to fund activity
12	**Initiative 12 –** Early Viability of Loss Adjustment Factors (LAF)	Explored an innovation to reduce LAFs	Continued stakeholder engagement on this idea
13	**Initiative 13 –** SCADA Based Near-Real-Time Losses Calculations	Continued consideration of the business case	Continued consideration of the business case

5.3 Our Method for Evaluating Actions

It is not always possible to quantify the losses saved through our wider initiatives, such as actions to improve our losses understanding, engaging with customers, or exploring early innovations. However, we must be able to justify the measures we implement as being cost efficient. Therefore, we evaluate loss mitigation measures using the latest Ofgem RIIO-ED2 CBA template and guidance, aligned with our RIIO-ED2 plan.

All CBAs compare one or more optional scenarios against a *baseline* scenario. The baseline scenario in our CBAs is the counterfactual or BAU course of action without the additional action to manage losses. The cost of losses (or value of avoided loses) is the total of the economic cost[9] and the carbon cost[10] –in line with the Ofgem CBA guidance. The whole lifecycle costs and benefits are then considered in order to inform this strategy. Unless where otherwise stated, typical lifetime of an intervention is assumed to be 45 years.

5.4 Stakeholder feedback



Most stakeholders we asked agreed with our approach to focus on managing losses that are within our control. Some stakeholders felt that SPEN should be incentivised to minimise the losses it can control, and others felt that the drive should be to "zero" losses (i.e. "as low as possible", noting that "zero" is not technically possible). We have taken a technically feasible and ambitious approach by minimising losses where it is overall beneficial to our customers when weighing up the costs against the socialised and environmental benefits. It is reassuring that our stakeholders support our loss minimisation ambitions.

[9] £58/17/MWh
[10] Updated short-term traded carbon values used for UK policy appraisal (2018), https://www.gov.uk/government/publications/updated-short-term-traded-carbon-values-used-for-uk-policy-appraisal-2018

6 Improving Our Understanding of Losses

6.1 Overview

Measuring distribution losses is inexact and difficult as there is limited data on power flows at the lower voltages. The difficulty with measuring losses is compounded by the changing demands placed upon our networks in the transition to Net Zero, which will continue in RIIO-ED2 and beyond.

It is important we continue to build a better understanding through information gathering (using network monitoring), more advanced models, and better data sharing (through Open Data platforms).

This section details the key activities we are undertaking to develop our understanding of losses, and a summary of these activities is presented in Table 6.

Table 6: Overview of Innovation Activities to Reduce Network Losses

Activity	Overview	Outcomes
How We Measure Losses (Section 6.2)	Losses are in fact calculated, not measured. We will combine different approaches taken to estimating losses across the business. We will seek better ways to calculate losses that remain efficient.	Improve our records of losses across the network. Make these records available throughout the business. Share our findings with industry.
Innovative Use of Smart Meter and Network Data (Section 6.3)	In ED1 work will give visibility of LV feeder and secondary substation losses using aggregated smart meter data in ED2. We will also be able to pair this with enhanced secondary substation monitoring data to gain enhanced visibility of LV network losses.	Better disaggregation of technical and non-technical network losses in ED2.
Enhanced Network Modelling (Section 6.4)	We made considerable progress in ED1 adding novel and advanced data mining / processing techniques to NAVI to maximise the utility of raw data to understand losses. Our industry leading ENZ platform has built upon NAVI.	Combine our advanced modelling approaches into this platform to help us model losses and losses reduction interventions more accurately.
Improving our Understanding of Non-Technical Losses (Specifically Theft) (Section 6.5)	We have permanently embedded technical staff within Merseyside Police to assist actively with electricity theft. This arrangement allowed us to develop our understanding of theft in the SPM zone.	Continue to actively pursue working relationships within Merseyside Police and Police Scotland.
Detecting Contact Voltage (Section 6.6)	This is an innovation that can provide early identification of faults (and corresponding losses) with our network and equipment connected to it. See Section 7.2 for details.	Better understanding of non-technical losses through unmetered supply inaccuracies.

6.2 How We Measure Losses

Losses cannot be measured directly; they must be calculated. They are determined by measuring the difference in the energy flowing into and out part of the part of the network (or the asset) for which losses are to be quantified.

Our reported losses values are calculated using *top-down* models of energy entering and exiting the system, relying on settlement data. They have averaged around 6-7% of units distributed over RIIO-ED1, but within the year fluctuate noticeably due to the measurement uncertainties.

Current industry approach for calculating losses has several limitations:

- It does not allow discrimination between technical and non-technical losses.

- Unmetered connections have estimated consumption, and any discrepancies between estimated and actual usage becomes a further source of losses.
- Lack of consumption data, and granularity therein, makes power flow modelling difficult. As losses are non-linearly related to current flow (I^2R) over time, aggregated consumption data is much less valuable than granular data from the perspective of understanding losses.
- Measurements that are available are subject to tolerances, such as from the metering equipment. These tolerances are large compared to the scale of the losses.
- Losses are becoming more complex to evaluate and manage due to LCT uptake and the amount of connected Distributed Generation.

To help us better manage losses as they increase in future, we need a *bottom-up* understanding of losses. Therefore, new methods to help improve our understanding of where losses are and in what quantities will help us develop this picture. This is critical to make sure we intervene where necessary, and only where necessary, such that our customers receive best value for money.

In RIIO-ED2, we will continue to improve the way we calculate losses across our network, with a view to producing a more comprehensive picture of where losses occur. We will consider various tools and approaches for doing this.

Detailed Network Modelling	*Network modelling allows losses to be quantified and attributed on a more granular level than the aggregated energy-in less energy-out approach, which has been used historically. Instead, losses can be quantified on an asset-by-asset basis and temporal, diurnal, or seasonal drivers of losses can be examined.* *To extract maximum value from this approach, we require reliable data. This could be at the consumer level through smart meter readings or could be aggregated at the secondary substation level. Greater aggregation reduces the challenges associated with processing and analysing the data but may also hide key trends.* *These models can be combined with our DFES (Annex 4A.6) and Engineering Net Zero platform (See Annex 4A.2 – Our Load Related Strategy; Engineering Net Zero and Section 6.4) to enable quantified estimates of future network losses to be calculated.*
Scaled Up Generic Modelling	*The detailed modelling approach is time and resource intensive, and the availability of robust data may make it economically unjustifiable. A lower cost, but less accurate, solution would be to model a small number of paths through the network and scale losses based on the total number of components.* *This approach may also be readily combined with our DFES but will offer less accurate estimates of future network losses than those produced using the detailed network modelling approach.*
Approximate Calculations	*As has been addressed earlier, network losses to environmental heating can be calculated using I^2R. Impedance values for typical network components (buried cables, OHL, transformers) can be identified, or derived, from datasheets. Based on assumed, known, or mixed current flow values, loss profiles can be approximated for a range of network sections. Again, these can be scaled up to approximate the wider system.* *This approach may also be combined with our DFES but offers substantially reduced loss estimates relative to the approaches summarised previously.*

6.2.1 Contributing to the Evidence Base

In line with Ofgem's expectations, in RIIO-ED2 we will commit to further contribute to the evidence base on the size and location of losses within our network.

We will ensure that the work we undertake to better understand and ultimately characterise the nature of losses on our networks is shared with the wider industry along with the outcomes.

Recognising the value in: sharing information; developing best practice; and minimising duplication of effort, we convened, and continue to chair, the TLWG. This has facilitated a bi-directional interchange of improved losses knowledge between our partner DNOs and ourselves.

We have conducted international engagement covering losses minimisation, detailed throughout this document. Examples include through our parent company, Iberdrola, and our engagement with Japanese and Nigerian energy delegations.

Through these media, we are actively contributing to the evidence base around the makeup of losses and aiding the characterisation of which losses may legitimately be controlled by DNOs.

6.2.2 Reporting on Losses

As part of our RIIO-ED2 strategy, we will report on the progress of implementing the losses strategy and the specific actions we are undertaking to successfully manage losses. We propose this will tie in with the annual losses snapshot reporting process.

To ensure industry maintains the level of ambition driven by the LDR in RIIO-ED1, a mechanism is required to incentivise loss reduction through the efficient delivery of all DNOs' strategies. Finding a suitable mechanism is not straightforward because losses are complex, difficult to measure, and vary based on regional topology and customers' electricity usage. Furthermore, a future mechanism must not provide any disincentive to the connection on LCTs.

Therefore, in RIIO-ED1, in our role as chair of the TLWG, we commissioned independent technical experts WSP to produce a report [12] that investigates best practice and makes independent recommendations as to future loss incentive mechanisms. We published key findings as part of our LDR Tranche 3 submission [5].

6.2.3 Our proposed RIIO-ED2 Reputational Losses Incentive (ODI-R)

In line with the guidance in the WSP report, we have proposed a reputational RIIO-ED2 losses mechanism which builds on the existing RIIO-ED1 framework and recognises the complexity in the measurement and management of losses arising from the Net Zero transition.

The proposal was presented at Ofgem's RIIO-ED2 Distributed Energy Working Group (DEWG) in October 2020. It proposes the introduction of a Reputational Output Delivery Incentive (ODI-R) to replace the LDR and sets out possible performance measures. We are keen to continue to work with Ofgem and with other DNOs to finalise and implement this proposal.

The proposed reputational measure is intended to give interested stakeholders a view of how well the DNO is executing their losses strategy plans, and to recognise and incentivise the ambition of this activity. A two-fold approach would score DNOs based upon both their 'ambition' of losses strategy and 'performance' of activities as part of this strategy. The final proposal element qualitatively assesses elements of the LDR considered during RIIO-ED1; namely understanding of losses, stakeholder engagement and losses innovation.

It is not possible to evaluate absolute losses, or to fairly compare absolute levels of improvement. Therefore, the proposed approach will better display the subtleties of each DNO position. This approach avoids incentivising low ambition. Assessment is both quantitative and qualitative, providing more flexibility in arranging activities aligned with DNO improvement opportunity. Further details can be found in Appendix 2.

6.3 Innovative Use of Smart Meter and Network Data

In order to better understand the location, nature, and drivers behind losses on our distribution networks, we must record and have access to the necessary data. We are achieving this improvement in two ways:

- Use of smart meter data from the housing and retail units of consumers.
- Increased metering of supply infrastructure, such as feeders at secondary substations.

Smart meter data allows a clearer picture of consumption habits to be established and will reduce erroneous reporting of consumption. Infrastructural metering allows a more robust understanding of network loading / utilisation, allowing us to ascertain where losses are occurring and what the underlying drivers are.

For example, DG tends to have less accurate measurement of its electrical output compared with larger centralised plant. Consequently, the use of infrastructural monitoring is of high value as the DG output measurement might misrepresent its electrical output and lead to incorrect inferences being drawn.

Further, the robust data allows us to build accurate models of the network at a commensurate level of fidelity. Such models can be used to assess the impact of network reconfiguration, technological changes or policy changes at low cost and negligible risk.

In RIIO-ED1, we delivered two LDR initiatives focussed on using smart meter data to better understand and manage technical and non-technical losses, namely:

- **Initiative 1 –** Using smart meter data to reduce non-technical losses.
- **Initiative 2 –** Using smart meter data to reduce technical losses.

As part of these initiatives we have developed several data analysis tools to evaluate smart meter data and locate high loss areas of the network or cases of non-technical losses. We have developed novel and advanced data mining / processing techniques to maximise the utility of the information gleaned from the raw data. These have been added as additional functionality to the Network Analyse and View (NAVI) tool, which was developed as part of our award-winning RIIO-ED1 Network Constraints Early Warning System (NCEWS) innovation project[11] and combined with an LV connectivity model as part of our ENZ Modelling capability.

This work will give visibility of LV feeder and secondary substation losses using aggregated smart meter data in RIIO-ED2. We will also be able to pair this with enhanced secondary substation monitoring data to gain enhanced visibility of LV network losses.

Annex 4A.21 Network Visibility Strategy sets out our LV network monitoring strategy for RIIO-ED2. It further demonstrates how losses are unique in their requirement for both LV monitoring data and smart meter data in order to sufficiently identify both technical and non-technical losses – neither data set can do it on its own.

In RIIO-ED2 we will deliver LV monitoring at over 14,100 secondary substations. When added to the 2,438 LV monitors we are delivering in RIIO-ED1, by the end of RIIO-ED2 over 50% of our larger secondary substations will have LV monitoring.

With LV data and our new tools for LV losses analysis:

- We will know which areas of the network are heavily loaded. Combined with the asset data in our Engineering Net Zero platform (see Section 6.4.), we can identify technical losses hotspots. This helps identify where and how we should be making losses-driven interventions.

[11] https://www.smarternetworks.org/project/nia_spen0016

- Combined with smart meter data, we can identify illegal abstraction by identifying areas where billed energy from smart meters is materially different to energy flowing through the network. This will also help identify unregistered unmetered supplies.

6.4 Enhanced Network Modelling

In RIIO-ED1, we completed two key LDR initiatives that significantly improved our modelling of system losses, namely:

- **Initiative 4 –** Improved Modelling of Complex Networks to Reduce Losses.
- **Initiative 5 –** Improved Modelling of Rural Networks to Reduce Losses.

These new modelling approaches have improved the quality and accuracy of our network models, thus improving our understanding of losses. The most fundamental change has been the paradigm reversal from *top-down* to *bottom-up.*

The bottom-up approach is much more computationally intensive and data driven. Consumption and conveyance metering data, in 30-minute intervals, offers an accurate picture of power flows across our networks. This data can then be used to model the losses in each transformer, overhead line (OHL), and cable, with 48 daily *snapshots (half-hourly)*. As has been discussed previously, losses vary with the square of the current, therefore a loading profile with periods of high and low demand will incur greater losses than a consistent profile of the same daily magnitude. Our bottom-up modelling approach allows us to understand factors such as time of day and time of year as drivers for losses.

We have used granular modelling to improve the quality of network assessments. We now have a much more holistic and inclusive approach towards:

- Network reinforcement studies and its impacts.
- Load growth management assessments.
- Connections of new loads and / or DG.

The use of holistic granular modelling has been incorporated into business as usual (BaU) during RIIO-ED1 and will be used to support innovation during RIIO-ED2, including shaping our losses management processes.

6.4.1 Engineering Net Zero Modelling

Building upon our NAVI platform, we have recently delivered a step change in network analytical capability. These developments are part of our extensive efforts to enable better monitoring, control, design, and operation of the LV network. In RIIO-ED2 it will provide real-time analytics to underpin network management functions and coordinate network interventions. We call this our Engineering Net Zero (ENZ) Platform.

As described in Annex 4A.1: Our Future System Strategy, the ENZ Platform incorporates a full connectivity model of the LV network, which allows for complex modelling and is a significant advancement on vectorised geographic information systems (GIS). It has been designed to operate with large data sets and provides access to full asset data including conductor types, ratings etc. Using our DFES forecasts, including the individual property level data from EV-Up and Heat-Up innovation project[12], coupled with information on all the different assets – their electrical characteristics, ratings etc. – we establish present and future loading on every single asset.

[12] https://www.smarternetworks.org/project/nia_spen_0037

The model establishes the location, magnitude & timings of constraints at an individual asset level and uses a mathematical optimisation solver to determine a set of solutions to minimise cost.

The next step for losses is to combine our advanced losses modelling approaches into this platform and develop and cultivate its use in network losses modelling.

6.5 Improving our Understanding of Non-Technical Losses

We have permanently embedded technical staff within Merseyside Police to assist actively with electricity theft. This arrangement allowed us to develop our understanding of theft in the SPM zone; and was an industry leading initiative when first launched. We are pursuing a similar arrangement with Police Scotland for SPD.

We are sharing information and best practice with our partner DNOs. On top of this, we are working with other users of smart meter data such as British Gas and Utilita to improve our processes for detecting, recording, and ultimately reducing non-technical losses.

Engagement with stakeholders in the development of our Theft Propensity Model is also ongoing. Our parent company, Iberdrola, encourages close collaboration amongst its international companies and we continue to work closely with colleagues in Spain, and elsewhere, to develop our data analytics capability.

We now have a firm knowledge of the data analytics processes that involve considerable network monitoring. Our strategy for the deployment of secondary substation monitoring throughout RIIO-ED2 will be informed by the Theft Propensity Model and outputs of industry forums to identify network areas with high potential for non-technical losses.

Our Revenue Protection team actively participate in the Electralink-led Theft Risk Assessment Service (TRAS) Expert Group and introduced innovative analysis of energy consumption with ambient temperature as an enhancement to existing TRAS detection algorithms. The TRAS Expert Group is now part of the larger Theft Issues Group (TIG), also led by Electralink.

We are influencing industry best practice, having recently participated in a working group examining how to improve the Theft Risk Assessment Methodology (the method in which TRAS identified potential leads for energy suppliers) by providing insights and findings of our analysis on the proposed use of substation monitoring data to identify energy theft.

6.6 Contact Voltage Losses on LV Networks

As part of our overall strategy to reduce losses, improve customer performance and enhance the safety of our network, we propose to employ a purpose-built vehicle called the MAAV – or Mobile Asset Assessment Vehicle – that detects electromagnetic fields and identifies exposed voltages (called ‘Contact Voltages’) that can occur on exposed surfaces due to faults in electrical equipment. This vehicle can be driven around our licence areas, providing early identification of faults.

Where these faults are due to unmetered connections to the network, the MAAV may provide a better (although not comprehensive) understanding of non-technical losses through unmetered supply inaccuracies. See Section 9.2 for more details.

In RIIO-ED2, we are proposing a Consumer Value Proposition (CVP) for the MAAV. For more information on our proposed CVP, see Annex 5C.4.

7 Processes to Manage Technical Losses

7.1 Overview

In some instances, we have decided to make *proactive* interventions to our network with losses reduction as the primary driver – in total, during RIIO-ED2 we shall spend £13.22 million on loss-driven projects. In other instances, we have decided to take *opportunistic* action to reduce losses during other network interventions. Finally, there are some actions that we have identified could be taken to reduce losses, but which we have determined do not provide overall value for money to our customers. This section provides an overview of engineering actions that we have evaluated as part of this losses strategy and explains the decisions we have taken. A summary of these actions is presented in Table 7.

Table 7: Technical Losses Reduction Initiatives Summary

Initiative	Overview	Losses Reduction over ED2 period	
		GWh	tCO2e
Transformer Replacement	We have earmarked four primary transformers for early replacement in SPD during RIIO-ED2. **Proactive, losses-driven scheme with a total cost of £1.76m.**	4.2	856
	Our policies to replace all transformers with new, low-loss equivalent designs lead to an "opportunistic" losses reduction associated with condition-based replacement of 10 grid transformers in SPM.	9.8	1,937
	Our policies to replace all transformers with new, low-loss equivalent designs lead to an "opportunistic" losses reduction associated with condition-based replacement of 104 primary transformers across SPM and SPD.	17.0	3,510
	We have earmarked 795 ground mounted secondary transformers for early replacement during RIIO-ED2 across SPM and SPD. **Proactive, losses-driven scheme with a cost of £11.46 million.**	31.8	6,547
	Our policies to replace all transformers with new, low-loss equivalent designs lead to an "opportunistic" losses reduction associated with condition-based replacement of 414 HV transformers across SPM and SPD.	15.4	3,146
	Opportunistic losses reduction through replacement of 8,620 pole mounted secondary transformers	28.2	5,757
Overhead Line Conductor Sizing Upgrades	Case-by-case conductor sizing on EHV and 132kV OHL specifically to reduce losses.	Unknown	
	For HV main line new build and offline rebuilds throughout ED2, we intend to Increase our minimum size of OHL conductors.	Analysis ongoing	
Underground Cable Conductor Sizing Upgrades	Case-by-case conductor sizing on EHV and 132kV cables specifically to reduce losses.	Unknown	
	For HV cable replacement, we intend to set minimum size(s) of conductors for all condition-based overlay (115km in total) and cable reinforcement (151km in total) in SPM and SPD. Proactive, losses-driven replacement of HV cables deemed uneconomical.	18.7	3,800
	For LV cable replacement, we intend to set minimum size(s) of conductors for all condition-based overlay 195km in total) and cable reinforcement (473km in total) in SPM and SPD. Proactive, losses-driven replacement of LV cables may be economical, but expenditure and delivery constraints may prevent intervention.	125.6	25,556
	For LV services, minimum conductor size is likely to be driven by capacity requirements.	Analysis ongoing	
Blown LV Fuse Detection	Voltage drop detection to identify blown LV fuses built into NAVI toolset.	Analysis ongoing	
Voltage Uprating	All remaining SPD 6.6kV islands and five SPM 6.6kV SPM islands to be upgraded to 11kV.	17.0	4,192
LV monitoring	Deploy a further 14,100 LV monitors on our network over RIIO-ED2.	36.8	3,718
Voltage Optimisation	Automatic voltage control to be installed at 320 locations, principally at 11kV.	Analysis ongoing	

7.2 Loss Reduction Opportunities in Network Design and Construction

7.2.1 Losses Policy and Standards Review

We want to ensure that the messages within this strategy can be simply and easily communicated throughout the entire business, and that all members of staff our clear of our strategic vision to **"Consider all reasonable measures which can be applied to reduce losses and adopt those measures which provide benefit for customers"**.

Therefore, in RIIO-ED1 we developed a Losses Policy that clearly articulates the actions we expect our staff to take in their day-to-day activities, to highlight where they can have an impact on reducing both technical and non-technical losses, and to signpost where to go if further information is required.

Supporting both the Policy and Strategy, we have completed our commitment to review and amend our design and operational guidelines to align with our vision. Many of our technical policies and procedures have been updated with references to aspects of the Losses Policy included where appropriate.

7.2.2 Transformer Purchase Using Total Cost of Ownership Model

When energised, the steel core of a transformer pulses, generating a characteristic *humming* sound. Additionally, the pulsing generates heat. The conversion of useful electrical energy to undesirable sound and heat energy is known as the *iron losses*. Iron losses can be reduced through improved material selection but cannot be eliminated. Iron losses are fixed losses, as discussed in Section 3, thus they are independent of electrical throughput of the transformer.

Transformer windings are generally constructed from copper or aluminium. Unlike the steel core, these incur variable losses (also discussed in Section 3), and the heating losses rise dramatically as the current increases. These variable losses can be reduced, but not eliminated, through improved material selection, and oversizing of conductors.

From a purely technical perspective, improvements to fixed and variable transformer losses are always justifiable. However, there are economic consequences associated with the procurement and installation of upgraded components. When purchasing transformers, we look holistically at the costs and benefits of the purchasing decision, which looks to reduce the 'Total Cost of Ownership' (TCO). We ask prospective suppliers to provide a detailed breakdown of loss values to be able to make this informed purchasing decision based on lifecycle cost, incorporating capitalisation of losses over the 45-year anticipated lifespan of the asset.

The formula, which underpins our transformer procurement policy is:

$$Cost\ (£) = Purchase\ Price\ (£) + \left(No\ Load \frac{£}{kW} \times No\ Load\ Loss\ kW\right) + \left(Load\ Loss \frac{£}{kW} \times Load\ Loss\ kW\right)$$

In RIIO-ED2, EU Directive 2009/125/EC mandates the adoption of 'Tier 2' Eco-design power transformers [13]. The transformers procured under our current frameworks already meet or exceed this value.

However, even lower-loss transformers are now available on the market, such as amorphous-steel core transformers. We have already begun to procure these 'very-low-loss' units on our pole-mounted transformer fleet after working with the supply chain to develop the first units compliant for the GB marketplace.

When our frameworks for the purchase of new transformers come up for renewal in RIIO-ED2, we will look to improve the specification of our transformers further, using the TCO model across all framework contracts to ensure this presents best value for money for our customers.

7.3 Transformer Upgrades

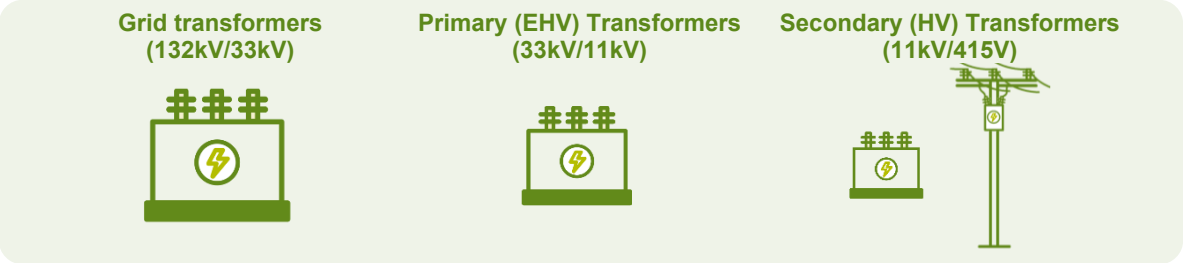


Figure 12: Transformer Types in Our Distribution Network

7.3.1 Grid and Primary Transformers

In RIIO-ED1 we considered whether to replace or refurbish grid and primary transformers. We identified that in many cases it is more efficient to undertake on-site refurbishment of grid and primary transformers until transformers are severely degraded and replacement is justified. It was generally found that losses where not a primary driver for replacement.

These findings remain valid in RIIO-ED2 for the largest (grid) transformers. However, an asset-specific analysis of primary transformers has identified several particularly high-loss assets, for which it is cost effective to undertake proactive early replacement. This is estimated to lead to a saving of 4.2 GWh over RIIO-ED2.

Furthermore, a total of 114 grid and primary level transformers are planned to be replaced due to approaching end of life. These are generally older units which will be replaced with newer, lower-loss assets in line with our network design policies, in these cases losses reduction is a secondary benefit.

7.3.1.1 Early Replacement of High-Loss Primary Transformers

During RIIO-ED1, we did not have a programme of losses-driven primary transformer replacement. However, we have found at the time of intervention that for some primary transformers the whole lifecycle benefits of early replacement outweighed the costs when including the losses benefits, when compared to refurbishment to extend the working life of the existing assets. This has driven a more detailed investigation of primary transformer losses in our planning for RIIO-ED2. This has identified several primary transformers in SPD[13] for which the costs of early replacement are outweighed by the monetised losses savings.

As a result, our strategy is now to include the ***"proactive"*** replacement of a small number of primary transformers where this presents the best value to customers. However; primary transformer replacement is a significant network intervention, and we must consider the deliverability of any early replacement plans.

We have earmarked four primary transformers for early replacement in SPD during RIIO-ED2, at a total cost of £1.76m. Financial justification is achieved solely on losses, achieving a losses reduction of 4.2 GWh over RIIO-ED2, as detailed in Table 8. The whole-lifecycle (45-year) losses saving is estimated to be 15.8GWh based on the transformers being replaced 10-15 years (depending on age and condition) before they would otherwise reach end of life. This analysis is detailed in Engineering Justification Paper **ED2-NLR(A)-SPEN-004-ENV-EJP**. A brief summary as to how losses values are derived is given in Appendix 1 Section A1.2.

[13] The models also showed possible candidates for replacement in SPM. However, the estimated value was generally not as high. There are significantly more transformers in SPM than SPD of a slightly smaller rating – as explained in Annex 4A.25 – SP Manweb Company Specific Factors. The difference due to smaller sizes on losses savings is greater than the difference in unit cost.

Table 8: RIIO-ED2 Losses-Driven Primary Transformer Early Replacement

	Volume	Losses Reduction over ED2 period	
		GWh	tCO_{2e}
SPD	4	4.2	856
SPM	0	0	0
Total	**4**	**4.2**	**856**

7.3.1.2 Replacement of Grid and Primary Transformers where Losses are not the Primary Driver

Loss reduction is not the only justification for replacing transformers. All assets have a serviceable life, after which they must be refurbished or replaced. Even if an asset's nominal life has not been reached, it may be prudent, or required, to replace an asset based on condition to ensure continued security of supply. While such replacement is not ***driven*** by losses, our policies to replace all transformers with new, low-loss equivalent designs means loss reduction is delivered as a secondary benefit. We refer to this as ***"opportunistic"*** losses reduction.

In RIIO-ED2, following a strategic asset risk management approach, we will undertake targeted replacement of end-of-life grid and primary transformers, and prioritised refurbishment of transformers to achieve life extension where the benefits of replacement (including loss reduction) do not outweigh the costs. This is to manage the risk of unplanned and catastrophic asset failure occurring through in-service deterioration.

In SPM, the condition-based grid transformer investment portfolio will replace 10 grid transformers over RIIO-ED2. In SPD, grid transformers from part of the transmission network.

To calculate the losses savings over RIIO-ED2, we have considered the additional losses that will be saved compared to the baseline option. The losses reduction achieved by using low-loss primary transformers in the wider modernisation programme is detailed in Table 9. The detailed programme of expenditure can be found in the nine relevant 132kV network Engineering Justification Papers: **ED2-NLR(A)-SPM-001-TX-EJP**, **ED2-NLR(A)-SPM-003-TX-EJP** to **ED2-NLR(A)-SPM-008-TX-EJP** inclusive, **ED2-NLR(A)-SPM-010-TX-EJP** and **ED2-NLR(A)-SPM-001-SUB-EJP**.

Table 9: RIIO-ED2 Condition-Based Grid Transformer Replacement (SPM only)

	Volume	Losses Reduction over ED2 period	
		GWh	tCO_{2e}
SPD	-	-	-
SPM	10	9.8	1,937
Total	**10**	**9.8**	**1,937**

The condition-based primary transformer investment portfolio will replace 64 units and refurbish 41 units in SPD; and replace 40 units and refurbish 19 units in SPM. Delivery follows an optimised profile over the price control period with aligned expenditure. Primary transformers will be replaced with equivalent, low-loss units that meet or exceed the Eco-Tier 2 design standard.

The losses reduction achieved by using low-loss primary transformers in the wider modernisation programme is detailed in Table 10. The detailed programme of expenditure can be found in Engineering Justification Paper **ED2-NLR(A)-SPEN-001-TX-EJP**.

Table 10: RIIO-ED2 Condition-Based Primary Transformer Replacement

	Volume	Losses Reduction over ED2 period	
		GWh	tCO_{2e}
SPD	64	10.3	2,122
SPM	40	6.7	1,387
Total	**104**	**17.0**	**3,509**

7.3.2 Secondary Transformers

In RIIO-ED1, we considered whether to undertake the early replacement of high-loss, ground mounted secondary transformers. We identified that it provides overall value to proactively replace ground mounted distribution transformers from circa. pre-1962 because these units are particularly high loss. This programme of early replacement continues in RIIO-ED2.

Furthermore, a number of ground mounted secondary transformers are being replaced due to approaching end of life. These older units will be replaced with newer, lower-loss assets in line with our network design policies.

We also considered whether to carry out any proactive replacement of pole mounted transformers in RIIO-ED1, and this was not determined to be cost effective due to their small ratings. Refreshed analysis upholds this decision in RIIO-ED2.

7.3.2.1 Early Replacement of High-Loss, Ground Mounted Secondary (HV) Transformers

Our population of secondary transformers contains units manufactured in or before the early 1960s. These units are likely to have particularly high-loss core design, in particular manufactured in hot-rolled steel cores. Our RIIO-ED1 analysis of replacement and refurbishment options for ground mounted secondary transformers identified that it was cost efficient to proactively replace pre-1962 ground mounted distribution transformers. In addition to our condition-based programme of asset replacement, we therefore began a programme of early replacement with losses reduction as the primary driver.

However, due to manufacturing constraints, it was not possible to replace all pre-1962 transformers during RIIO-ED1. As of March 2021, we have concluded that over 4,000 pre-1962 transformers are still present on our networks, with:

- Over 3,000 units in SPD (Figure 13),
- Over 1,000 units in SPM (Figure 14).

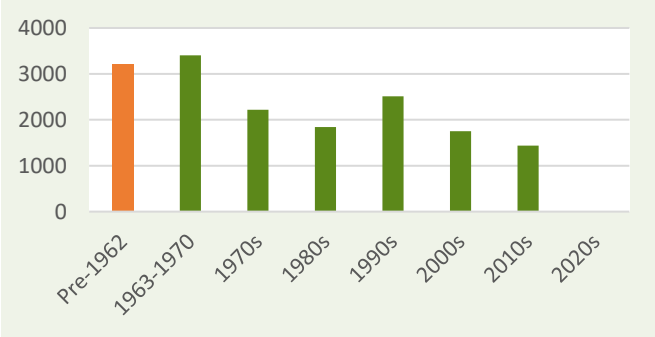


Figure 13: SPD HV Tx Age Profile (Source: CBRM, Mar 21)

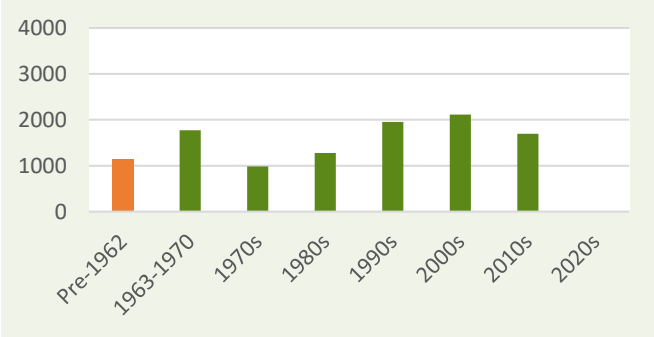


Figure 14: SPM HV Tx Age Profile (Source: CBRM, Mar 21)

We will continue this programme in RIIO-ED2. However, due to supply chain and deliverability constraints, we are unable to replace the full volume of pre-1962 (or high loss) transformers. Instead, we have earmarked the maximum volume we could achieve over RIIO-ED2, and transformers are prioritised using a holistic benefits evaluation also accounting for asset health and criticality.

Following a slightly higher focus on losses-driven replacement in SPM, the number of transformers in the pre-1962 category has reduced as a percentage of the whole when compared to SPD. Overall, our models show that the HV transformer fleet in SPD has more avoidable core losses – in part due to the age profile, and also because it is a bigger network. In RIIO-ED2, our planned volumes for early replacement reflect this.

We have earmarked 795 ground mounted secondary transformers for early replacement during RIIO-ED2, at a cost of £11.46 million. Financial justification is achieved solely on losses, achieving a losses reduction of 31.8 GWh over RIIO-ED2. The whole-lifecycle (45-year) losses saving is estimated to be 109.4 GWh based on the transformers being replaced on average 10 years before they would otherwise reach end of life. This analysis is detailed in Engineering Justification Paper **ED2-NLR(A)-SPEN-004-ENV-EJP**. A brief summary as to how losses values are derived is given in Appendix 1 Section A1.2.

RIIO-ED1 and RIIO-ED2 volumes are shown in Table 11, along with estimated losses reductions and carbon benefits. Estimated losses savings have increased from approximately 4.7 GWh/yr on average in RIIO-ED1 to 6.4 GWh/yr on average due in part to more detailed losses modelling driving our plans to include increasing load losses, and also due to a higher rate of intervention and updates to new transformer design standards to improve losses (Eco-design Tier 2).

Table 11: Losses-Driven Secondary Transformer Early Replacement During RIIO-ED1 and RIIO-ED2

	RIIO-ED1			RIIO-ED2		
	Volume	Losses Reduction over ED1 period		Volume	Losses Reduction over ED2 period	
		GWh	tCO_{2e}		GWh	tCO_{2e}
SPD	483	15.9	6,852	570	23.1	4,759
SPM	627	22.0	9,457	225	8.7	1,788
Total	**1,110**	**37.9**	**16,310**	**795**	**31.8**	**6,547**

7.3.2.2 Replacement of Secondary Ground-Mounted Transformers where Losses are not the Primary Driver

In RIIO-ED2, there are also a number of ground mounted secondary transformers that **must** be replaced to manage the risk of unplanned and catastrophic asset failure occurring through in-service deterioration. Our policies to replace all transformers with new, low-loss equivalent designs, and not to refurbish any pre-1962 units, leads to ***"opportunistic"*** losses reduction.

The reduction achieved by using low-loss secondary transformers in the wider modernisation programme is detailed in Table 12. The detailed programme can be found in Engineering Justification Paper **ED2-NLR(A)-SPEN-001-SWGTX-EJP**.

Table 12: Condition-Based Secondary Ground-Mounted Transformer Replacement During RIIO-ED2

	Volume	Losses Reduction over ED2 period	
		GWh	tCO_{2e}
SPD	187	4.1	841
SPM	225	11.3	2,305
Total	**412**	**15.4**	**3,146**

7.3.2.3 Proactive Replacement of Pole Mounted Transformers

Our policy in respect of pole mounter transformers (PMT), prior to and during RIIO-ED1 has been to replace on failure rather than proactive replacement. The drivers for this include:

- PMTs are generally located in rural areas and are typically lightly loaded (approximately 20% utilisation); therefore, variable losses are much lower than if the utilisation was higher.
- Replacement of PMTs with heavier and larger reduced losses units is generally driven by the need to increase rural transformer capacity (supporting rural decarbonisation).

During RIIO-ED2, our PMT modernisation programme will primarily be driven Polychlorinated Biphenyl contamination removal, more details on this programme are available in **ED2-NLR(A)-SPEN-003-ENV-EJP**. All PMTs will be replaced with very-low-loss amorphous steel core units, as the TCO principle has been applied at procurement. The estimated losses savings through this proactive programme is detailed in Table 13. This is a conservative estimate as in addition, PMT modernisation will also take place as part of the overhead line modernisation programme of work **ED2-NLR(A)-SPEN-002-OHL-EJP**, but much fewer numbers will be replaced.

Table 13: RIIO-ED2 PCB-Based Secondary Pole-Mounted Transformer Replacement

	Volume	Losses Reduction over ED2 period	
		GWh	tCO_{2e}
SPD	3,423	12.8	2,618
SPM	5,197	15.3	3,139
Total	**8.620**	**28.2**	**5,757**

7.3.3 Stakeholder feedback



The vast majority of stakeholders agreed with our strategy to accelerate the replacement of high-loss assets. Stakeholders' main comments with respect to this activity revolved around the cost implications flowing from accelerating the replacement of high-loss assets. This demonstrates the importance of applying a robust cost benefit analysis approach before making any strategic investments, and only pursuing those that have overall value for money for customers.

7.4 Underground Cable and Overhead Line (OHL) Upgrades

Given the increases in network utilisation that are predicted in RIIO-ED2 to support the transition to Net Zero, we have considered setting minimum conductor sizes and investigated whether there is a case for proactive replacement of cables or Overhead Lines (OHL) with losses as the primary driver.

Most of our existing policies are upheld, although in preparation for RIIO-ED2 we will refresh our LV and HV cable policies to uplift the recommended minimum cable size, e.g. minimum cross-section of 300mm^2.

7.4.1 Options considered

Losses in conductors are nearly exclusively variable losses, driven by utilisation. To reduce these losses, conductors with a lower resistance must be used e.g. using a copper conductor in place of aluminium or increasing the conductor cross-sectional area (as outlined in Section 3.1). This must be weighed up against the following practical factors:

- The capability of towers to support conductors with larger cross-sectional area, and therefore greater mass.
- The capability of existing buried cableways and trenches to accommodate conductors of larger cross-sectional area.
- Disruption caused by taking key OHL or cables out of service for a sustained period while upgrade works are completed.
- The implications for fault current levels likely to be experienced in the network.
- The costs of procuring and installing upgraded conductors.

In preparation for RIIO-ED1, we evaluated several investment decisions associated with underground cables and OHL, namely:

OHL

- Should we increase cross-sectional area of overhead line conductors at EHV /132kV to reduce network losses?
- Should we increase cross-sectional area of overhead line conductors at HV to reduce network losses?

Cables

- Should we increase cross-sectional area of underground cables at EHV or above to reduce network losses?
- Should we increase cross-sectional area of underground cables at HV or LV to reduce network losses?
- Should we increase cross-sectional area of LV service cables to reduce network losses?

Given the increases in network utilisation that are predicted in RIIO-ED2 to support the transition to Net Zero, we have considered these investment decisions again. Furthermore, given the volume of cables being replaced due to load growth, we have also investigated whether there is a case for proactive replacement of these assets with losses as the primary driver.

7.4.2 Uprating of OHL

7.4.2.1 EHV and 132kV OHL

In line with previous investment decisions, we believe at the higher voltages (132kV in SPM and 33kV in SPM & SPD) there is no clear and generalised cost benefit from upgrading overhead conductor sizes.

These network sections are generally efficient, with losses approximately 0.3% of energy served. Further, the higher loss sections tend to be supported by wooden poles, rather than metal towers, which would be incapable of supporting increased conductor mass (and increased cable tensions) required without reinforcement works.

In areas of interconnected network, any alteration in conductor size/impedance must be considered on a case-by-case basis. This is because the changes are likely to affect the balance of power flow across all interconnecting circuits in the group. The change in power-flows not only affects losses, but also can affect the capacity of the group. This analysis needs to consider the projected use of the network (including demand and generation growth) across the planning horizon to ensure that the network continues to be fit for purpose and as economically efficient as possible.

As a result, during RIIO-ED2, we shall continue our policy of case-by-case conductor sizing on higher voltage OHL specifically to reduce losses. It follows that there is no value in a programme of proactive replacement of higher voltage OHL.

7.4.2.2 HV OHL

In RIIO-ED1, we decided to uplift the minimum size of HV OHL in normal weather areas in line with the conductor size used in severe weather areas. The larger conductor size:

- Reduces network losses;
- Delivers enhanced network resilience in bad weather conditions;
- Enhances provision for load growth;
- Improves the ability to connect renewable generation in 11kV circuits.

Our construction policy for distribution OHL [14] specifies that for main and radial lines with more than 450 customers, 100mm^2 conductor must be used. The analysis in RIIO-ED1 that set this value was conducted using loading factors appropriate at the time. However, given the load growth projected in RIIO-ED2 and beyond, this criterion is being re-evaluated.

Increasing the conductor size of some circuits may not be cost effective or achievable due to planning and wayleave constraints associated with a heavier construction line (which typically requires additional stays and H pole structures). Line uprating must also be considered in the context of more significant network reconfigurations.

For HV main line new build and offline rebuilds throughout RIIO-ED2, we intend to increase our minimum size of OHL conductors. Analysis is ongoing to specify this size and develop appropriate guidance.

Uprating will only take place in conjunction with other works, i.e. there is no proposed programme of proactive replacement of HV OHL. The detailed programme of expenditure for HV OHL replacement can be found in Engineering Justification Papers **ED2-NLR(A)-SPEN-002-OHL-EJP** for condition-based modernisation and **ED2-LRE-SPEN-002-CV2-EJP** for load growth related reinforcement.

7.4.2.3 LV OHL

For LV, there is currently no minimum size of OHL conductor specified. Compared to HV, LV OHL tend to be shorter. This is reflected in the overall asset volumes: there are 8,400km of LV compared to over 26,000km of HV OHL conductor across SPEN as shown in Table 14.

Furthermore, these lines have typically low levels of utilisation, though this can vary. For these reasons, LV OHL generally lend themselves to case-by-case conductor sizing, and the losses present on any one line can vary quite significantly.

Proactive replacement LV OHL may be justifiable in some instances, but a strategic approach is difficult given the disparate lengths and loadings across LV OHL and the absence of utilisation information on specific LV conductors.

Table 14: HV and LV Conductor Volumes per Licence Area

Asset	Unit	SPD	SPM
HV Conductor	km	13,711	12,294
LV Conductor*	km	2,660	5,740

**Including LV Services OHL Length.*

In RIIO-ED2, we will use our growing volume of network data (see section 6.2.2) to develop better models of losses conductors, including at LV. This will then drive shortlists of highest-loss lines, and support cost benefit analysis into appropriate conductor sizing that can be better reflected in our policies.

7.4.3 Uprating of Underground Cables

7.4.3.1 EHV and 132kV Cables

At 132kV and 33kV, we found that there was no cost benefit associated with the proactive uprating of these cables. These network sections are generally efficient, with losses accounting for approximately 0.3% of energy served. Further, as higher voltage cables tend to be larger than lower voltage cables, the incremental costs associated with overrating are therefore higher. Our policy for RIIO-ED2 has not changed and our decision not to proactively replace EHV cables based on network losses will continue.

7.4.3.2 HV Mains Cables

We undertook detailed analysis to understand the potential value realisable through proactive replacement of HV underground circuits to reduce losses. This analysis considered various loading scenarios and the impact of using different cable cross sectional areas with our study considering the deployment of two cable sizes (185 mm^2 and 300 mm^2) at three load factors[14] (LF) (0.3, 0.5, 0.7). Annex Section A1.1.1 presents the outputs of the related CBA for HV circuits.

We found that proactive replacement of HV sections of network did not provide an economic benefit under any of the scenarios considered. Furthermore, the losses related benefits of cable upgrades do not appear to cover other ongoing costs such as depreciation (i.e. Net Present Value (NPV) reduces over time). Therefore, our continued policy is to not undertake proactive replacement of HV cables based on network losses as the primary driver.

Setting a minimum cable size for replacement where losses is not the primary driver

Our plans for load-related cable reinforcement in RIIO-ED2 include replacement of 82km of HV cable in SPD and 59km in SPM, as set out in Engineering Justification Paper **ED2-LRE-SPEN-002-CV2-EJP**. In addition, in RIIO-ED2 we plan to undertake additional condition-based replacement of 71km of HV cable in SPD and 48.5km in SPM, as set out in Engineering Justification Paper **ED2-NLR(A)-SPEN-002-UG-EJP**.

For reinforcement and modernisation activities, all reasonable steps are already undertaken to minimise losses including economically justified conductor sizing. However, given the anticipated load growth and step change

[14] Load factor is the ratio of average power throughput to capacity of the cable being considered.

in secondary reinforcement required from RIIO-ED1 to RIIO-ED2 (as demonstrated in the EJP) we have investigated whether a minimum cable size for replacement activities should be formalised in our policies.

Our analysis (Appendix 1 Section A1.1.1) shows that for all cables with a load factor of 0.7 then given a choice between upgrading with 185 mm^2 and 300 mm^2 conductor, the 300 mm^2 conductor has a higher NPV. This outcome is more likely to be relevant to volumes in the RIIO-ED2 load plan; however, given the expected increase in network utilisation, future loading should be considered for all cable replacement.

For HV mains cable replacement throughout RIIO-ED2, we intend to set minimum size(s) of conductors. Analysis is ongoing to specify this size and develop appropriate guidance.

We have estimated the losses benefits over RIIO-ED2 for all cable replacements if we were to set minimum conductor sizes of 185 mm^2 for cables with a lower future capacity requirement (present LF of 0.3-0.5) and 300 mm^2 for cables with higher future capacity requirement (present LF of 0.5-0.7). The results are shown in Table 15.

Table 15: RIIO-ED2 HV Cable Replacement Losses Savings

	Replacement driver	Volume (km)	Losses Reduction over ED2 period	
			GWh	tCO_{2e}
SPD	Condition-based	65.0	2.61	531
	Reinforcement	82.2	8.17	1,662
SPM	Condition-based	50.0	2.01	408
	Reinforcement	59.5	5.90	1,199
Total		**256.8**	**18.7**	**3,800**

7.4.3.3 LV Mains Cables

Annex Section A1.1.2 presents the results of our CBA carried out to understand the potential value realisable through proactive replacement of LV circuits. Our analysis shows that LF was a key parameter impacting the potential economic benefits and that as LF increases, the economic case supporting proactive intervention does become positive. The analysis shows that when operating with an average to high load factor (LF in the range 0.5 to 0.7 in this case), proactive replacement of loss-heavy sections may be beneficial due to the typically higher operating currents (and hence losses).

Using our developing network models, including the Engineering Net Zero model (see Section 6.4.1), we will develop our understanding of losses on LV cables, which will enable us to optimise cable selection. This will be supported by additional domestic smart meter and network metering data becomes more available (see section 6.2.2). Therefore, whilst it is not currently our policy to proactively upgrade LV circuits, this CBA combined with better understanding of our network loading, and losses, through enhanced data gathering and analysis may drive future proactive upgrades.

Setting a minimum cable size for replacement where losses is not the primary driver

It is also noted that many of the most heavily loaded (and therefore likely the most lossy) cables on our network may exceed capacity throughout RIIO-ED2, and hence are already planned for upgrade as part of our load plan.

Our plans for load-related cable reinforcement in RIIO-ED2 include replacement of 259 km of LV cable in SPD and 147 km in SPM, as set out in Engineering Justification Paper **ED2-LRE-SPEN-002-CV2-EJP**. In addition, in ED2 we plan to undertake additional condition-based replacement of 94.2 km of LV cable in SPD and 100.6 km in SPM, as set out in Engineering Justification Paper **ED2-NLR(A)-SPEN-003-UG-EJP**.

As above, conductor sizes will be selected using a losses-inclusive approach. Following a 2019 update, our design framework for planning new underground networks [15] specifies a minimum conductor size of 185 mm^2 for radial feeders and a minimum size of 300 mm^2 for interconnected feeders. From this, it can be deduced that where LV Mains are overlaid, radial feeders will be modernised with 185 mm^2 cabling as a minimum standard, and interconnected / inter-connectable mains replaced with 300 mm^2.

Our analysis suggests that many of the LV cable reinforcements with a current load factor of above 0.3 would be efficiently sized to at least 300mm^2 to meet capacity need and realise loss reduction benefits over a 45-year asset lifecycle. Therefore, we have estimated the losses benefits over RIIO-ED2 from setting a minimum conductor size of 300 mm^2 for all RIIO-ED2 cable replacements, the results of which are shown in Table 16.

Table 16: RIIO-ED2 LV Cable Replacement Losses Savings – estimate based on 300 mm^2 Minimum Conductor Size

	Replacement driver	Volume (km)	Losses Reduction over ED2 period	
			GWh	tCO_{2e}
SPD	Condition-based	94.2	12.59	2,560
	Reinforcement	258.8	63.52	12,920
SPM	Condition-based	100.6	13.44	2,734
	Reinforcement	147.1	36.09	7,342
Total		**600.7**	**125.6**	**25,556**

For cable overlay, the selection of conductor needs to be balanced against other operational considerations such as ability to install the larger conductor and network issues such as increased fault level. Furthermore, given the expected increase in network utilisation, cable losses across the whole network are likely to increase in future periods, which further influences our analysis.

We will seek to increase the minimum size of LV cables in RIIO-ED2 for new build and replacement scenarios to a minimum of 300mm^2 cross-sectional area. We will continue modelling to optimise cable size on a case-by-case scenario and refine our policies.

7.4.3.4 LV Service Cables

Service cables are used to provide a 230 V single-phase supply or 400 V 3-phase supply from the 400 V 3-phase LV mains cables in the local network. Typically, this is achieved using a 25 mm^2 or 35 mm^2 aluminium conductor, with voltage drop and thermal loading considered when selecting conductor size. In RIIO-ED2 we will use a minimum of 35mm^2 service cables, providing additional capacity and reducing variable technical losses.

Our 2020 LDR Tranche 3 submission presented a case study where the losses in service cables were considered using estimated smart meter data combined with Geographic Information System (GIS) data. It was estimated that the worst performing service cables would have losses of 310 kWh / year, representing a capitalised value of £420. The conclusion of this study was that where higher loading, due to uptakes of LCT, is foreseen; it is economically beneficial to utilise higher-rated service cables. This outcome has shaped our policy for providing new service cables for new-build premises.

The use of *real* smart meter data, instead of estimated data, will improve our ability to prioritise proactive upgrades of service cables. This forms part our LDR Initiative 2 covering *Smart Meter Data to Reduce Technical Losses.*

In RIIO-ED2, our interventions will concentrate on looped services cables – where the service cable is shared across multiple properties. We have 561,130 customers supplied from looped service cables. At the time of

installation, a single service cable had sufficient capacity to supply two or more properties without risk of overloading. As we transition to electric heating, heat pumps, and EVs, domestic electrical demand could increase threefold. Consequently, feeding multiple properties from a single looped service cable is not a feasible long-term option.

During RIIO-ED2, we shall proactively replace over 43,000 looped service cables with dedicated single property cables. The incremental cost of installing a three-phase service at the time of installation is small in comparison to the cost of future upgrade, and so our proposed intervention is the proactive unlooping of services by providing new three-phase supplies where practicable. This future-proofs the installation and avoids the need to upgrade upon installation of a second LCT. Three-phase services have additional advantages of reducing the disruption and cost associated with future balancing of load across phases, as well as potentially reducing losses and power quality impacts associated with large LCT demands.

We will consider the necessary increase in service-cable rating. Losses will be considered hand-in-hand when determining the appropriate sizes of the new services. Our plans for service cable reinforcement are set out in Engineering Justification Paper **ED2-LRE-SPEN-001-CV2-EJP** and discussed further in Annex 4A.22: Our LV Service Cable and Cut-Out Strategy.

7.5 LV Mains Fuses

LV fuses failures in interconnected networks have the potential to increase technical losses. Where power is normally conveyed across multiple *paths*, current flow is divided between the paths. When an LV fuse failure occurs, one (or more) of these paths becomes unavailable and current flow on the remaining paths is increased.

In a simple case where current is divided equally between two conductors: each conveys 0.5 per-unit (pu) of the total current. If the resistance of each conductor is 1 pu, the total losses on each conductor, in accordance with I^2R, is 0.25 pu; thus, the aggregated loss is 0.5 pu. If all current is now conveyed along a single conductor, I is now 1 pu with R remaining at 1 pu, as before. Thus, the losses are now 1 pu: double the previous magnitude.

Reconfiguration of power-flows does not always result in disruptions to customer supplies. Consequently, in a network with low levels of metering, it may not be immediately obvious that a fuse has failed. Therefore, additional losses may continue unchecked for a substantial period.

We have developed algorithms to use voltage drop detection as an early warning of LV fuse failures; and we are building these into the NAVI toolset for operational deployment in combination with our increase LV monitoring visibility.

7.6 Voltage Uprating

In SPM and SPD, majority of the HV network is operated at 11kV voltage level, with few patches of the network operated at non-standard 6.6kV voltage level. These non-standard voltage networks can result in constrained system capacity and increased system losses.

In RIIO-ED1, we made the decision to rationalise voltage in legacy areas of HV distribution still at 6.6kV to 11kV. This programme of work will continue in RIIO-ED2.

The primary driver for the schemes is to increase thermal and fault level headroom. However, the decision has also been partially justified by losses. Theoretically, variable losses are typically 2.78 times higher in the 6.6kV network compared to the 11kV network, due to higher current flows.

Additionally, 6.6kV has become a non-standard voltage across the industry. Therefore, fault repairs and spare parts for existing assets have become harder to source. This will likely get worse, going forward. A few of the

6.6kV primary substations operate with legacy switchgear and do not have telecontrol for remote switching operations, requiring manual switching during outages/abnormal conditions on the network does not provide the operational flexibility.

Justified by this comprehensive needs-case, in RIIO-ED2 we plan to uprate three islands of 6.6kV operation in SPD and five in SPM. The resultant losses savings are estimated as shown in Table 17. This is the benefit realised incrementally over ED2 compared to baseline/alternative investment option.

Table 17: Losses from Uprating of 6.6kV Islands to 11kV in RIIO-ED2

	Islands Uprated	Losses Reduction over ED2 period	
		GWh	tCO_{2e}
SPD	3[15]	6.0	1,578
SPM	5	11.0	2,613.8
Total	**8**	**17.0**	**4,192.1**

Full details of the uprating schemes can be found in Engineering Justification Papers **ED2-LRE-SPM-008-CV3-EJP** for SPM and **ED2-LRE-SPD-026-CV1-EJP** for SPD.

7.7 Voltage Optimisation

During RIIO-ED1, we were involved in two projects relating to voltage control and optimisation:

- As part of a Tier 2 Low Carbon Networks Fund (LCNF) project, we examined the voltage dependency of load and the opportunities presented to optimise voltage set-points at primary substation in relation to demand and loss management.
- Initially, this was focussed on rural networks where circuit lengths are longer, voltage drops are greater, and losses potentially higher than urban networks.
- We pursued a study examining voltage control philosophies and the supporting technologies required at grid and primary substations.
- This focussed initially on rural networks; due to higher losses and higher voltage drops across longer circuit lengths.

The permitted range of domestic supply voltages in the UK is 230 V -6%, +10%. Thus, the supply voltage may fall within 0.94 *per-unit* (pu) and 1.1 pu, and still be within tolerance.

In the case of **a simple resistive heating element**, its power draw can be calculated by V^2/R. The power consumed by this heater therefore varies between 0.8836 pu and 1.21 pu depending on the voltage level (all within the statutory limits), as shown in Figure 15. Consequently, electrical equipment can be draw excessive power and increase losses.

However, in reality this is much more complicated as “the kettle will take longer to boil” and for capacitive and inductive loads (increasingly common due to propensity of power electronics, motors, inverters and chargers) power consumption and losses may actually increase inversely as voltage is reduced.

[15] For SPD, there is no viable option not to uprate. For SPM, there is a viable option not to uprate and so the losses savings have factored into the optioneering process.

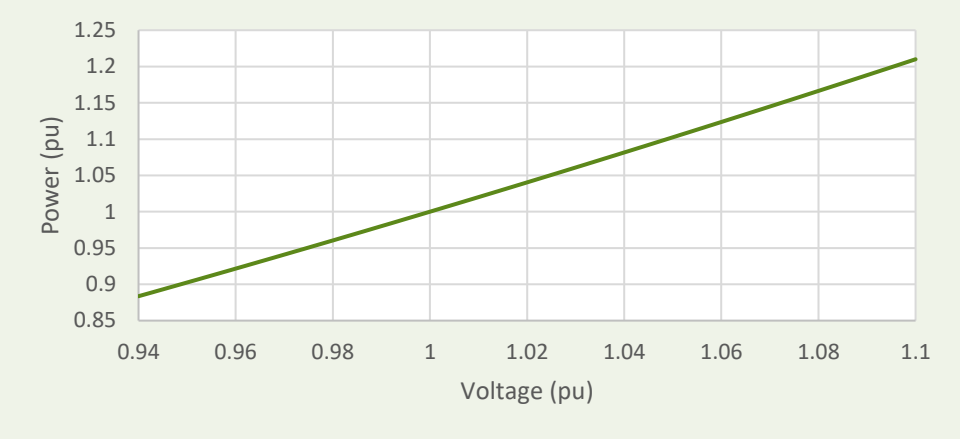


Figure 15: Power Consumption by Voltage Level

While there are undoubted benefits associated with the LV voltage optimisation, there are also significant challenges. Some of the primary obstacles to effective implementation include:

- National Grid, as the Electricity System Operator (ESO), has the power to administer demand reduction measures if active power levels are insufficient to meet demand, through Operating Code No. 6 (OC6). There are scenarios where each network operator must inform the ESO if they plan to reduce network voltages below statutory limits[16] [16]. If the voltage limits change, it is possible that OC6 will have to be updated to allow *national network operation* to take precedence over *local network* ethos.
- All electrical equipment is designed to operate within a range of voltages. When the voltage is outside of this range, it is possible for serious or catastrophic damage to occur. Under-voltage protection automatically detects voltage lower than a defined threshold and breaks the supply during this scenario.
- Depending on the cut-off threshold at which equipment is set, protection systems may have to be reconfigured to allow the newly reduced voltage limit to be accommodated.

As discussed earlier, increased data availability offers significant value to electricity network operators. Domestic smart metering and metering at secondary transformers both allow scope for real-time accurate and widespread voltage measurement, which could be utilised to inform and enact voltage optimisation actions.

Through the CIRED 2017 conference, we formed a bilateral partnership with Japan's Tokyo Electric Power Company (TEPCO) and held a bilateral workshop on losses in November 2017. TEPCO reported on a demonstration project of voltage optimisation to reduce losses, the *Central Voltage Control System*. The principal finding of their work has pointed towards the need for better smart meter data to allow network losses and capacity to be reported in quasi-real time.

Within RIIO-ED2, we intend to deploy 320 AVC on our networks, broken down as:

- 68 units on 11kV side of primary transformers on SPD network.
- 195 units on 11kV side of primary transformers on the SPM network.
- 57 units on the 33kV side of grid transformers on the SPM network.

AVCs provide a mechanism to achieve voltage optimisation. We will continue to review the use of this equipment, in conjunction with the greater visibility of our LV network, to understand how it can be best used to minimise losses whilst delivering on our other obligations. Our detailed plans for Enhanced Voltage Control are set out in Engineering Justification Paper **ED2-LRE-SPEN-001-CV1-EJP**.

[16] National Grid ESO - Operating Code No. 6 - Demand Control, 2021.

8 Processes to Manage Non-Technical Losses

8.1 Overview

In line with Ofgem expectations, we make all reasonable endeavours to reduce the volume of non-technical losses on our networks. Our approach in RIIO-ED1 to identify and stop theft are industry leading and we will continue these activities in RIIO-ED2. During RIIO-ED2 we shall spend £6.3m[17] on proactive revenue protection activities and related customer and stakeholder engagement (more on this in Section 10) to meet our objectives:

- **Reduce and deter theft anywhere in the electricity supply chain.**
- **Improve accuracy of the record of unmetered supplies.**
- **Improve accuracy of the metering of energy supplied (Conveyance).**

This section provides an overview of these actions. A summary of our initiatives to reduce non-technical losses over both RIIO-ED1 and RIIO-ED2 is presented in Table 18.

Table 18: Non-Technical Losses Reduction Initiatives Summary

Initiative	Overview	Outcomes
Theft and Revenue Protection (Section 8.2)	Continued inspections for meter tampering during installation of smart meters.	Forecast losses savings in ED2: 74.4 GWh in SPD and 85.9 GWh in SPM.
	HV/LV monitoring to be deployed at over 14,000 more secondary substation locations across SPD and SPM. These will gather data to feed and help refine our cutting-edge algorithms developed in ED1 – see Section 8.3.	
	Continue use of Theft Propensity Model to shape substation monitoring strategy.	
LV Network monitoring (Section 8.3)	The roll-out of HV/LV monitoring to over 14,000 more secondary substation locations across SPD and SPM will improve our ability to detect technical losses.	Forecast losses savings in ED2: 36.8 GWh across SPEN.
Unmetered Supplies (Section 8.4)	Auditing of unmetered connections, to better understand consumer types.	Better understanding and therefore management of non-technical losses through unmetered supply inaccuracies.
	Enforcement of policy to resolve inconsistencies between load registers and observed consumption.	
	Use of the MAAV to provide early identification of faults (and associated non-technical losses) with equipment connected to the network.	
Theft in Conveyance (Section 8.5)	Data sharing with suppliers & metering providers to improve settlement data quality.	Forecast losses savings in ED2: 7.1 GWh in SPD and 15.8 GWh in SPM.
	Best practice sharing with our partner DNOs.	

[17] Reported in CV39, under Directly Remunerated Services 5

8.2 Theft and Revenue Protection

Revenue Protection refers to the prevention, detection and recovery of losses caused by interference with electricity supplies. Our Revenue Protection team continue to offer us an improved understanding of how and where electricity theft is occurring.

We have developed the Theft Propensity Model and we are continuing to engage stakeholders in its evolution. This model drives the actions we take in preventing theft. It implements multi-factorial pattern detection algorithms to identify suspicious profiles within consumption data, which allows us to determine which properties worthy of investigation for potential theft.

During RIIO-ED1 we have engaged with other smart suppliers, including British Gas and Utilita to share best practice and establish suitable alerts, which merit further investigations. Through our parent company, Iberdrola, we have access to advanced non-technical loss detection algorithms, which allow energy balancing (difference between power or energy at the secondary transformer compared to the total metered data at the point of load) to be calculated.

Through this work in RIIO-ED1, the model is now delivering better quality leads to suppliers. In RIIO-ED2, the roll out of smart meters will improve the accuracy of our theft identification yet further, allowing us to make better use of the data analytics capability we have learnt from our parent company. This will improve the efficiency and outcomes of our revenue protection inspection visits to properties. Smart meter data may also necessitate change in our practices. Consequently, we will continually evaluate our policies during the roll-out and amend where appropriate.

In our business plan, we have made estimates of the future activity level and resultant losses savings by projecting average RIIO-ED1 values. The ongoing Covid-19 pandemic has restricted our non-essential access to properties in the short term, but our forecasts assume a return to at least current levels of activity before RIIO-ED2. The forecasts are shown in Table 19.

Table 19: RIIO-ED2 Losses Savings as a Result of Revenue Protection Inspections

	Volume of inspections	Losses Reduction over ED2 period	
		GWh	tCO_{2e}
SPD	85,196	74.4	15,763
SPM	47,795	85.9	18,186
Total	**132,991**	**160.3**	**33,950**

8.3 LV Network monitoring

Network monitors provide visibility of the network. The data they deliver helps us efficiently and safely plan, develop, and operate the network to meet our customers' needs. For this reason, our network has extensive monitoring at the HV and EHV voltage levels. However, there is very little monitoring on the LV network as there hasn't historically been a need.

The transition to Net Zero means that LV customer power flows will increase, and the rise of LV customers actively engaging with markets means that power flows will become much more dynamic. We also expect a surge in notifications, connection applications, and customer enquiries to connect low carbon technologies.

These changes are going to require significant investment in network capacity. Without the data and visibility that LV network monitors deliver, this investment would be less efficient and less timely, leading to higher costs and a poorer service for our customers.

Given this, we need to increase LV monitoring over RIIO-ED2. By the end of RIIO-ED1 less than 8% of our 31,808 HV/LV substations (≥200kVA) will have monitoring. During RIIO-ED2 we will deploy monitoring at an additional 14,102 of these substations to increase this coverage to 52%, covering 76% of customers. LV network monitors are complimentary to the increasing penetration of smart meters, and customers get the greatest benefit when these two data sources are combined. For more information please see Annex 4A.21: Network Visibility Strategy.

By combining the LV monitoring data and smart metering data, we will have unprecedented insight into losses on these areas of the network. Once we have developed data and business processes, they will enable us to determine the location and volume of losses in these areas of the network. We estimate this will lead to up to a 50% reduction in non-technical losses within a three-year period using smart meter data.

To calculate the losses savings over RIIO-ED2, we have applied this to the forecast levels of non-technical losses, accounting for the increasing coverage of LV monitoring each year. The estimated losses reduction achieved is detailed in Table 20. In addition, there will be an unquantified benefit to mitigating technical losses, as increased visibility of the electricity entering and exiting the LV system will help us to make better-informed asset-based interventions to reduce technical losses.

The benefits are captured in the Digitalisation Cost Benefit Analysis: **ED2-CAP-SPEN-001-DIG-CBA**.

Table 20: RIIO-ED2 Losses Savings as a Result of Increased LV Network Monitoring

	Losses Reduction over ED2 period	
	GWh	tCO_{2e}
Total	**36.8**	**3,718**

8.4 Unmetered Connections

Unmetered connections often perform *societal work,* as discussed in Section 3.2. Examples include streetlights, traffic lights, road signs, and network infrastructure such as substation lighting and heating. However, they can cause additional losses through discrepancies between estimated consumption and actual consumption.

At present, the load magnitude of unmetered supplies is estimated. This process involves establishing records for each unmetered supply and applying a representative profile to estimate consumption. When there is a discrepancy between the estimated usage and the actual usage, losses occur[18]. These losses, as with all other technical and non-technical losses, are ultimately borne by the consumers.

Throughout RIIO-ED1 we have audited customers with unmetered supplies, so that we can develop a better understanding of their demands. Further, we are also actively identifying customers who fail to maintain accurate load information and are considering reasonable and economic steps to resolve these inconsistencies. Steps to refine and embed processes to tackle unregistered Meter Point Administration Numbers (MPAN) and confirm inventories for unmetered connections are BaU in RIIO-ED1 and will be continued throughout RIIO-ED2.

We are also proposing to begin surveying for contact voltages using the MAAV technology (see Section 9.2) which will provide significantly more information on the presence of non-technical losses caused by faults in unmetered equipment connected to our network.

In line with our Losses Vision, all actions must be proportionate, and we will first target the largest customers which typically include councils and local authorities.

[18] It is possible for the actual consumption to be less than the estimated consumption. In this case, negative losses occur. The typical case is for under-recording of unmetered energy consumption.

These actions will:

- Improve the accuracy and equitability of the settlement process.
- Improve our understanding of non-technical losses attributable to unmetered supplies.

The use of combined smart meter and enhanced network monitoring, such as secondary transformer monitoring, will assist our efforts to understanding the magnitude and nature of unmetered supplies (see Section 6.4).

8.5 Theft in Conveyance

Situations arise where energy is delivered and consumed but is not accurately recorded in the electricity settlement system and therefore becomes lost energy. These non-technical losses are often regarded as 'Theft in Conveyance', although they do relate to both intentional and unintentional acts. The main causes of these types of losses are:

- Missing and unregistered metering points.
- Incorrect recording of the energisation status for metering points.
- Incorrect registration of metering system information.

Mitigating or reducing conveyancing errors can be improved through better identification and understanding, and hence many of our actions are common to identifying illegal abstraction as follows:

- Increased smart meter and network metering data, allowing discrepancies to be identified more easily than before (as per Section 8.3).
- Continued work with energy suppliers and providers of metering services to improve settlement data quality and metering point registration accuracy. In line with the Revenue Protection Code of Practice, we receive monthly reports from all suppliers detailing all detected instances of theft in conveyance.
- Continue to proactively monitor the number (and check the status) of metering points registered as disconnected and de-energised by suppliers.
- Sharing information with the other UK DNOs through the TLWG as to how and where inaccuracies have occurred, and what steps can be implemented to prevent such inaccuracies. We will record instances we discover and detail how they may have happened to inform policy development and prevent recurrence of common mistakes. This will be shared through the TLWG group.

During RIIO-ED2, we do not envisage any significant changes in our policies to tackle theft in conveyance from our RIIO-ED1 measures, beyond the use of smart metering and LV monitoring data as discussed in our transactional theft section. In our business plan, we have therefore made estimates of the future activity level and resultant losses savings by projecting average RIIO-ED1 values. The forecasts are shown in Table 21.

Table 21: RIIO-ED2 Losses Savings as a Result of Theft in Conveyance Investigations

	Volume of investigations	Losses Reduction over ED2 period	
		GWh	tCO_{2e}
SPD	133	7.1	1,503
SPM	131	15.8	3,339
Total	**264**	22.9	4,842

9 Losses Innovation

9.1 Overview

We have demonstrated our commitment to loss reduction during RIIO-ED1 through a number of initiatives. We shall continue to apply successful innovation through our Consumer Value Proposition (CVP) during RIIO-ED2. Throughout this strategy, we have detailed the challenges for DNOs going forward and the inevitable losses rises that will occur due to increased EV, DG and electric heating usage. The drivers for these losses fall outside of our control, are necessary to achieve *Net Zero* carbon emissions, and present many challenges to us as a DNO to limit losses on our systems.

Table 22: Overview of Innovation Activities to Reduce Network Losses

Activity	Overview	Outcomes
Mobile Asset Assessment Vehicle (MAAV) (Section 9.2)	Propose MAAV technology through CVP. This will detect electric fields emitted by network faults, and hence we will discover and remove corresponding network (and customer) losses.	Forecast network losses savings in ED2: 85.5 GWh.
DC Distribution (Section 9.3)	Controllable, bidirectional DC 33kV link in the flagship Angle-DC project, and development of secondary Smart Transformers (STs) which provide LCTs with a DC supply directly through flagship LV Engine project. Wider exploration of DC in LV networks ongoing in smaller innovation projects.	Losses reductions across the Anglesey and North Wales link. Future losses savings through ST technology roll-out and future LV DC innovations.
Active Network Configuration (Section 9.4)	We have highlighted opportunities to implement the switching in/out of transformers. We must now complete the business case by weighing this against the additional costs, with an intent to trial this if positive NPV is realised.	Detailed CBA and possible trial, realising losses savings as high as 64.3% of transformer losses at present.
Data Processes (Section 9.5)	Continue to improve our ability to automatically detect statistical outliers in the consumption data.	Improved efficiency of targeted investigations and inspections.

9.2 Mobile Asset Assessment Vehicle

As part of our overall strategy to reduce losses, improve customer performance and enhance the safety of our network, we propose to employ a purpose-built vehicle called the MAAV – or Mobile Asset Assessment Vehicle – that detects electromagnetic fields and identifies exposed voltages (called 'Contact Voltages') that can occur on exposed surfaces due to faults in electrical equipment. This vehicle can be driven around our licence areas, providing early identification of faults. This leads to a wide range of benefits including:

- Financial benefits to our customers (through significant volumes of avoided network and customer losses discovered by the MAAV)
- Environmental benefits (through the avoided carbon cost of these losses)
- Better reliability of our system (through reduced customer interruptions and customer minutes lost due to early identification of faults, allowing for less disruption at the point of repair)
- Safety benefits to everyone in the areas concerned (through avoided fatal and non-fatal injuries caused by exposure to live voltages discovered by the MAAV – very low probability but severe incidents)

Evidence suggests that Contact Voltages occur most commonly in third party equipment such as lamp posts, though they can also occur as a result of faults in underground cables. They can even occur at the customer-end of a metered supply. The MAAV therefore has highest value in urban areas where there is a high density of street furniture and also a high footfall. We therefore propose to deploy the MAAV predominantly in the following areas of our network: Liverpool, Glasgow, Edinburgh, Birkenhead. We propose to reach out to neighbouring DNOs who may wish to survey their highest density urban areas 'on route', to ensure that maximum value is achieved from the vehicle to all GB customers.

In RIIO-ED1, we have trialled the Mobile Asset Assessment Vehicle (MAAV) system in the SPM area. This allows for the detection of electric fields emitted by network faults, and hence losses, caused by live contact voltages. A 40-mile trial survey in Liverpool identified 27 issues deemed serious enough to warrant further investigation. Four of these were recommended for immediate investigation – of these, one posed a possible public safety concern, one was expected to be causing significant losses on an unmetered supply, and one was found the customer-side of the meter – potentially costing the customer through wasted energy. We also found that 50% of the issues were associated with network equipment, and 50% were associate with third-party equipment connected to it.

We have estimate the size (and therefore value) of the societal benefits using data on the types and causes of contact voltages found by an early UKPN trial – shown in Table 23, making assumptions about the expected number of contact voltage that would be discovered each year based on UKPN and international findings. Both the data and the assumptions made correspond to the investigations in our Liverpool trial. The resultant losses benefit is shown in Table 24.

Table 23: Contact Voltage Types

CV type	#	%	Average Annual Network Losses (MWh)
Customer-side, phase	8	12.9%	1.21
Cable, neutral	10	16.1%	Negligible
Cable, phase	9	14.5%	49.26
Lighting column, neutral	24	38.7%	Negligible
Lighting column, phase	11	17.7%	41.87

Table 24: Network Losses Savings as a Result of Contact Voltage Discovery and Repair[19]

Miles surveyed (annually)	Losses Reduction over ED2 period		Losses Reduction over 7-year lifecycle	
	GWh	tCO_{2e}	GWh	tCO_{2e}
7,000	85.5	18,169	108.7	22,483

We currently do not have the means to test for Contact Voltages caused by our network or by the equipment connected to it. Indications are that the MAAV is currently the only certified solution available to UK utilities. Following reports from UKPN's use of the MAAV, and supported by our own trial in Liverpool City Centre, we are confident that the MAAV is a reliable and proven technology for identification of Contact Voltages, and the evidence suggests early detection and removal of the responsible faults offers good customer benefit.

However, many of the issues it identifies are not a result of faults with our own equipment. Furthermore, the benefits case is almost entirely based on a societal return on investment only.

[19] This does not include the carbon costs of shipping and running the vehicle. These are small in comparison but are factored into our investment decision.

Due to unique resources and proven expertise in resolving LV faults, we believe we are the best agency to own and operate the MAAV technology. This means that we will need to set up new business processes and communication channels to ensure third parties are aware of Contact Voltages and ultimately the presence of faults discovered on their equipment. We may need to provide additional support and information to our customers to enable them to complete the necessary repairs.

In RIIO-ED2, therefore, we are proposing a Consumer Value Proposition (CVP) to cover the forecasted costs of £10.1m over RIIO-ED2. We believe that, as the cost-benefit case is so heavily dominated by the societal return on investment, including the MAAV as a CVP will drive ambition in our losses strategy. See Annex 5C.2 on our CVPs for the details of this proposal.

9.3 DC Distribution

Conventionally, electricity networks provide an alternating current (AC) supply. However, many LCTs operate on a direct current (DC) voltage, which requires conversion from AC. It may be more efficient, in some cases, to consider DC distribution for the purposes of supplying LCTs. Furthermore, carrying power at a higher voltage reduces the current, which may allow additional capacity out of existing circuits. We have two flagship projects exploring DC technologies – Angle DC at the primary distribution voltage level, and LV Engine at the secondary voltage level.

Not only will our DC projects need to carefully consider the impact on network losses, but these projects may in fact have some losses benefit compared to the baseline. There is a lot still to learn and explore when it comes to DC distribution, but we are leading innovating in this area.

9.3.1 LV Engine

The LV Engine innovation project[20] intends to trial Smart Transformers (ST) within secondary substations as the central point of an active and intelligent 11kV and LV distribution network. The ST trialled during the project will bring together sophisticated power electronic hardware with intelligent network monitoring and control to maximise the performance and efficiency of the distribution network.

A Smart Transformer consists of a Solid-State Transformer (SST) and a Smart Control System (SCS). SST uses power electronic technologies to deliver several functions. SCS provides the control set points to SST based on data gathered and analysed from different monitored points in the network.

LV Engine aims to demonstrate the following core functions can be delivered by deploying SST at secondary substations:

- **Voltage regulation at LV Networks:** Using the LV feeder profile it can be optimised with real-time adjustments to the phase voltage at the secondary substation from monitoring voltage at varying lengths along the LV feeders. As discussed in Section 7.7, this can be used to optimise losses.
- **Capacity sharing with other substations:** With the use of power electronics ST can control power flow and share load among transformers to manage any thermal or network constraints. A more evenly distributed utilisation minimises the increase in losses.
- **Cancellation of LV imbalance load seen by the HV network:** Independent regulation of the LV and HV terminals means voltages on the HV network can be regulated. As above, a more evenly distributed utilisation reduces losses.
- **Reactive power compensation and power factor correction at secondary substations**: this is useful to improve the voltage profile and reduce losses.

[20] https://www.spenergynetworks.co.uk/pages/lv_engine.aspx

- **Provision of LV DC to supply rapid and ultra-rapid EV chargers:** Allowing EV chargers to access DC supply directly from the secondary substation avoids repeated rectification of AC to DC, allowing the quick connection of EV chargers to the network without additional reinforcement. The introduction of new power electronics onto the system introduces a new source of losses, and therefore improving the efficiency of the SST is a project priority, with recent advances to the SST controller design have increased predicted efficiency from 97% to 99% demonstrated in the last project report. In fact, the avoidance of repeated rectification stages may result in a holistic losses benefit. This is being carefully considered by the project as it develops the future use cases of LV supplies.

We forecast that STs will be deployed on the network at 1,700 potential ground mounted substations by 2035[21]. As the project is still in a developmental stage the holistic benefits are still being assessed, with particular interest in the loss reduction that can be achieved.

9.3.2 Angle DC

Our Network Innovation Competition project Angle DC[22] is deploying a controllable bidirectional Medium Voltage Direct Current (MVDC) link between two sections of our network, Isle of Anglesey, and North Wales. This is achieved through converting existing 33kV Alternating Current (AC) assets to DC.

The conversion to DC and the enhanced controllability offered by the associated power electronic converters offers several benefits. These include increased power flow capacity through existing circuits and the ability to offer ancillary services. Specifically related to losses, the Angle DC solution enables a reduction in operating losses in the wider distribution network due to improved voltage control. It is approximated that this will lead to a 20% reduction in losses in North Wales and Anglesey area, equating to a reduction in 13,030MWhr per annum, compared to a traditional reinforcement approach.

The upgrade of the connection between Anglesey and North Wales provides additional headroom (in the order of a 15% increase in capacity [18] for the connection of distributed generation. Encouraging the connection of low carbon generation has the effect of both reducing whole system transmission losses and supporting decarbonisation of the electricity network. It is approximated that the ANGLE-DC solution can be used to transport up to 45.4GWh of renewable generation across the link annually.

9.3.3 Additional Activities

We are also combining the learning from the above two flagship innovation projects (Angle-DC and LV Engine) to look at the conversion of LV mains to DC. The primary driver for this innovation is that in principle, this would allow LV mains to be converted to DC at a higher distribution voltage and therefore increase the maximum load capacity. Whilst generally a higher cable utilisation leads to higher losses, through distribution at a higher voltage level (and therefore possibly reduced current) this solution may reduce losses compared to traditional AC network solutions given the same level of utilisation.

We are currently assessing the feasibility (and efficiency) of inversion to AC at the point of demand (i.e. at the service end). However, ultimately losses will be evaluated holistically, including both cable losses and the power electronic losses from converting to DC and inverting back to AC, and the costs (or benefits) of any distribution losses will be factored into any future design decisions.

9.4 Active Network Configuration

One way to reduce the fixed losses on the network is to switch assets off if they are not required, e.g. where there are parallel or reserve assets on standby. This does affect the security of supply, and therefore the holistic benefit of such procedures must be carefully considered. However, developments in network

[21] LV ENGINE Smart Transformer Technical Specifications
[22] https://www.spenergynetworks.co.uk/pages/angle_dc.aspx

management and control systems in RIIO-ED2 and beyond will facilitate active network configuration, which will alleviate some of the current concerns about security of supply.

We have actively investigated the implementation of the Transformer Auto Start Stop (TASS) method on our networks. This is a scheme first trialled by Scottish and Southern Electricity Networks (SSEN) on their licence area as part of their Low Energy Automated Networks (LEAN) LCNF Tier 2 project. The basis of TASS is technically simple: a number of primary substations have parallel 33:11kV transformers and it may be more efficient to operate using only a single transformer under certain circumstances. If we consider a simple example where:

- Variable resistance of transformers is 1.0 pu.
- Fixed losses of transformers is 0.25 pu.

In this case, the relationship between current flow and total losses for single and parallel transformers is as shown in Figure 16. In this example, if the current is less than 70.7% of the maximum **single** transformer current then it is more efficient to operate only one transformer.

If the current is greater than 70.7% of the maximum **single** transformer current then it is more efficient to operate using parallel transformers. If the current exceeds 100% of the maximum single transformer current then both units need to be operated simultaneously.

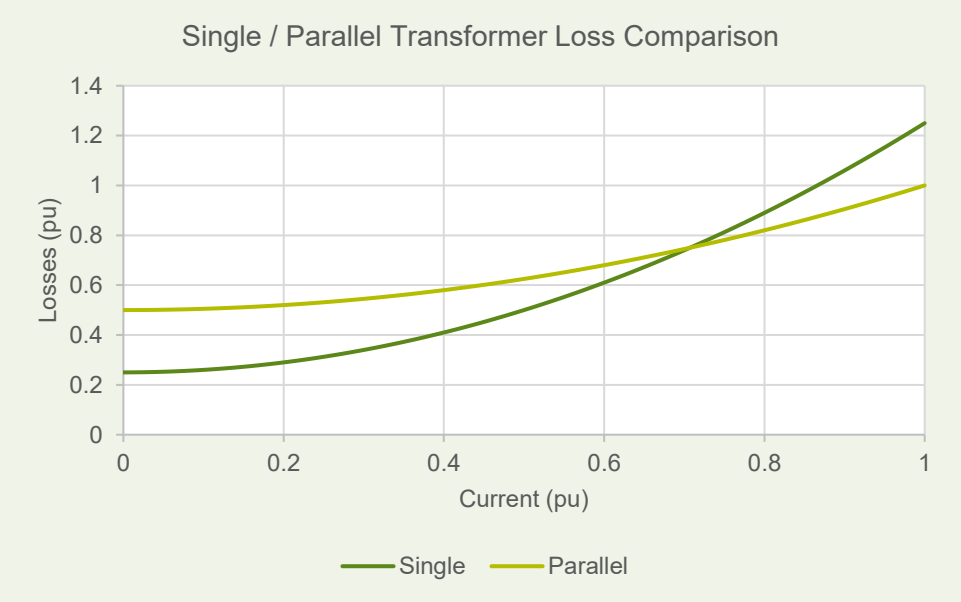


Figure 16: Single / Parallel Transformers Losses Comparison

Given that load demand will change throughout the day, it is advantageous to be able to switch between single and parallel transformers quickly and remotely. TASS offers this functionality. We have conducted assessments on deploying TASS at some of our high-loss primary transformer sites, such as Burghlee, where encouraging results have been produced.

Table 25 details the losses achievable if TASS functionality is implemented at a range of primary transformer sites. Losses are calculated for both retaining 1950s inefficient transformers and replacing these units with modern Eco-design Tier 2 units.

The value of the benefit must be weighed up against the cost of any additional asset degradation that may occur through frequent switching. This includes the additional wear and tear on the Circuit Breakers (CBs), which would have to operate more frequently, and the wear and tear on transformers through repeated inrush

currents. There would also be significant additional maintenance requirements to allow for. We must also consider the increased risk of outages through temporarily reduced redundancy.

In RIIO-ED2, we commit to undertaking a fully detailed CBA study and sensitivity analysis to assess the true value in one or more locations within the network, looking at how often the transformers might expect to be deenergised and reenergised because of the TASS implementation. Subject to a positive NPV, we would then seek to start a trial.

Table 25: TASS Energy Savings

	Losses Saving (%) for TASS Implementation	
Site	***1950s Base Case***	***Eco-design Tier 2***
Burghlee	33.1	17.7
Yair Bridge	47.6	44.9
Penpont	50.9	64.3

9.5 Data Processes

We have put in place policies to allow the capture of consumption and conveyance data on our networks in high fidelity. This allows us to understand where and when power flows are occurring, and to infer drivers such as weather, time of day, time of year, etc which can shape our planning of maintenance and reinforcement.

We have built high fidelity, data driven, *bottom-up* models of our networks. These models when combined with smart meter and network metering data allow us to characterise where and when losses occur on our networks, with losses being non-linearly related to current flow. We can use our models to predict losses, which may occur as part of initiatives such as network reinforcement, new customer connection, or the connection of DG.

Further, we have developed algorithms and computational methods to automatically assess data too voluminous for human interpretation. This allows us to build our understanding of both the mainstream cases and outliers. In some cases, outliers will be examples of theft, with our algorithms primed to identify such cases and to instigate further investigation.

During RIIO-ED2, we shall progressively improve our ability to automatically detect statistical outliers in the consumption and LV monitoring data, which may be characteristic of energy theft, conveyance errors or unmetered supply errors. This will involve new manipulation of the increasing volume of smart meter data available. Targeted investigations can then be initiated, offering cost efficiency while achieving reductions in theft and, therefore, the cost of theft passed onto legitimate consumers.

10 Collaboration and Stakeholder Engagement

10.1 Overview

Table 26: Overview of Collaboration and Stakeholder Activities to Raise Awareness of and Reduce Network Losses

Activity	Overview	Outcomes for ED2
Technical Losses Working Group (Section 10.2)	We will continue to chair this group in ED2.	Better processes for measuring, managing, and reporting losses.
Early Loss Adjustment Factors (Section 10.3)	We will engage with Elexon with a view to reviewing BSCP128 and assessing alternative options for site-specific LAFs.	Customers incentivised to install loss-reducing equipment.
Losses Management through DSO Transition (Section 10.4)	Continue active engagement with ENA.	Greater opportunities for demand-side flexibility with DNO collaboration.
Holistic Consideration of Losses (Section 10.5)	Develop our working relationship with National Grid's Electricity System Operator (NGESO) and Electricity Transmission (NGET) divisions to go beyond BAU network assessments and encourage a holistic losses consideration.	Mechanisms for holistic losses consideration (making distribution losses 'in scope') for generator applications and Static Reactive Power Service tenders (for example).
Community Engagement though Revenue Protection Activities (Section 10.6)	Continue to support the extensive programme of stakeholder engagement under Revenue Protection.	Continue to save lives through reducing electricity theft. Additionally, make the reduction of non-technical losses more efficient.

10.2 Industrial Engagement

Throughout this document, many references are made to our initiating and convening the TLWG through the ENA. This forum has offered many benefits, principally:

- Information sharing.
- Collaborative formation and refinement of best practice.
- Reduced duplication of effort.

We will continue to drive the TLWG, with future aims including:

- Better understand and quantify ("measure") the network losses (see Section 6.2.1).
- Standardisation of engineering processes for DNOs, to manage network losses (see Section 6.2.1).
- Development and continuous improvement of future losses reporting and incentive mechanisms for losses management (see Section 6.2.2).

We believe that the TLWG has a crucial role to play in mitigating rising losses on distribution networks, and the UK electrical system more generally, as further electrification occurs in the coming decades.

We have also built a working relationship with other participants in the electricity generation and delivery system, such as NGESO, NGET, and small-scale operators of embedded generation. Until now, these

relationships are largely informal. During RIIO-ED2, we shall seek to formalise these as we work towards a common goal of achieving *Net Zero*.

10.3 Distributed Generator Customer and Stakeholder Engagement

Throughout RIIO-ED1, we have been involved in a number of programmes and initiatives to engage more fully with our customers and other stakeholders. This enhanced engagement will continue into RIIO-ED2.

In our LDR Tranche 1 submission, we introduced an initiative directed at improving network loading by active stakeholder engagement. This work recognised the impact on network loadings of customer / prosumer behavioural change and additional distributed generation. Where these changes resulted in higher loads on existing assets there is a consequential increase in technical losses. For example, if an active network management scheme is used to defer network reinforcement then network loading, and therefore technical losses, will increase. We are continuing to assess those parts of our networks where flexible connection schemes will be deployed and this includes a detailed losses assessment.

Other activities include engagement with specific customers to assist them in understanding their usage patterns and the impact on losses. For example, the ongoing work with Flintshire County, their Supplier, and the Welsh Assembly to understand the impact of demand and generation on energy costs.

We will build upon this proactive engagement, with a focus on improving energy efficiency, into RIIO-ED2.

We shall continue auditing of unmetered connections and refinement of policies to *close the gap* between anticipated / declared consumption and actual consumption.

Our initiatives under LDR have increased our awareness of the impact of Loss Adjustment Factors (LAFs) and we are now looking to support a change to the Balancing and Settlement Code that will ensure customers who make the right decisions and install lower loss equipment are not penalised by the application of generic LAFs.

BSCP128 on Production, Submission, Audit and Approval of Line Loss Factors, which requires a new EHV connection to be subject to generic LAFs until sufficient data (typically 1 year) is available to calculate site specific LAFs.

For those customers who consider installing loss-reducing equipment, the generic LAFs have the potential to increase their operating costs in year one compared to the true cost of their losses. This is the case even though we could calculate losses that are more representative with reasonable confidence. We will engage with Elexon with a view to reviewing BSCP128 and assessing alternative options for site specific LAFs.

10.4 Losses Management through DSO Transition

Traditionally, electrical provision in the UK has been freely available: a consumer can start an electrical appliance such as a washing machine or dishwasher in their house without having to request increased supply or having to disconnect other loads. While this approach offers maximum flexibility for consumers, it requires that network is capable of conveying sufficient power to allow this flexibility. In order to cope with the uptake in network loading anticipated over the coming decades through EVs, DG, and electric heating; maintaining this approach would require significant network reinforcement. At times of peak loading, electrical losses shall be very high as the losses rise with the square of the current flowing through a conductor.

Demand Side Management (DSM) approaches offer scope to change this approach. Non-time critical loads such as washing machines, dishwashers, and refrigerator duty cycles can be manipulated to allow some degree of *peak-clipping* or *valley-filling*, with minimum disruption to the end user. Such automated load control allows network capacity to be managed and losses kept under control.

Time of use (ToU) tariffs offer an intermediate solution between automated load control and having no restrictions on usage. Consumers will be given the choice to power loads during expensive times or to schedule

loading at less expensive times when capacity is higher, and losses are lower. This may get further complicated by the roll out of EVs, with customers able to buy energy at cheaper times, store it in their EV battery, and sell it during times that are more expensive.

In our transition to DSO, we will procure both generation and demand flexibility services like these in order to maximise the utilisation of the network. While the technical feasibility of both DSM And ToU tariffs are clear, there are a number of social and economic factors, which still need to be resolved to ensure fair and equitable access for all. We are therefore actively engaged in studies and policy making with the ENA around DSM.

10.5 Holistic Losses Consideration

As a DNO, we do not, and cannot, operate as an island. Instead, we must be aware of operations on the transmission system and the intentions of small-scale embedded generation. In SPM, we have an existing relationship with National Grid's Electricity System Operator (NGESO) and Electricity Transmission (NGET) divisions for network assessment near the transmission boundary. During RIIO-ED2, we hope to utilise this relationship to consider losses on a more holistic, best-for-consumers basis.

Our distribution networks form a core link in the electricity *supply chain* interfacing those who generate electricity with those who consume it. It is not a standalone system; thus, it is important to understand our interfaces, and effectively manage our relationships with external actors. For example: what we do, as a DNO, affects the transmission network and vice-versa. The importance of transmission and distribution network operators understanding what the other is doing will grow in value as small-scale generation connected to distribution networks increases, and the effect this can have on voltage control on the transmission network.

In our LDR Tranche 2 submission, we reported on investigations into whole system operating regimes. These considered the management of boundary conditions when utilising DG for a losses-inclusive optimised regime with NGESO. This has the potential to reduce the requirement for reinforcement on the transmission network, even if losses within parts of distribution networks increase.

The impact on distribution network losses was calculated across a range of power factors (±0.90), with the base case reflecting current operating conditions. Dependent on the operating regime, studies estimated that SPM network losses may increase by up to 5.5 GWh / year, and SPD by up to 3.3 GWh / year.

This learning is currently being developed and applied as part of our investigations for the Reactive Power Services being tendered by NGESO. Distributed Generators connected to our 33kV and 132kV networks can apply to absorb, or inject, reactive power to relieve voltage constraints on the transmission system.

Recent modelling has confirmed that such schemes will reduce transmission losses and increase distribution losses. We are currently reporting our findings with National Grid Electricity Transmission (NGET) and sharing our models to better understand the balance between different system losses.

There is currently no mechanism for the resulting increase in distribution system losses to be considered by the generator in its application, and we are working towards a method to ensure holistic system losses are properly accounted for. This includes ensuring it is in scope of upcoming Static Reactive Power Service tenders.

Whilst network assessment work is BaU, we are applying additional concerted effort to ensure that a holistic consideration of losses is included in the tendering activities utilising the above approach to ensure the true cost of losses to customers is considered within the tenders to participate.

10.6 Wider Community Engagement through Revenue Protection Activities

With respect to non-technical losses, our in-house Revenue Protection service and engagement with the industry via the Electralink Theft Issues Group and UK Revenue Protection Association represent best practice.

As well as the environmental and economic cost of theft, meter tampering and illegal abstraction is also very dangerous, with scope for electric shocks and ignition of fires. Therefore, theft causes significant safety concerns for the perpetrators, the occupants of any properties where theft is occurring, and those in adjacent properties. This drives us to go further than our minimum Revenue Protection activities in this area. Our aim is to save lives, but it has the additional benefits of making our non-technical losses reduction even more efficient.

In the SPM zone, we continue to engage with Merseyside Police to combat illegal abstraction. Throughout RIIO-ED1, we have embedded a member of staff full time within Merseyside Police. This has led to sustained losses identification estimated to be worth at least £4 million annually and benefits all suppliers operating on the network. This long-term partnership will be maintained throughout RIIO-ED2.

We have proactively pursued further engagement with Police Scotland to set up a similar practice for the SPD zone and we are working to embed a similar permanent employee that suits the organisation.

A key function of the Revenue Protection team is to facilitate awareness sessions, to encourage multi-agency support to tackle non-technical losses further. A summary of our recent industry-leading activities in this area are as follows:

- Presented to stakeholders in our SPD licence area who may encounter meter tampering and safety issues during their work, including Fife Council and Glasgow Housing Association. We have also developed a similar working relationship with Liverpool Housing Trust.
- We continue to participate in the SP Smart Contractors Forum with several sessions held with appointed meter operators. We commonly liaise with new suppliers onto the market to share relevant information of non-technical losses and Revenue Management.
- We were asked by UK Revenue Protection Association (UKPRA) to provide an awareness session to Greater Manchester Police, highlighting the success of the close working relationship we have with Merseyside Police. We have held exercises with Police Scotland to disseminate lessons learned from the SPM area, which has resulted in confirmed detection of interferences.
- Our Revenue Protection teams actively participate within the TRAS Expert Group and are actively improving the Theft Risk Assessment Methodology. We have worked with suppliers who have significant experience in the handling and use of smart data, including British Gas and Utilita, to share best practice. Our learning from this engagement has improved our processes for detecting non-technical losses. We attend the Theft Best Practice Forum relating to energy theft and to share details of SPEN practices.
- As vice-chair of the Executive Committee at the UKRPA we regularly present at industry events. We delivered three presentations at the UKRPA 2018 conference and have presented at two seminars in 2019. This covered the work we do with Merseyside Police, the Scottish Prison Service, Iberdrola data analytics techniques use in detecting energy theft, and compliance with industry legislation (Acts of Parliament, Licence Conditions & Codes of Practice).
- We have established a new relationship with Merseyside Fire and Rescue, simulating a cannabis farm to build awareness of safety issues and energy theft. We have identified potential target areas where theft may be more prevalent and carries a higher risk of fire (through the provision of heat maps).
- We have established a relationship with the Scottish Prison Service to educate on the dangers and safety consequences of meter interference, this also mitigates occurrences of theft amongst released offenders.

We will continue to develop these stakeholder relationships in RIIO-ED2, expanding the breadth of our stakeholder groups further if possible.

11 Conclusion

Given the changing nature of the load on our network it is inevitable that network losses will begin to increase in RIIO-ED2 as we transition to Net Zero. This view is supported by our own analysis, driven by the DFES, and that of independent consultants, such as WSP.

Whilst the carbon impact of losses will decrease as the grid decarbonises, the economic cost of losses is still significant, driven by the increasing cost of carbon and affected by future energy prices.

Therefore, more than ever we must maintain our strategic vision to: ***Consider all reasonable measures which can be applied to reduce losses and adopt those measures which provide benefit for customers.***

To support this, we have developed a new losses policy in RIIO-ED1 that ensures we keep losses central to everything we do in policy, procurement, design, and standards. In our role as chair the ENA Technical Losses Working Group, we are leading the development of a suitable mechanism to incentivise losses management and minimisation across the industry, see Appendix 2.

A summary of our headline actions in RIIO-ED2 are as follows:

Continue to replace high-loss assets, such as old design transformers, with more efficient new technologies. Pro-actively avoiding 36GWh of losses.

Increase the minimum cross-sectional area of HV and LV cables and overhead lines in conjunction with other works.

Improve our knowledge and understanding of losses through:

- Applying our intelligent network algorithms to smart meter data.
- Increasing metering capabilities, particularly at secondary substations.
- Improving network modelling.

Continuation of our use of industry-leading Revenue Protection services.

Procure a Mobile Asset Assessment Vehicle (MAAV) under a Consumer Value Proposition to detect contact voltages and subsequent network (and customer) losses.

Continuing our work in our flagship innovation projects investigating DC distribution use cases.

Continuing to chair the ENA Technical Losses Working Group to work collaboratively on better processes for measuring, managing, and reporting losses.

By implementing this strategy, we forecast predicted losses savings of 573GWh in ED2 over the baseline 'do nothing' scenario. A summary is as follows:

	Cost attributed to losses (£m)	Losses Reduction over ED2 period	
		GWh	tCO_{2e}
Proactive, losses-driven transformer replacement	13.22	36.0	7403.2
Opportunistic losses savings through policy-driven, losses-informed intervention	0[23]	268.6	51616.6
Theft and Revenue Protection activities	0[24]	183.1	38791.4
Contact Voltage detection using the Mobile Asset Assessment Vehicle (MAAV)	0[25]	85.5	18168.8
Total	**13.22**	**573.2**	**115,980**

[23] Costs attributed wholly to other Non-Load and Load related schemes.
[24] Costs of £6.74m attributed to Directly Remunerated Services 5.
[25] If successful, costs will be claimed under a £10.1m Consumer Value Proposition, see Annex 5C.2.

12 Glossary

AAAC	All Aluminium Alloy Conductor
AVC	Automatic Voltage Control
BaU	Business as Usual
BS	British Standard
CBA	Cost Benefit Analysis
CI	Customer Interruptions
CIRED	International Conference on Electricity Distribution
CML	Customer Minutes Lost
CO_2	Carbon Dioxide
CVP	Consumer Value Proposition
DFES	Distribution Future Energy Scenarios
DG	Distributed Generation
DNO	Distribution Network Operator
DPCR	Distribution Price Control Review
DSM	Demand Side Management
DSO	Distribution System Operator
DUKES	Digest of United Kingdom Energy Statistics
ED1	Electricity Distribution Price Control 1
ED2	Electricity Distribution Price Control 2
ED3	Electricity Distribution Price Control 3
EHV	Extra High Voltage (33kV)
ENA	Energy Networks Association
ESO	Electricity System Operator
EU	European Union
EV	Electric Vehicles
FES	Future Energy Scenarios
G2V	Grid to Vehicle
GIS	Geographic Information System
GSP	Grid Supply Point
GW	Giga-Watts
GWh	Giga-Watt Hours
HV	High Voltage (11kV)
I^2R	Ohmic heating losses – Current squared × Resistance
ICE	Incentive on Connection Engagement
IET	Institute of Engineering & Technology
kg	Kilogram
km	Kilometre
kV	Kilo-Volts
kVA	Kilo-Volt-Amperes
kW	Kilo-Watts
kWh	Kilo-Watt-Hours
LAF	Load Adjustment Factor
LCNF	Low Carbon Networks Fund
LCT	Low Carbon Technologies
LDR	Losses Discretionary Reward
LF	Load Factor
LV	Low Voltage (400 V 3-phase / 230 V 1-phase)
MAAV	Mobile Asset Assessment Vehicle
MDI	Maximum Demand Indicator
MJ	Mega-Joules
mm^2	Square millimetres
MPAN	Meter Point Administration Numbers
NAVI	Network Analyse and View
NCEWS	Network Constraint Early Warning System
NCP	Network Controllable Points
NGESO	National Grid Electricity System Operator
NGET	National Grid Electricity Transmission
NPV	Net Present Value
OC6	Operating Code No. 6
Ofgem	Office for Gas and Electricity Markets
OHL	Overhead Line
PLC	Power Line Carrier
PMT	Pole Mounted Transformer
pu	Per-Unit
PV	Photovoltaic
RIIO	Revenue = Incentives + Innovations + Outputs
SPD	SP Distribution
SPEN	SP Energy Networks
SPM	SP Manweb
SSEN	Scottish and Southern Energy Networks
TASS	Transformer Auto Start Stop
tCO_2e	(Metric) Tonnes of Carbon Dioxide Equivalent
TEPCO	Tokyo Electric Power Company
TIG	Theft Issues Group

TLWG	Technical Losses Working Group	**V**	Volts
ToU	Time of Use	**V2G**	Vehicle to Grid
TR	Technical Report	**Wh**	Watt Hours
TRAS	Theft Risk Assessment Service	**XLPE**	Cross-Linked Polyethylene
TWh	Tera Watt-Hours		

13 References

[1] SP Energy Networks, “Losses Strategy: Reducing Network Energy Losses & Greenhouse Gas Emissions. Issue 2.1.,” 2015.

[2] Ofgem, “RIIO-ED2 Business Plan Guidance,” 2021.

[3] SP Energy Networks, “Losses Discretionary Reward: Tranche One Submission.,” 2016.

[4] SP Energy Networks, “Losses Discretionary Reward: Tranche Two Submission.,” 2018.

[5] SP Energy Networks, “Losses Discretionary Reward: Tranche Three Submission.,” 2020.

[6] OFGEM, “RIIO-ED1 Network Performance Summary 2019-20 - Supplementary Data File,” 2021.

[7] Nexans, “6-36kV Medium Voltage Underground Power Calbes: XLPE Insulated Cables,” https://www.nexans.co.uk/UK/files/Underground%20Power%20Cables%20Catalogue%2003-2010.pdf, 2021.

[8] P. D. D. P. I. K. R. M. Goran Strbac, “Strategies for reducing losses in distribution networks,” Imperial College London, 2018.

[9] WSP, “ENA Working Group Project: Impact of Low Carbon Transition – Technical Losses,” 2017.

[10] UK Deparment for Business, Energy & Industrial Strategy, “The Energy White Paper: Powering Our Net Zero Future,” 2020.

[11] UK Deparment for Business, Energy and Industrial Strategy, “Digest of United Kingdom Energy Statistics 2020,” 2020.

[12] WSP, “WSP, CEP023 Technical Losses Mechanism Study, Development of a Losses Incentive Mechanism: Phase 1 Final Report,” September 2019.

[13] European Union, “Commission Regulation (EU) No 548/2014 of 21 May 2014 on Implementing Directive 2009/125/EC of the European Parliament and of the Council with Regard to Smarll, Medium and Large Power Transformers,” 2014.

[14] SP Energy Networks, *Construction Policy for Distribution Overhead Lines: OHL-01-008, Issue 4,* 2018.

[15] SP Energy Networks, *Framework for Design & Planning of LV Housing Developments, Including U/G Networks and Associated HV/LV S/S: ESDD-01-012, Issue 7,* 2019.

[16] National Grid ESO, “Operating Code No. 6 - Demand Control,” 2021.

[17] SP Energy Networks, “Investment Business Case: SPEN LCT Monitoring Strategy,” 2014.

[18] J. Y. A. M. L. Gayan ABEYNAYAKE, “Analysis and Control of MVDC Demonstration Project in the UK: ANGLE-DC,” *Journal of Distribution & Utilization,* vol. 37, no. 10, pp. 44-50, 2020.

APPENDIX 1 – SUPPLEMENTARY ANALYSIS

A1.1 Losses on Underground Cable Circuits

CBAs for our HV and LV network sections were undertaken to assess the value realisable through **proactive** replacement of high loss circuits before their due date for replacement and, where replacement is considered, to compare the relative impact using cables with different cross-sectional areas. This analysis considers net present value (NPV) of losses only and hence does not factor in other potential monetised benefits of asset replacement. Nor does it include the societal costs of customer supply interruptions that may result from the outages required to complete replacement works.

The inputs into this CBA are:

- We have assessed a nominal volume of 100km of cable for both the HV network and LV network. This allows the relative merits of each scenario to be assessed but is not intended to provide a specific NPV for planned works. Specific cable reinforcement volumes are contained in Engineering Justification Papers; these are referenced in Section 7.4.3 of this document.
- The counterfactual case (i.e. assessing the losses impact of not replacing or upgrading cables) has been modelled with a conductor size that is an average value across existing cables on our network which have been identified as potentially highly utilised.
- Two options have been modelled: replacement of existing cables with cables with a cross sectional area of 185 mm^2 and 300 mm^2. Appropriate costs for cables have been approximated using the unit cost manual used to underpin our RIIO-ED2 business plans.
- Three load factors[26] (LF) (0.3, 0.5, 0.7) have been considered to represent low, average, and highly utilised sections of our network. It is noted that 0.7 LF is a highly loaded cable and may only be realistic in a system containing high penetrations of low carbon technologies (LCT) alongside smart controls to manage loads.
- Peak current carried by these cables is based on the modelled SPEN DFES Baseline View scenario for 2028 (i.e. the end of the RIIO-ED2 period).

Results of our analysis for HV and LV cables are presented in the following sections.

A1.1.1 *HV cables*

Our analysis for HV cables is summarised in Table 27. This table illustrates that:

- It is not cost effective to replace HV cables proactively for any of the load factors considered based solely on losses.
- When LF is 0.3, if proactive replacement is required for other reasons (e.g. condition-based modernisation), then it is generally more economically efficient (based on losses only) to use 185 mm^2 cables, rather than 300 mm^2 cables.
- When the LF is 0.5, if proactive replacement is required for other reasons, the NPV is similar for the 185 mm^2 and 300 mm^2 cables for a 45-year term. Case-by-case decisions must be made if possible.
- When the LF is 0.7, if proactive replacement is required for other reasons, then it is more economically efficient to use the larger 300 mm^2 cables.

[26] Load factor is the ratio of average power throughput to capacity of the existing cable being considered for overlay/upgrade.

Table 27: Proactive High-Loss Cable Replacement on HV Network

Load Factor	Years from Install	NPV (£m) Proactive Replacement	
		185 mm²	300 mm²
0.3	16	-£3.67	-£4.22
	24	-£5.58	-£6.36
	32	-£6.71	-£7.62
	45	-£7.51	-£8.51
0.5	16	-£3.05	-£3.39
	24	-£4.30	-£4.63
	32	-£5.02	-£5.35
	45	-£5.43	-£5.70
0.7	16	-£2.24	-£2.29
	24	-£2.60	-£2.34
	32	-£2.77	-£2.33
	45	-£2.67	-£1.99

A1.1.2 *LV cables*

Our analysis for LV cables is summarised in Table 28. This table shows that:

- It is not cost effective to replace LV cables proactively when the LF is 0.3, using either 185 mm² or 300 mm² cabling. If proactive replacement is required for other reasons, the NPV is similar for the 185 mm² and 300 mm² cables for a 45-year term. Case-by-case decisions must be made if possible.
- It may be cost effective to replace LV cables proactively when the LF is 0.5 using 300 mm² cabling. The realisable value increases with duration (i.e. loss reduction benefits exceed ongoing costs) in service for both the 185 mm² and 300 mm² cable case.
- It is likely cost effective to replace LV cables proactively when the LF is 0.7 using either 185 mm² or 300 mm². As can be expected, the realisable value is higher for the 300mm² cable and hence represents the more economically efficient option and the biggest reduction in losses.

Table 28: Proactive High-Loss Cable Replacement on LV Network

Load Factor	Years from Install	NPV (£m) Proactive Replacement	
		185 mm²	300 mm²
0.3	16	-£3.00	-£3.14
	24	-£4.18	-£4.11
	32	-£4.86	-£4.66
	45	-£5.23	-£4.85
0.5	16	-£1.61	-£1.09
	24	-£1.28	£0.18
	32	-£1.04	£1.00
	45	-£0.53	£2.11
0.7	16	£0.22	£1.64
	24	£2.56	£5.87
	32	£4.02	£8.50
	45	£5.69	£11.35

A1.2 Estimated Transformer Losses

The average losses savings per high-loss HV transformer in ED1 was modelled as 11.39 MWh per year for a pre-1955 transformer and 9.64 MWh for a 1955-1961 transformer.

A more asset-specific approach is taken in the ED2 modelling accounting for transformer size, that includes copper losses.

Iron ('fixed') losses are estimated using transformer age and rating to look up per unit losses values, taken from some standard industry references for different transformer-types based on year of manufacture. Although smaller in comparison, copper ('variable') losses are estimated in ED2 only and are based on average maximum demand indicator. This analysis is done on a transformer-by-transformer basis across the full fleet of ground-mounted HV transformers[27].

The average losses savings per high-loss HV transformer in ED2 is modelled as 13.8 MWh per year in SPD and 13.5 MWh in SPM – all of which are in the pre-1955 or pre-1962 category.

The increase in losses savings per year per transformer is likely to be in part due to the more detailed modelling and inclusion of load losses, and in part due to real effects including during ED1 the minimum EU Eco-design standard for new transformer losses has moved from Tier 1 to Tier 2, reducing the losses of a new transformer further.

Losses savings per EHV transformer are modelled in the same way with losses values estimated from available literature; however, as load losses are generally more influential on the decision whether or not to replace, the detailed loading profiles are used (also, monitoring is more widely available in the EHV transformers so the information is more widely available to enable this detailed view).

[27] This has allowed us to make comparisons of changing the selection criteria of HV transformers for replacement.

APPENDIX 2 – REPUTATIONAL INCENTIVE PROPOSAL

A2.1 ODI-R Proposal

As discussed in Section 6.2.2, independent technical experts WSP have worked with the TLWG to produce a report [12] that investigates best practice and makes independent recommendations as to future loss incentive mechanisms. We published key findings as part of our LDR Tranche 3 submission [5].

We have proposed a reputational RIIO-ED2 losses mechanism which builds on the existing RIIO-ED1 framework and recognises the complexity in the measurement and management of losses arising from the Net Zero transition.

The proposal was presented at Ofgem's RIIO-ED2 Distributed Energy Working Group (DEWG) in October 2020. It proposes the introduction of a Reputational Output Delivery Incentive (ODI-R) to replace the LDR and sets out possible performance measures. **We are keen to continue to work with Ofgem and with other DNOs to finalise and implement this proposal.**

The reputational measure is intended to give interested stakeholders a view of how well the DNO is executing their losses strategy plans, and to recognise and incentivise the ambition of this activity. A two-fold approach would score DNOs based upon both their 'ambition' of losses strategy and 'performance' of activities as part of this strategy. The final proposal element qualitatively assesses elements of the LDR considered during RIIO-ED1; namely understanding of losses, stakeholder engagement and losses innovation.

Each DNO must already have an up-to-date and publicly available losses strategy, which should include the methodology of how they are measuring losses on their network. Losses strategies will be included within the Environmental Action Plan (EAP) and DNOs will be expected to report on delivery against the activities set out within their strategies in the Annual Environmental Report (AER), which is in itself is an ODI-R and Licence Obligation.

A2.1.1 *RIIO-ED2 Losses Strategy Scoring Approach*

It is not possible to evaluate absolute losses, or to fairly compare absolute levels of improvement.

We propose a two-fold scoring approach, explained below, will better display the subtleties of each DNO position. This approach avoids incentivising low ambition. Assessment is both quantitative and qualitative, providing more flexibility in arranging activities aligned with DNO needs.

- Firstly, a ranking based on 'ambition factor' is calculated, which is numerically heavily weighted towards ambition (but influenced by performance to remove extreme values).
- Secondly, a RAG score based on performance, can be adjusted ±1 RAG status using qualitative assessment of key criteria (which we propose aligns to the RIIO-ED1 LDR criteria: understanding of losses; sharing of best practice/ stakeholder engagement; and losses innovation).

A2.1.2 *Structure of the Scoring*

For each action a DNO plans to undertake to minimise losses, the DNO should provide the associated losses reduction in "GWh of losses avoided" which will be achieved by the strategy implementation over a consistent period e.g. over the course of RIIO-ED2.

Proposed losses reductions should be summed to give a total of proposed losses avoided in GWh. A normalisation factor should be applied to the GWh summation of losses reduction, accounting for network length and customer number. Normalisation factor allows for comparability across DNOs.

Activities should be underpinned by CBA. Activities may be grouped e.g. Technical and Non-Technical.

A2.1.2.1 Evaluation

We propose a two-fold scoring approach set out as follows.

1. Ambition will be measured in the planned amount ('target') of GWh of losses to be avoided. This will underpin a **DNO ranking** based on the annual losses score calculated as follows:

$$Losses\ score = GWh_{Performance} \times \left(1 - \frac{most\ ambition\ (GWh) - ambition\ (GWh)}{most\ ambition\ (GWh)}\right)$$

$$= GWh_{Performance} \times 'ambition\ factor'$$

   Ambition should be considered annually, on either a 'cumulative losses avoided' basis or 'year-by-year losses avoided' basis.

2. Performance will be measured annually in GWh actuals and in percentage of the target. An **initial RAG** score should be given to each DNO based upon the DNO percentage performance against the target as follows:

$$RAG = \frac{GWh_{Performance}}{GWh_{Target}}$$

   Initial RAG scoring could be assessed as: **Green** at or above 85% of ambition; **Amber** between 50% and 85% of ambition; and **Red** below 50% of ambition.

   There would then be a qualitative assessment of performance, which can influence the final DNO RAG score. Ofgem would qualitatively evaluate this area using criteria similar to the LDR.

   Comparatively excellent performance in two or more areas would allow DNOs +1 RAG status position based upon evaluation of qualitative performance. Comparatively poor performance in sections would reduce outcome by 1 RAG status position. DNOs will achieve a **final RAG** status as follows:

$$Final\ RAG = \frac{GWh_{Performance}}{GWh_{Target}} \pm 1\ RAG\ status$$

SP ENERGY NETWORKS

SP Energy Networks
320 St Vincent Street
Glasgow, G2 5AD

Contact us
facebook.com/SPEnergyNetworks
twitter.com/SPEnergyNetwork
RIIO_ED2@spenergynetworks.co.uk
spenergynetworks.co.uk