Losses Discretionary Reward

TRANCHE THREE SUBMISSION

MARCH 2020

SP ENERGY NETWORKS

Contents

1 | Foreword

Distribution networks are the key enabler to the UK Net Zero transition. To facilitate the electrification of heat and transport and accommodate more decentralised renewable generation, distribution networks must operate more flexibly and transfer more power to customers. This will increase the utilisation of our network assets, in turn increasing network losses.

At SP Energy Networks we recognise that losses have a societal cost, borne by today's and tomorrow's customers. Whilst it is not appropriate to prioritise losses reduction at the expense of the Net Zero transition, it is vital that we continue to manage losses to the level of greatest benefit to customers.

Throughout RIIO-ED1, we have actively pursued a range of technological and procedural initiatives to manage losses, driven by our Losses Strategy and guided by our high-level vision:

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

We have invested in activity over and above a return-on-investment basis. This is demonstrated in all three tranches of activity under our Losses Discretionary Reward (LDR) programme.

Our LDR Initiatives have delivered new processes to help us manage our network losses to economically optimum levels.

On non-technical losses, a major success has been our Revenue Protection team continuing to deliver material benefits through stakeholder engagement and relevant partnerships with law enforcement agencies.

On technical losses, we have made continued improvements and implemented enhanced network modelling techniques to enable losses informed network decisions.

Industry has also transformed its approach to losses over the course of RIIO-ED1, led by SP Energy Networks substantial efforts in convening and chairing the ENA Technical Losses Working Group.

This group, established in 2016, provides a forum for DNOs to progress and share best practice on losses management. The group has built a comprehensive understanding of the losses impact of low carbon technologies and reviewed options for regulatory management of losses in RIIO-ED2. This work provides the foundations to deliver long-term benefit for our customers.

In tranche one, Ofgem acknowledged our strong set of initiatives to address both technical and non-technical losses, awarding £770,000. We chose to re-invest the full reward in further loss management activities, demonstrating our ongoing commitment to effective losses management, including embedding a dedicated Losses Engineer in our System Planning team.

In tranche two, Ofgem recognised the strength of our submission and the clear progress from tranche one, again commenting on the quality of our initiatives and our holistic consideration of losses. However, Ofgem considered DNOs had not provided sufficient evidence in their submissions, and decided not to reward any party.

In tranche three, we are embedding the learning from our thirteen innovative initiatives, pursuing new activities, and contributing to the development of regulatory mechanisms for RIIO-ED2. We are proactively investigating new innovations to limit losses through reactive power management and working to ensure whole system losses are considered as part of transmission-level voltage management schemes.

I am delighted to submit this final submission under the LDR which looks back on our losses management achievements in RIIO-ED1 and how our progress will inform our Losses Strategy and plans for RIIO-ED2.

Scott Mathieson
Network Planning & Regulation Director

2 | Introduction

All electricity networks experience losses. The costs of losses are paid for by customers, and they contribute to society's carbon footprint. As such, they are a fundamental consideration of our distribution network design and operation. They are grouped into two categories;

Technical losses: these result from the laws of physics – they are an inherent result of power flowing through network assets where a small proportion of energy is always lost as heat. They can be minimised but never eliminated

Non-technical losses: these are units of energy transferred but not correctly accounted for due to errors in unmetered supplies, inaccurate billing estimations and illegal abstraction.

Losses management is complex. Losses are difficult to measure, are influenced by factors outside of DNO control, and must be considered within the Net Zero context. Technical losses will increase with the delivery of Net Zero – the electrification of heat and transport, greater levels of decentralised renewable generation and the need to operate to network more flexibly will increase network power flows, and therefore losses.

At the beginning of RIIO-ED1, we recognised that a key opportunity to optimise GB wide distribution network losses is through industry-wide collaboration. Prior to this, there was no platform for DNOs to discuss the issues related to understanding and managing technical losses.

To address this gap, we convened the ENA Technical Losses Working Group (TLWG). This Group, which we continue to chair, now forms the hub for all discussions regarding technical losses. Given the significant changes faced by all network operators to facilitate Net Zero, we view this as a key enabler to developing best practice, reducing duplication and sharing learning.

Following considerable effort in the development of industry understanding on the impact of the low carbon transition, the Group has also evaluated regulatory approaches for losses management. We are using this work to produce proposals for an RIIO-ED2 mechanism that holds DNOs accountable for actions within their control, and for the efficient management of network losses amongst other industry and societal priorities.

This work, together with our own initiatives provide key components to support the development of an RIIO-ED2 regulatory approach which will incentivise the economic and efficient management of losses though the Net Zero transition for the benefit of GB customers. We are now feeding this work into ongoing RIIO-ED2 working groups.

This collaborative approach is one of our eight key themes identified at the start of the LDR process, illustrated in Figure 1. These themes are addressed by our LDR activity and represent previously unfunded approaches to the management of technical and non-technical losses.

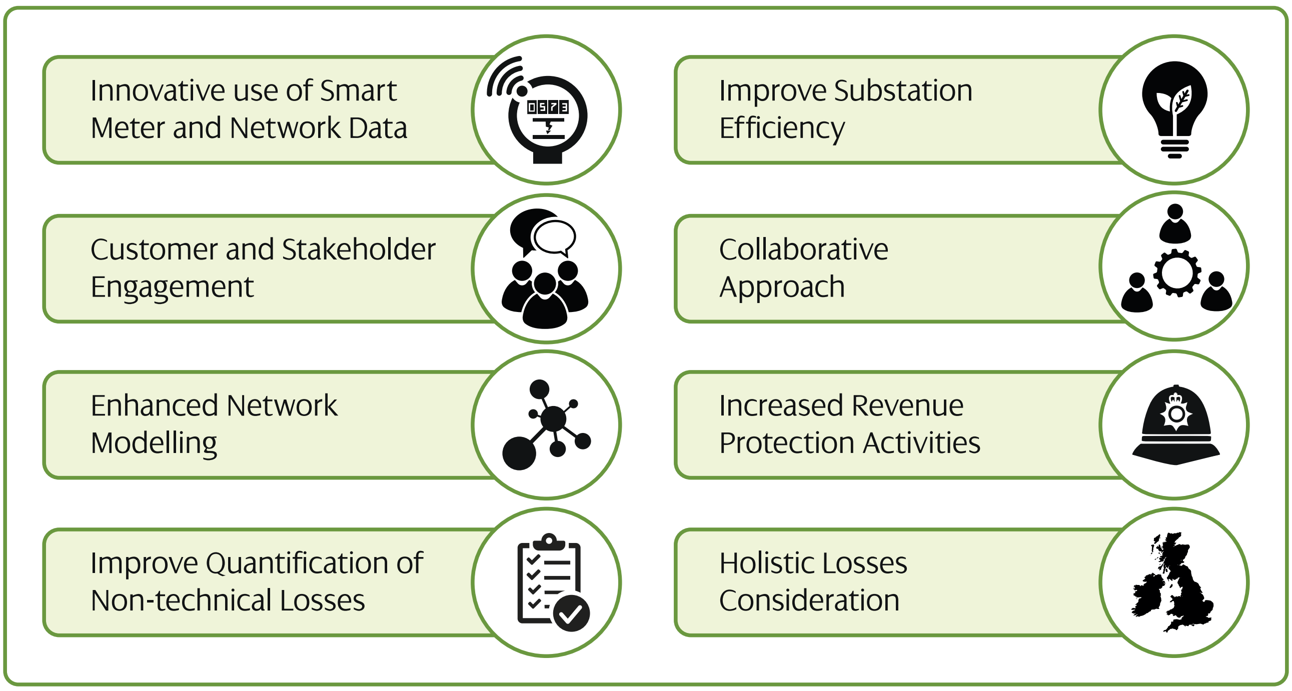
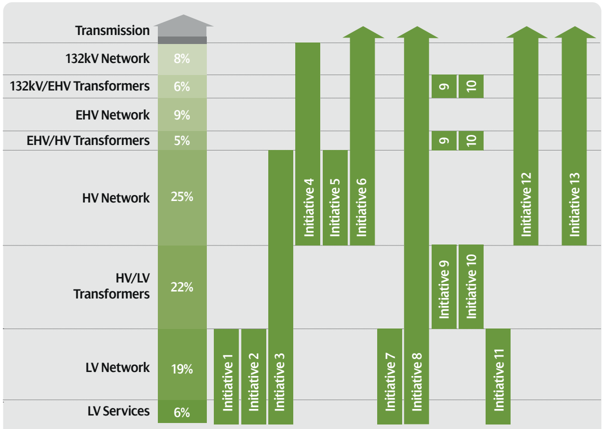


Figure 1: LDR key themes

2.1 LDR Programme

Throughout RIIO-ED1, we have actively pursued a range of activities to ensure losses are as low as reasonably practical where this is of benefit to customers, this has been driven by our Losses Strategy. Recognising the societal cost of losses, we have also developed approaches over and above a simple return-on-investment basis under our LDR programme.

Our LDR programme comprises a portfolio of thirteen initiatives, ten introduced during tranche one, and a further three at tranche two. Some initiatives have delivered successful outputs, some, based on the initial results, will not be pursued at this time and some are ongoing. We have made a material difference to our understanding and to the effectiveness of our losses management. Figure 2 summarises the voltage level, and corresponding estimated proportion of losses, affected by each of our initiatives.



Initiative	1	Smart Meter Data to reduce non-technical Losses
Initiative	2	Smart Meter Data to reduce Technical Losses
Initiative	3	Voltage Optimisation to improve Network Losses
Initiative	4	Improved Modelling of Complex Networks to Consider Losses
Initiative	5	Improved Modelling of Rural Networks to Consider Losses
Initiative	6	Assessment of Power Factor to Improve GB Losses
Initiative	7	Improved Detection of Theft through Revenue Protection
Initiative	8	Improved Network Loading through Stakeholder Engagement
Initiative	9	Substation Efficiency - Waste Heat Recovery
Initiative	10	Substation Efficiency - Monitoring and Self-Sufficient Substations
Initiative	11	Consider case for Mobile Asset Assessment Vehicle (MAAV)
Initiative	12	Early viability of Loss Adjustment Factors (LAFs)
Initiative	13	SCADA based near real-time losses calculations

Figure 2: LDR initiatives by voltage level, and estimated proportion of losses at each voltage level

2.2 Tranche Three Submission

In its assessment of tranche two, Ofgem requested more evidence of how both processes and innovations, either considered or deployed, will deliver clear benefits in terms of management of losses. Additionally, Ofgem wanted further details on the development of understanding of our own network, details on the outcome of the ENA TLWG, further details on the progress of the theft reduction initiatives and, more broadly, evidence on how the progress made from tranches one and two will help feed into losses in RIIO-ED2.

In this document, we reflect on actions undertaken in tranches one and two, providing further information where requested. We discuss our progress since the last submission, our activities for the remainder of RIIO-ED1 and further details of how our LDR programme will shape both our Losses Strategy and plans for enhanced losses consideration in RIIO-ED2 **(which we have called 'Beyond LDR')**.

We are proud of our considerable progress achieved to date. Compared to the start of RIIO-ED1, we now better understand the levels, locations and measures to minimise losses on our network. The understanding developed in the lead up to tranche two is now being applied, and we have plans in place for continued learning. We recap on this learning in Section 3, and present a consolidated view of our key findings.

Our stakeholder engagement on network losses increased over the course of the LDR, and we will maintain and increase our collaboration going forward, as demonstrated in Section 4.

A considerable amount of groundwork has been completed to select which techniques should be established to yield most benefit for customers, and this is already driving new behaviours in the way we plan our network. We are also working on processes that optimise the way we operate our network.

Our heightened focus and understanding of losses is transitioning into real action and changes to the way we operate. Section 5 demonstrates how we have made a concerted start on this journey, which will continue for the remainder of RIIO-ED1 and into RIIO-ED2.

Finally, we are proud of our reputation as leading adopters of innovation, this is also true of our approach to losses as demonstrated in Section 6.

2.3 Balancing the Cost of Losses

Fundamental to our LDR programme is our responsibility to deliver improved benefits to consumers. Establishing to what extent it is beneficial to reduce losses is a complex undertaking, and we have considered the following three principles over the course of the LDR.

Firstly, there is a balance to be played during the low carbon energy system transition. Embedded generation at the distribution level plays a significant role in electricity system decarbonisation, but has been shown to increase technical losses, often significantly, due to increased network utilisation. A holistic view of technical losses must be taken such that losses reduction does not become a barrier to the Net Zero transition.

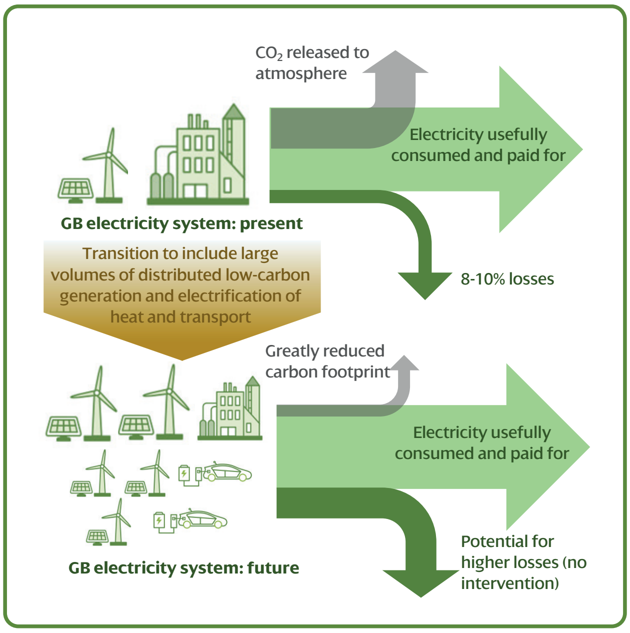


Figure 3: Effect of low carbon energy transition on losses

Secondly, in the short term, a significant proportion of GB electricity is still generated through the burning of fossil fuels. As such, losses currently have a carbon footprint. Over time, as the electricity generation mix approaches carbon-neutral, the relative carbon footprint of electrical losses also reduces, this largely reduces the environmental cost of losses. In future, there may be reduced emphasis on the importance of loss minimisation for the purposes of reducing emissions.

Thirdly, the cost of losses is determined over a 45 year asset life to ensure efficient interventions are progressed. In order to assess lifecycle losses costs, an accurate view of network demand is required.

This is complicated by uncertainty around future demand and generation trends, particularly Net Zero electrification and deployment of smart and flexible solutions. We are developing informed and stakeholder endorsed Distribution Future Energy Scenarios (DFES), aligned with the National Grid FES methodology, to understand future local network loading and the impact of these changes on network losses.

This gives an improved view of the cost of losses and of the overall customer benefit of loss reduction measures, ensuring interventions that offer greatest customer value are adopted.

3 | Understanding Losses

Since the beginning of RIIO-ED1, we have made significant and continued progress in not only our own but also industry understanding of the level and sources of losses in our networks.

Our thirteen initiatives have identified new knowledge through improved modelling techniques, the use of smart meter data and extensive collaboration on the handling of non-technical losses. This is combined with work we have lead at the TLWG to understand the impact of Low Carbon Technologies (LCTs) on technical losses and international approaches to mechanisms for encouraging losses management.

Key Improvements during LDR

- **Impact of LCTs:** Since the start of the LDR period, we have led considerable advances in understanding of network losses in the context of the low carbon energy transition, and we have used this learning to investigate the effects of LCT on our own network.
- **Smart meter data and advanced modelling tools:** We have developed and used advanced modelling techniques to understand the losses in detail in our HV, EHV and 132 kV networks. We have developed algorithms and data processing techniques to apply to smart meter data. We await smart meter data to realise more learning at LV.
- **Understanding theft in our network:** We have continued to develop our understanding of theft patterns from our own revenue protection activities and through consultation with other stakeholders.

3.1 The Impact of LCTs

Despite having 14% of UK demand connected to our networks, we have a significant portion of UK distributed generation (DG) with approximately 8GW already connected or contracted to connect, equivalent to 25% of UK average demand in 2019. Therefore, it is crucial that we have a heightened understanding of the impact of LCTs and decentralised generation on our network.

We have led considerable advances in the understanding of network losses in the context of the low carbon energy transition. Since tranche two, combined with our advanced modelling tools developed by our LDR initiatives, this work has helped us develop our understanding of our own networks.

Collaborative Approach

In tranche two, as Chair of the TLWG, we proposed and coordinated delivery of comprehensive studies to assess the impact of a low carbon transition on technical losses. We collaborated closely with the other network operators to scope, review and present these studies that push the boundaries of what the industry understands about the impact on losses of future LCT uptakes and how our networks evolve to accommodate them. These studies have focused on:

- Consideration of the impact of LCT uptake on technical losses.
- Consideration of the impact of smart reinforcements / increased network utilisation.
- The influence of customer usage patterns.

As part of these studies, simulations were performed using the DS2030 network models, derived from real DNO network data, to improve our understanding of the losses impact of 2030 LCT uptakes. All distribution voltage levels were considered. The detailed report[1] was published at the start of the tranche three period and informs network operators, Ofgem and other stakeholders about options and losses impacts regarding future network development strategies. New understanding from this work includes:

- Generation may reduce losses when it does not result in significant net export, particularly given the future increase in LV demand, but at maximum levels of penetration it can increase losses to 250% of existing levels as shown in Figure 4.

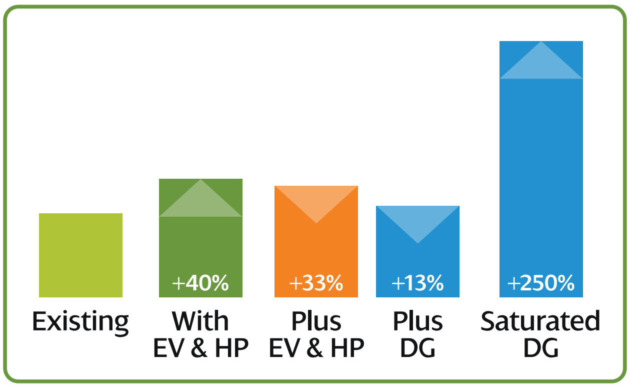


Figure 4: cumulative effect on network losses from key network interventions

[1] http://www.energynetworks.org/assets/files/ENA%20-%20Impact%20of%20Low%20Carbon%20Transition%20on%20Losses%20-%20FINAL.pdf

- Whilst conventional reinforcement to accommodate generation and demand growth will maintain or reduces losses, smart solutions (including demand side management) often increase losses, although they can offer significant whole-life cost savings compared to traditional reinforcement. Therefore, the transition from a DNO to a DSO, offering the provision of flexible and active network management will increase losses as we accommodate LCTs.

- Losses are complex, difficult to measure and vary based on regional topology. Adoption of a parametric simulation for evaluation of losses must balance the benefits and accuracy of the results with the cost, time and resource of extensive network dynamic modelling studies.

- Uncertainty around LCT and DG deployment means that future losses modelling and measurement is increasingly inaccurate. Large generators have high accuracy instantaneous metering and steady power output. Smaller generators have much lower accuracy metering and intermittent/stochastic outputs. Accuracy of both losses measurement and modelling is reduced through decentralisation.

- Networks employing smart solutions will have greater utilisation and operate at greater temperatures. Modelling overhead conductors at an approximate 20°C will no longer be an appropriate approximation. Similarly, cables with constant power flow profiles will operate without cyclic loading which presently allows cables to cool when current flow is lower.

These studies have helped to inform losses inclusive design principles, the level of modelling complexity, the scale of uncertainty and the losses impact of smart solutions.

Enhanced Network Modelling

In their tranche two decision, Ofgem requested to see more on how the work on LCTs helps to develop our view and understanding of our own network. We have combined the outputs of the LCT report with advanced network analysis and modelling techniques (discussed further in Section 5) to allow us to better understand areas of increased losses on our 132kV, EHV and HV networks. Some results are shared in Appendix 2 with key findings from our network discussed below. For wider system impacts, see section 3.4 “Holistic Consideration of the Network”.

3.1.1 General Findings

- On the SP Manweb (SPM) 132kV network, most circuit losses are significantly less than 0.5% as a percentage of the group infeed. One circuit (Carrington) had notably high losses of ~1.7%.

- On the 33kV network, most circuit losses are significantly less than 0.5%. Ca. 10% of circuits studied had notably high losses of between ~1.4% - 1.9%. Cable fixed losses are negligible.

- In SPM, 64% of132kV/EHV transformer losses are fixed, and the highest loss transformers appear to be explained by transformer age, as expected.

- In SP Distribution (SPD), the urban/highly urban 132/33kV BSPs showed <0.2% losses, the semi-urban 0.6%, and the rural showed 4.3%. One rural BSP (Linmill) connects eight DG sites. The generation is a mixture of wind and solar parks along with two sites with pump storage stations. At certain times of each day, the substation experiences reverse power flow due to excess of generation and low demand.

- In SPD, 71% of 132/33kV transformers losses are fixed.

These findings are helping us to prioritise higher loss assets for consideration within our RIIO-ED2 investment plans and longer-term business strategies to ensure losses do not exceed levels in customers interests. The costs can be accurately considered within whole-life cost benefit analysis for alternative solutions which may reduce losses.

3.1.2 Effects of LCT on the Network

- Both heavily interconnected substation groups, common to SPM, and the radial networks, common to SPD, saw times in the year when embedded generation reduced the losses compared to baseline. However, generally losses within substation groups with embedded generation reached up to 200% of losses compared to with the generation off scenario. Losses are highest during high-demand periods e.g. winter months of November to January.

- As networks are reconfigured to accommodate additional demand/generation, this affects power flows throughout the group. This in turn has a dramatic effect on the location and magnitude of losses. The extent of the variation is not yet predictable.

- Although generation is connected in areas of network with underlying demand, generation has been found to increase the overall losses significantly in some cases. The power flows and hence losses are becoming more stochastic in nature.

In conclusion, for reinforcements of existing substations, there is no 'one size fits all' design to optimise losses – each network configuration will need to be carefully considered to manage losses whilst low carbon generation increases.

A robust set of tools to model losses are required to support design decisions on a case-by-case basis, i.e. the advanced modelling tools developed under the LDR which are transitioning into business as usual (BAU) under tranche three. These have already been tested in several high value scheme designs including determining the optimal losses arrangements for our ANGLE-DC project and in holistic transmission-distribution interface assessments in the Mersey Ring area. We will be using these methods directly for the development of the RIIO-ED2 business plan.

3.2 More on Enhanced Modelling

Enhanced Network Modelling

We have also investigated the effect of HV Phase Imbalance in our network. At the beginning of the period, as acknowledged in our tranche one submission, phase imbalance on long rural overhead 11kV circuits was a major contributor to 11kV network losses. However, relatively little was known about the degree of phase imbalance, as determining this on 11kV circuits had traditionally required expensive monitoring.

We developed a modelling tool under Initiative 5 to assess the extent and location of phase imbalance on rural 11kV networks. This modelling tool utilises readily available network metrics to identify feeders that are likely to exhibit high imbalance. This reduced the need for monitoring and informed our understanding of this source of losses.

Upgrading single-phase spurs to three-phase lines was found to be cost prohibitive; however, the low-cost solution of phase-phase line reconnections shows a payback period of between 7 to 14 years. The maximum potential losses savings associated with 232 assessed feeders are circa 1.08GWh per annum.

The results of this analysis, and extensions of the assessment, are feeding into our ongoing asset investment planning and our investment planning for RIIO-ED2.

3.3 Smart Meter Data

Innovative use of Smart Meter and Network Data

Our LDR Initiatives 1 and 2 are focussed on the use of smart meter data to better understand and manage technical and non-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.

This ongoing work demonstrates the benefits of using smart meter data to better understand and manage network losses. We have applied data science techniques to our asset data and Geographic Information System (GIS) records to create power-flow impedance models of our LV networks. These have been tested with example smart meter datasets to improve understanding of technical losses on LV network (please refer to service cable Case Study).

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

Since our tranche two application, there has not been a significant increase in the availability of smart meter data to enable further analysis, however major progress has been made on a new network analysis platform called NAVI (Network Analyse and View). This incorporates our strategic Network Constraint Early Warning System (NCEWS) and includes a full LV connectivity model to manage LV networks as LCT adoption increases and customer behaviour changes.

Case Study: Service Cables

It is possible for losses in service cables to be accurately calculated using smart meter data combined with GIS data. Using this method (with estimated data) worst-case service cable losses are estimated to be 310kWh per annum. This represents a capitalised value of £420. At this value, it is economic to utilise higher-rated service cables where higher loading is foreseen due to the uptake of LCTs. This gives a much clearer understanding of the size of service cables for new build properties and has allowed us to update our policies.

As reported in tranche two, our analysis has shown that the greater the level of disaggregation the greater the value from smart meter data. Whilst we now have the tools to undertake a loss-inclusive approach to service cable replacement, a service cable-specific loss value requires access to individual smart meter data linked to a property. Currently, DNOs are not permitted disaggregated data to an individual customer level. Full clarity on aggregation requirements for privacy are being discussed currently and this is expected to inform future service cable replacement policy. We have developed data analysis methods that allow mixed simulated and real data models, which will bridge some of the gap.

We will continue to review the business case for service cable upsizing in RIIO-ED2, supported by access to smart meter data. SPENs Losses team and Smart Meter Data team will continue to share ambitions and requirements as we deliver our Data Privacy Policy.

The requirements for smart meter data analysis tools to enhance the visibility of LV network losses are now well understood due to our LDR initiatives. Since tranche two, the Smart Meter Data team have been considering the ongoing development plan for NAVI modelling tools, this includes the functionality to meet our Beyond LDR objectives.

For example, in future we will use smart meter data to establish voltage pattern recognition algorithms that can define property phase connectivity and improve visibility of phase connectivity throughout our LV networks. The effectiveness of this work will depend on the level of smart meter penetration and access to data.

Our investigations also show that using a time step of less than half an hour may be necessary to determine LV losses accurately. This is certainly true at a disaggregated level, and particularly in sections of the network with fewer customers and less natural demand diversity. While the availability of real data grows, we have established methods to generate and in the absence of disaggregated data estimated smart meter data within a mixed simulated and real data environment.

In addition to phase connectivity, we aim to distinguish between technical and non-technical losses in the LV network using network impedance and topology data. The extent to which this is possible will be revealed as greater levels of smart meter data become available after implementation of our smart meter Data Privacy Policy.

3.4 Non-Technical Losses

Our extensive revenue protection activities have given us a better understanding of the nature of electricity theft in our network and assist in locating electricity theft. We have developed in-house data analytics capability and an internal Theft Propensity Model that enhances the data we already receive via the Theft Risk Assessment Service (TRAS) Expert Group led by Electralink (now part of the Theft Issues Group).

Smart meter data is also key to identifying non-technical losses. Via LDR initiatives, we developed Smart meter data analysis tools to explore demand patterns across approximately 4,000 smart meters that illustrated the broad range of annual demand profiles using day-by-day granularity. This;

- Identified high and low demand outliers that may warrant further investigation.
- Examined the extent and impact of missing data and how it may be managed.

Since tranche two we have progressed our understanding through engagement with Smart suppliers, including British Gas and Utilita, to establish suitable alerts that requires further investigation. More about our new processes because of this understanding are discussed in Section 5.

From our parent company Iberdrola, we have access to non-technical loss detection algorithms that allow energy balancing (difference in power or energy at the secondary substation compared to the total metered data at point of load) or data-mining (looking for a reduction in metered power or energy consumption). These techniques rely on high penetrations of smart meter data on the SPD and SPM networks; as above, the level of penetration required before detailed network studies can be carried out is subject to ongoing investigation.

3.5 Holistic Consideration of the Network

Holistic Losses Consideration

As deployment of distribution-connected generation continues, managing the distribution / transmission interface is increasingly challenging, in particular, the NGESO (National Grid Electricity System Operator) is facing voltage control challenges.

In our tranche two submission, we reported on investigations into whole system operating regimes and how we are considering the management of boundary conditions utilising DG for a losses-inclusive optimised regime with the NGESO. This may reduce requirements for reinforcement on the transmission network even if losses within parts of the distribution network increase.

The impact on distribution network losses was calculated across the power factor range +/-0.90 with the base case reflecting current operating conditions. Dependent on the operating regime, studies estimate that SPM network losses may increase by up to 5.5GWh/year, and SPD by up to 3.3GWh/year.

This learning is currently being applied and developed as part of our investigations for the Reactive Power Services being tendered by NGESO. Distributed Generators on the 33kV and 132kV network can apply to absorb (or inject) reactive power to relieve voltage constraints on the transmission system. Recent modelling has confirmed that transmission losses will go down, and distribution losses will go up because of these schemes. We are currently reporting our findings with National Grid Electricity Transmission (NGET) and sharing our models to understand the balance between the different system losses further.

There is currently no mechanism for the resulting increase in system losses to be considered by the generator in its application. However, for the upcoming Static Reactive Power Service in the Mersey area from 2022-2031, there is still scope to ensure losses are accounted for. 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.

3.6 Regulatory

Collaborative Approach

Since tranche two, in our position as chair of the TLWG, we have championed the improved understanding of losses incentives. The Group has reviewed different approaches to how losses management should be incentivised and has also commissioned independent technical experts WSP to investigate best practice and make independent recommendations for future loss incentive mechanisms. This looks at the current incentive approaches in the context of the low carbon transition and collated information on different incentive structures in transmission and distribution markets internationally for comparison.

Different approaches were evaluated against criteria based upon the following guiding principles:

- Incentivise the economic and efficient management of losses;
- Balance between today's and tomorrow's customers;
- Harmonious with other incentives and revenue streams;
- Efficient to operate and practical to implement.

The CBA-Based incentive scored the highest out of each incentive mechanism, highlighting its flexibility and usability to incentivise losses. The Reputational incentive also scored highly with slightly more weaknesses compared with the CBA-Based incentive, but with the benefit of encouraging innovative approaches. The final two mechanisms, the Measured Output-Based incentive and DNO Procurement of Losses, scored poorly showing that they had considerable drawbacks compared with the CBA and reputational approaches.

The work found no clear evidence to support a measured output-based incentive, in fact, previous models have led to undue rewards and penalties and suitable targets being difficult to establish. Given the impact of LCT uptake on losses it is not appropriate to use historic losses to set future targets.

Holistic Losses Consideration

The report also found that many of the contributing factors influencing the volume of network losses are not directly within the control of DNOs, for example, the consumer-led adoption of renewables and variations in patterns of electricity consumption have significant impact on LV losses. Future regulatory approaches must reflect the ability of the DNO to manage losses.

3.7 Beyond LDR

We have made significant and continued progress in our own and industry understanding of the level and sources of losses in our networks throughout the LDR programme. There is still more we intend to do, however. Our priorities beyond the LDR are as follows:

- Efficiently facilitate the transition to Net Zero through the electrification of heat and transport, and decentralisation of generation to accommodate renewable technologies, by operating more flexibly and with greater levels of utilisation. Optimising the level of losses on our network through design and operation to meet these objectives and deliver greatest overall customer benefit.

- Use our new understanding of losses on our LV, HV, EHV and 132kV networks in the development of our RIIO-ED2 business plan. Specifically, identifying and evaluating options for assets with higher than normal losses, reducing phase imbalance in rural HV networks and using smart meter data to facilitate the Net Zero transition efficiently.

- Continue to use our new processes and analytical tools to further our understanding as more smart meter data becomes available. Specifically, we will use smart meter data to establish voltage pattern recognition algorithms to define phase connectivity and distinguish between technical and non-technical losses in the LV network using network impedance data. This will continually refresh our understanding of the scale of electricity theft. We will maximise the value from smart meter data after our Data Privacy Policy is implemented.

- Focus on losses in discussions with NGET and NGESO regarding Reactive Power Services, to ensure losses are holistically considered.

- Continue to work with the TLWG and Ofgem to monitor relevant international regulatory mechanisms and to develop future incentive mechanisms for losses management.

4 | Stakeholder Engagement & Sharing Best Practice

We have continued our strong focus on stakeholder engagement, liaising with existing and new organisations who can contribute to our understanding and management of losses. We have seen a successful collaborative approach amongst DNOs via the TLWG and have widened our engagement with key stakeholders, organising Teach-Ins with Ofgem, presenting at industry forums and sharing learning with international delegations. We continue to host a dedicated Losses website[2] to inform interested customers of our Losses Strategy and LDR work, and to seek feedback from them.

Key Improvements during LDR

- **ENA Technical Losses Working Group:** By convening and chairing this Group we have provided a platform for DNOs to discuss and share best practice. As a group, we commissioned key pieces of work relating to the impact of the Low Carbon Transition on Losses and evaluation of a RIIO-ED2 regulatory mechanism.
- **Revenue Protection Services:** Our industry leading approach to working with law enforcement agencies has led to higher detection of cannabis farms in our licence areas and is now stretching beyond on own licenced areas with awareness sessions undertaken in Greater Manchester.
- **Loss Adjustment Factors:** Our initiatives under LDR have increased our awareness of the impact of 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.

4.1 ENA Technical Losses Working Group

Collaborative Approach

At the beginning of RIIO-ED1, we recognised that a key opportunity to optimise GB wide distribution network losses is through industry-wide collaboration. Prior to RIIO-ED1 there was no platform for DNOs to discuss the issues related to understanding and managing technical losses. Given the significant changes all network operators are facing we viewed this as a key enabler to developing best practice, reducing duplication and sharing learning. To address this gap, we established the TLWG which now forms the hub for all discussions regarding technical losses.

In our tranche two submission, Ofgem sought further clarification on the outcomes of this working group. Therefore, an overview of the benefits and outcomes are as follows:

4.1.1 Leadership

Since its creation, we have led this group, chairing the meetings and providing extensive support via our Losses Team. DNO representation and input at the meetings has been consistently high with all companies recognising the importance, changing landscape and impact of network losses on customers and the environment. NGET have also been a key member of the Group.

4.1.2 Sharing of Best Practice

Although the LDR is a competitive process, many of our initiatives have involved on-going and open discussions with other DNOs. We have maintained an industry initiatives matrix, which gives visibility of individual DNO activities across Losses Strategies and LDR submissions. Whilst there were many common initiatives within Losses Strategies (e.g. early replacement of high loss transformers), the LDR initiatives were innovative and varied. This matrix, and presentations at the TLWG, allowed us to explore UKPN's MAAV initiative and assess its viability for our own licence areas (details in Section 6).

4.1.3 Collaborative Studies

The TLWG has been focused on increasing the understanding of losses given the network challenges currently faced and commissioned highly informative and relevant studies on the impact of Low Carbon Technologies on losses (evidenced in Section 3), developing common processes for assessing losses, and investigating regulatory incentive structures to encourage losses management (evidenced in Section 5). The Group is extending this work to develop engineering guidance documents relating to losses.

4.1.4 Dissemination

The group has continued to share findings with Ofgem, providing Teach-In sessions and feedback. The TLWG engage with wider external audiences through presentations at industry conferences to raise awareness of network losses and advocate a greater industry focus.

Since tranche two, we have presented papers on advanced modelling and LCT impacts at the 2019 LCNI, including digital audience participation, and at the international CIRED conference.

[2] https://www.spenergynetworks.co.uk/pages/what_are_we_doing_about network_losses.aspx

4.2 Engagement on Non-Technical Losses

4.2.1 Revenue Protection

An industry leading initiative was to embed a full-time member of staff permanently within Merseyside Police to counter electricity theft. Given the success of this initiative to address losses theft and the potential safety implications, we have maintained this arrangement and are actively continue to pursue a similar initiative with Police Scotland.

As discussed in Section 3, 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.

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 to develop our data analytics capability. We now have a firm knowledge of the data analytics processes which involve considerable network monitoring. Our strategy for the deployment of secondary substation monitoring in the remainder of RIIO-ED1 and for 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.

We previously advised that 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.

We have previously reported on the awareness sessions we run to disseminate learnings of our Revenue Protection team, this is an area where we continue to be active and more detail is provided in the following case study.

Case Study: Awareness Sessions

A key function of the Revenue Protection team is to facilitate awareness sessions, to encourage multi-agency support to tackle non-technical losses further. Examples of recent awareness sessions 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 working relationship with Liverpool Housing Trust because of this.
- We continue to participate in the Scottish Power 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.
- As well as the TIG, we attend the quarterly Theft Best Practice Forum to assist other parties in all matters 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 are contributing to a book on the dangers of electricity meter interference for primary-school children, recognising the importance of early education to improve safety around electrical equipment and prevent future occurrences of theft.
- 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.

4.3 Holistic Assessments

Holistic Losses Consideration

Delivering holistic solutions, intended to accommodate distributed generation or load customers without incurring reinforcement on Transmission or Distribution networks, may involve an increase in losses for one or more network stakeholder. Our LDR modelling initiative on voltage optimisation helped us to understand the interactions with other networks and the impact of others on our own network losses.

For example, flows on the transmission network can impose parallel power flows through the SPM network, thereby increasing losses. Similarly, losses on the distribution network may also be incurred by managing conditions at the transmission interfaces caused by transmission connected generation.

This information is helping us to engage with NGESO and NGET, and embedded generators to identify holistically considered losses-optimising regimes. These investigations have now been transferred to the ENA Open Networks Project[3], as we identified overlap between the two pieces of work.

We now seek to establish more procedural bilateral discussions with NGESO and NGET for the holistic consideration of losses, such as regular losses management meetings with the SPM and SPD system design teams. This will make a co-ordinated approach to losses management BAU during the transition to Distribution System Operator (DSO), and ongoing decentralisation of renewable generation under the Net Zero transition.

4.4 Smart Solutions

Utilising smart solutions to address constraints on the networks has the potential to increase losses. For example, to ensure the most efficient solution is implemented we must assess the value of losses when determining the cost of procuring flexibility services from our customers.

During 2019, we launched competitive tenders for flexibility services in 10 locations across SPD and SPM. Responding to stakeholder feedback, we were the first DNO to issue site-specific pricing signals. To do this we developed a valuation model that would calculate the true cost of flexibility services.

A simple model comparing the cost of the two solutions does not provide the full value and neglects several important factors, including the costs of losses. Increased utilisation will increase losses, especially when compared to the level of losses if new lower loss equipment where installed as part of a traditional reinforcement scheme. This must be considered fully to ensure the true cost of flexibility services is compared to the cost of a conventional solution.

A more detailed description of our model can be found on our website[4]. We seek feedback on this approach and are also leading, along with ENWL, the Open Networks product looking to develop a common Valuation Model Link above.

4.5 Influencing Customer Behaviour

Customer and Stakeholder Engagement

In our tranche one submission, we included 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 result 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.

4.6 Connection Customers

As part of our LDR initiatives, we have considered how customer connections affect losses and provided information on a customer's likely site-specific Loss Adjustment Factor (LAF) at the outset to allow them to consider losses as part of their connection decision.

[3] *https://www.energynetworks.org/electricity/futures/open-networks-project/*
[4] *https://www.spenergynetworks.co.uk/pages/flexibility.aspx.*

Another recent development has been in relation to the Balancing and Settlement Code, specifically 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 have instigated discussions with Elexon with a view to reviewing BSCP128 and assessing alternative options for site specific LAFs.

4.7 International Engagement

In our tranche two submission, we reported on our presentation of our LDR initiatives to a wide audience at the 24th International CIRED Conference[5] in June 2017. This led to direct engagement from TEPCO (Tokyo Electric Power Company) and a bilateral losses workshop in November 2017. We remain in contact with TEPCO and are currently awaiting the learning of their field trials into a Central Voltage Control System[6].

As another positive consequence of our wider communication strategy, through the Scottish Government, we were contacted by an energy delegation of the Nigerian Government who requested an overview of the GB challenges regarding network losses. We hosted a bilateral workshop in May 2019 which was very well received. The challenges in Nigeria are considerable, especially regarding non-technical losses and there was great interest in the activities of our revenue protection team, the role of smart meters and secondary monitoring in identifying losses and the losses impact of the Net Zero transition.

Figure 6: Losses Team meeting the Nigerian Government delegation

4.8 Beyond LDR

Our engagement with stakeholders and sharing of best practice have had a sustained and positive impact on the understanding and management of losses. We believe there is significant benefit to our customers, our communities, industry and the international community because of our actions. We will continue this approach beyond the LDR. Our main objectives are as follows:

- As a DSO responsible for delivering the Net Zero transition we will engage with stakeholders including TOs, NGESO, aggregators and customers to ensure that DG and LCT load growth is accommodated through holistically optimised system design and operation, inclusive of losses.
- We will continue to work with Ofgem to share our findings and analysis for an appropriate approach to a regulatory mechanism for RIIO-ED2 via the RIIO-ED2 working groups.
- We will continue to lead the TLWG as we look to develop standard engineering documents and practices. The collaboration and sharing of best practice within the group to-date has been a clear success. We will also continue to present on and raise the profile of network losses at key industry events, and with international partners.
- We will continue to provide clear input to the Open Networks project which provides an additional route to stakeholders who will be impacted by new network solutions. We will incorporate stakeholder views to influence how policies and processes are developed, and ensure losses are appropriately considered as part of this work.
- We will inform our RIIO-ED2 strategy for deployment of secondary network monitoring equipment with outputs from the Theft Propensity Model and industry forums on revenue protection to identify cases of illegal abstraction early.

[5] http://www.cired-2017.org
[6] Field demonstration and evaluation of centralized voltage control system for distribution network, Watanabe, Miyata (TEPCO), Itaya, Takano (Mitsubishi Electric). CIRED 2017

5 | Processes to Manage Losses & Proposals for RIIO-ED2

This section provides clarity and further evidence of the processes that have been considered and adopted when managing losses on our network. This includes how we have considered best practice, both nationally and internationally, and using work completed under our own LDR initiatives. We will discuss the processes we have now put in place plus those that we plan to feed into RIIO-ED2, particularly those involving the use of smart meter data to manage losses.

Key Improvements during LDR

- **Managing losses in complex networks:** By developing new tools that allow enhanced network modelling based on a 'bottom-up' approach, a more accurate and granular value for losses is now considered when making new design or reinforcement decisions.
- **Theft Detection:** Our theft detection practices remain industry leading, and we have made continued improvements to our Theft Detection methods over the course of LDR. We are now delivering better quality leads and have sustained high levels of detection.
- **Regulatory Mechanism:** We have championed the development of potential incentive mechanisms that most effectively drive the continued minimisation of losses.

5.1 Changes Following LDR Activities

5.1.1 Network Design Policies

The importance of managing losses is now widely recognised, we acknowledge that technical losses are an unavoidable consequence of operating the network but understand that they warrant significant consideration when making investment decisions. Our network philosophy is to consider the whole-life cost and benefit of all solutions, including the cost of losses, and to make informed decisions which are of the greatest benefit to our customers.

We already have an ambitious losses strategy, which considers all reasonable measures that can be applied to reduce losses and adopt those measures that provide benefit for customers. For context, our strategy looks to address several design policies, including:

- Accelerate the replacement of pre-1962 distribution transformers
- HV main line new build and offline rebuilds to be constructed using larger conductor

Where the cost benefit to the customer was not clear, investment decisions are made on a case-by-case basis, for example:

- Project specific evaluation of installing larger cross-section cables on new circuits
- Project specific evaluation of early replacement of higher-loss assets during planned activities such as OHL refurbishment and rebuild

Throughout RIIO-ED1, we have taken the societal cost of losses into account when evaluating network options using the Ofgem CBA template. However, at the start of RIIO-ED1, we did not have the tools to quantify losses associated with specific network solutions to maximise these planning processes. A considerable amount of work on enhanced network modelling has been done under the LDR to understand these losses better.

5.1.2 Losses Policy

Our Losses Strategy is a comprehensive document and contains important messages. In order to ensure that those messages can be simply and easily communicated, we have developed a Losses Policy that clearly articulates the actions we expect our staff to take in the day-to-day activities where they can have an impact on reducing both technical and non-technical losses.

Supporting both the Policy and Strategy, we have developed supplementary material to help our staff implement our vision to consider all reasonable measures that can be applied to reduce losses and to adopt those measures that provide a benefit for customers. In addition to providing a generic methodology for loss assessment, it also provides methods, and examples, where a more detailed assessment may be required, for example:

1. Line loss factor calculations.
2. An approach for selecting conductors.
3. Transformer loss calculations.
4. Practices in Network Operations to control losses, e.g. load balancing, phase imbalance correction and optimising voltage levels.

Many of our technical policies and procedures are currently being updated as part of their normal review cycle. As changes are being made, where appropriate specific reference to relevant aspects of the Losses Policy will be included.

5.1.3 Modelling Complex Networks

Enhanced Network Modelling

Prior to work undertaken as part of the LDR, our losses modelling traditionally used a 'top-down' approach to quantify losses across voltage levels (Losses = Energy In – Energy Out). This calculation was based on metering data and estimations of demand based on consumption records, which were prone to significant inaccuracies. With this historic approach, the network could not be accurately disaggregated into subsections and a portfolio of assets could not be ranked based on the losses incurred on each asset. Where losses interventions needed to be studied in more detail, network analysis and modelling studies have historically been restricted to small scale models with a limited number of network operating conditions, typically reflecting times of peak demand or generation. This has made determining the loss characteristics of the SPM area particularly challenging, as for a meshed network the whole network needs to be considered

Case Study: 'Bottom-up' tool for modelling HV, EHV, 132 kV network losses

A 'bottom-up' model automates modern power systems analysis tools to assess the network in a much more granular manner and to derive losses in each individual asset. It applies half-hourly demands at all locations in the network where these are known. Where half-hourly demands are not available, the tool utilises defined profiles or disaggregates the supply in-feeds.

This new approach gives much more detailed information on the losses characteristics of the network, which facilitates the identification of high loss circuits and network components. It enables increasingly complex networks to be designed and operated with tighter operating margins, leading to opportunities for improved loss management.

As a result, we now have losses information by network group and at an individual asset level. Our ability to consider our planned network throughout all operating periods in a year is delivering a reduction in network losses through our ability to optimise how we operate our assets. This tool is now being used to support the following processes as BAU:

- **Reinforcement Schemes:** Assessing reinforcement scheme designs
- **Load Growth Management:** Selection of appropriate solutions to manage load growth whilst considering losses impact.
- **Customer Connections:** Enabling detailed consideration of losses in customer connection design (load and generation)

Recognising that more advanced tools were required to help quantify losses, we engaged power system specialists, TNEI, to consider national and international best practices in the development of an advanced network modelling tool, and have investigated, designed and prototyped a more advanced 'bottom-up' modelling approach.

For RIIO-ED2 we will now look to use this tool to go beyond what is currently BAU. We will identify the network assets with disproportionately high losses. This will be subject to detailed cost benefit analysis, bundled and optimised with a range of investment drivers to deliver proactive replacement programmes which are in our customers interests.

5.1.4 Phase Imbalance

As mentioned in Section 3, we have developed and implemented a modelling tool to assess the extent and location of phase imbalance on rural HV networks. This modelling tool utilises readily available network metrics to identify feeders that are likely to exhibit high imbalance and has significantly reduced the need for monitoring. This now allows us to conduct scenario assessments when considering reinforcement decisions and to include phase re-balancing within our investment decision criteria.

5.1.5 Theft Reduction

Increased Revenue Protection Activities

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

In SPM, we continue to engage with Merseyside Police to combat illegal abstraction. Throughout RIIO-ED1 we have embedded a member of staff full time within the Merseyside Police, this has led to sustained losses identification estimated to be worth at least £4m every year[7] and benefits all suppliers operating on the network. This long-term partnership will extend into RIIO-ED2.

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

[7] *Based on 16p/kWh and extrapolated for 12 months.*

5.1.6 Substation efficiency

Improve Substation Efficiency

It is important to recognise where some interventions are not suitable for our distribution networks, or, at least, it is not yet appropriate to implement. For our tranche one submission we identified a number of projects recovering waste heat from substations. We sought to understand the range of technical challenge and feasibility of retrofitting heat exchangers to existing equipment and identified candidate sites for trial. However, data from temperature and humidity monitors installed during Q3 2017 have not supported a convincing case to proceed with trials due to low thermal differentials.

Further consideration of the proposed trial sites demonstrated limited heat recovery potential and, significantly, safety concerns in retrofitting systems into smaller primary distribution transformers – the basis of our study. Overall, the schemes were not considered economically viable. Other network operators have drawn the same conclusion on heat recovery[8].

Whilst an extensive trial will no longer be actively pursued, we will however continue to engage with stakeholders on heat recovery and remain open to proposals where a demonstrable financial and safety benefit to the customers can be realised.

A further initiative was looking at reducing the electricity used by distribution substations – both through improved efficiency and self-sufficiency. Our substation auxiliary/domestic demands (e.g. electricity used for lighting, space heating, equipment cooling and oil pumps) are registered as unmetered supplies, they are unavoidable and offer improved network performance; maintaining reasonable ambient conditions for indoor equipment improves equipment reliability and maintains condition. However, minimising substation auxiliary power consumption will reduce overall network loading, and therefore losses.

Substation self-sufficiency through the installation of low-carbon, embedded generation is currently not viable: there is limited opportunity to export power and the low potential utilisation is not economic. Additionally, a number of substations did not have access to ground or roof space for the installations of solar panels.

A proactive approach to monitoring substation efficiency and adopting solutions where the cost can be reasonably justified will continue as BAU. As the costs of photovoltaics and energy storage systems decrease, retrofits of embedded generation may prove economically viable in future and the opportunities for new build sites are also under investigation.

Extra efforts have also been invested into ensuring substation equipment itself is more efficient, as this demonstrates better value for money for network customers. In addition to proactively replacing transformers as part of our baseline strategy, following development with manufacturers, we are now procuring amorphous steel core transformers as a matter of course. We revised our internal transformer specification to recognise the total cost of ownership when making procurement decisions which includes an increased £/MW Loss Coefficient, in line with ENA TS 35-1 on Distribution Transformers.

These transformers have a significantly reduced no-load loss compared to non-amorphous steel core transformers. We have fully integrated this into BAU and understand this to be a leading approach from engagement with the TLWG.

5.2 Preparations for Smart Meter Data

Innovative use of Smart Meter and Network Data

Under the LDR, we have developed tools which directly compare secondary network monitoring data with Smart Metering data. This allows us to better quantify and compare differences between energy supplied and energy metered in local areas of LV network.

This functionality fed in to the development of our NCEWS, designed specifically to identify and manage potential network constraints e.g. thermal, voltage, fault level and high losses as LCTs become more widely adopted.

The system utilises GIS data and an enhanced connectivity model together with smart meter data to increase the visibility of changing demand patterns, including identifying the emergence of LCT hot spots where LV main and service cable upsizing may offer whole life cost savings. This functionality will feed into our RIIO-ED2 investment planning.

[8] *https://www.northernpowergrid.com/asset/0/document/4799.pdf*

Our NCEWS losses analysis functions have now been successfully integrated into our new LV network analytical platform called NAVI. Major progress has been achieved on the NAVI platform which can also now facilitate analytics to better quantify losses. Our new smart meter data management IT system, EnergyIP, is almost ready for integration of smart meter data, although final testing is required once sufficient data is available.

We are currently embedding NAVI as the principal platform for LV network design within BAU and innovation project use. NAVI, and its losses calculation capability, is a fundamental component of our RIIO-ED2 HV and LV Network design strategy to design a network which can accommodate LCT adoption and the Net Zero transition.

Further details on the tools used to utilise smart meter data can be found in Appendix 3.

5.2.1 Technical Losses

The NAVI platform will form the basis of our LV network constraint assessments (including losses) in the remainder of RIIO-ED1 and for the preparation of our RIIO-ED2 plans. This will be aligned with our network asset health index assessments and network performance characteristics to identify network investment opportunities which offer customer benefit. The NAVI platform will be used to compare viable solutions inclusive of whole life losses costs.

We are preparing to use smart meter data for the following specific actions:

- To prioritise proactive service cable and LV main reinforcement.
- To identify areas of rapid growth (e.g. LCT clusters) or unusually high network utilisation, without requiring additional network monitors to be installed. Reinforcement will be prioritised by the network planning teams using BAU processes.
- To inform stakeholder co-operation to shift or reduce loads.
- As electric vehicle technology is rolled out, to enable consideration of how network usage may be incentivised to maximise capacity and minimise losses.

In preparation for RIIO-ED2, we will further evaluate the effectiveness of data simulation approaches, combined with real smart meter data to trial losses management actions.

We have also previously presented a method for reducing technical losses through detection of LV fuse failures using LV monitoring data. LV fuse failures in an interconnected network do not always interrupt supplies but do increase losses through increased circuit loading. We have further developed algorithms to use voltage drop detection for the early identification of LV fuse failure. We intend to use voltage profiles from smart meter data and substation monitoring to test this voltage analysis method before fully integrating this approach into NAVI and providing the information to our operational engineers.

Additionally, we are reviewing options for losses informed active network management decisions, this requires a fully maintained impedance model within our Network Management System (PowerOn). Deploying an impedance model in PowerOn requires significant investment and would currently offer limited operational improvements. However, in the context of the Net Zero transition, we are assessing the benefit of using network management and nearer-real-time information for deployment in RIIO-ED2 to improve our real-time understanding of losses (levels and locations) to inform automated operation philosophy.

5.2.2 Non-technical losses

Improve Quantification of Non-technical Losses

We have been developing our Theft Propensity Model, which drives the actions we take in identifying and preventing theft, implementing multi-factorial pattern-detection algorithms to identify suspicious profiles. During the tranche two period, we met with suppliers, as discussed in Section 4, and improved this model further and it is now delivering better quality leads to suppliers. In every case where a supplier terminates an illegal abstraction customer our customer base benefits from a reduction in both non-technical and technical losses.

As also discussed in Section 4, we have been engaging with our parent company Iberdrola to study international best practice in the detection of non-technical losses from smart meter data to advance our Data Analytics capability. We will replicate this process in the UK following smart meter rollout and availability of smart meter data.

We have also assessed the level of monitoring required to identify other cases of non-technical losses. Iberdrola is a member of the CIRED working group on network monitoring, and we have taken learning from international best practice and Iberdrola's Spanish DSO has implemented power line carrier (PLC) technology between smart customer meters and secondary substations metering. The smart meter and secondary substation meter values are sent to a central system to perform balancing calculations. This allows secondary substations with high losses to be identified for inspection and determination of the cause of the losses. Due to limited smart meter data availability, we have not yet been able to trial this approach within the SPM or SPD areas. The algorithms to make this comparison are included within the NAVI platform and will be refined through learning from Iberdrola trials.

Other processes to address non-technical loss include engagement with councils and housing trusts in the SPD Fife area, where we have now set up processes for local authority housing officers to follow when entering a property that enable them to detect suspected meter tampering or meter error.

We have refined and embedded processes to tackle unregistered MPANs and confirm inventories for unmetered supplies. These are now BAU.

5.3 Continued Evaluation of Current Best Practice

5.3.1 International

Collaborative Approach

Iberdrola is an active member of the CIRED Working Group on Losses Reduction. This international group is primarily engaged in reviewing European practices in the measurement, management and mitigation of distribution network losses. The scope of work has been broadened to a worldwide perspective where information was available. A final Working Group report on the Reduction of Technical and Non-Technical Losses in Distribution Networks was published in November 2017. We have worked with our Iberdrola colleagues to capture best practice losses management and mitigation techniques to inform the approaches and processes we have adopted and plan to implement.

5.3.2 National

We will also continue to be a fast follower of best practice from our DNO colleagues. For example, through the TLWG we are observing the December 2019 results of SSEN's LEAN LCNF project on Transformer Auto Stop Start (TASS) processes for reducing network losses.

SSEN has reported total energy savings of over 100 MWh from two trial sites to date, and good trial performance. As SSEN has provided the TASS Evaluation Tool to all DNOs, we are completing an assessment of our own network with a view to executing trials of this process and delivering viable investments under our RIIO-ED2 plans.

5.4 RIIO-ED2 Losses Incentives

Prior to RIIO-ED1, Ofgem indefinitely suspended the DPCR5 measured incentive mechanism (Losses Rolling Retention Mechanism) due to data volatility and an inability to link changes in losses to DNO actions.

During RIIO-ED1, Standard Licence Condition (SLC) 49 ensures DNOs maintain losses as low as reasonably practicable and ensures they comply with their DNO Losses Strategy.

The leading factor influencing losses is customer demand. If peak demand and duration increases or reduces, technical losses will vary significantly. This is outside of DNO control though it has a direct consequence on network losses, and customer bills.

As reported in Section 3, in RIIO-ED2, we anticipate that under an efficient Net Zero transition, technical losses within distribution networks will increase with the electrification of heat and transport, and the increase of low-carbon distributed generation. A future losses incentive must therefore focus on the management of losses that are within DNO control and be harmonious with other RIIO incentives to ensure a holistically efficient approach is taken. For example, to not discourage flexible or smart solutions where these are in the best interests of customers.

We have led the TLWG to commission independent reports on regulatory approaches for managing network losses in the context of the low carbon transition[9]. Outputs of this work and our LDR initiatives have determined that a mechanism focussed on measured losses would suffer from:

- An inability to link DNO actions to changes in losses,
- Ongoing volatility and uncertainty in the measurement of losses, and
- An inability to apply benchmarking due to the impact of Net Zero on network loading.

Following review of the independent report, we endorse an approach which combines coordinated losses appraisals (through investment decision CBAs) with a new reputational measure; this approach is similar to the RIIO-ET2 Sector Specific Methodology Decision.

5.4.1 CBA Losses Appraisal

- Losses must be considered within investment decisions as part of our existing RIIO-ED1 licence requirements and within DNO Losses Strategies, the current arrangements form a solid basis for a refined ED2 approach.
- Ensuring DNOs are accountable for solutions which holistically consider the value of losses ensures volatility and factors outside of DNO control do not influence the mechanism whilst still incentivising the economic and efficient management of distribution network losses to their optimum level.

5.4.2 Reputational Losses Measure

- A reputational performance measure would transparently allow stakeholders to review DNO actions for managing losses and to track DNO progress against their strategy commitments, with limited risk of unintended consequences or interactions with other incentives.

We continue to work closely with the RIIO-ED2 working groups to collaboratively develop a Losses mechanism which will incentivise the economic and efficient management of losses through the low carbon transition.

5.5 Beyond LDR

As the LDR progressed, we have considered and adopted numerous processes to better managing losses on our network, and assessed best practice, both nationally and internationally. We have a Losses Policy that states the company's vision and clearly articulates the actions we expect our staff to take in the day-to-day activities where they can have an impact on reducing both technical and non-technical losses. We will continue to progress our management of losses in future and our plans include:

- Formalising the use of enhanced network modelling processes within our network design policies. We will work more closely with ICPs and IDNOs to establish better losses management processes in RIIO-ED2, through application of common processes.
- Continuing to implement and improve theft reduction processes in both licenced areas.
- Conducting further modelling of specific LV network assets using the NAVI tool, including service cables and LV mains. We will maintain processes for service cable upgrade and replacement setting out exactly how to analyse the network and conduct losses-informed cost benefit analysis. In preparation for RIIO-ED2, we will generate simulated smart meter data where real smart meter data is not available.
- Reducing technical losses by replacing faulted LV fuses; identified using LV main voltage drop profiling where there is sufficient smart meter data.
- Continuing to assess the cost-effectiveness of using network management and nearer-real-time information to improve real-time understanding of losses (levels and locations) and using this understanding to inform operational policies. We will develop the business case for a trial of TASS in our network areas.
- Work with Ofgem to develop an appropriate Losses regulatory mechanism for RIIO-ED2.

[9] *https://www.energynetworks.org/electricity/engineering/technical-losses/*

6 | Innovation & Incorporation as Business as Usual

Many of the approaches discussed throughout this submission have been innovative or have incorporated innovative aspects – our LDR initiatives were new and inventive by nature.

Our tranche one submission looked to extend the boundaries of our losses management capabilities through these initiatives. We progressed our successful initiatives into BAU and in this submission describe the overall progress over the course of the LDR. We present new innovative approaches identified since our tranche two submission and identify which will be taken through to the remainder of RIIO-ED1 and into RIIO-ED2.

Key Improvements during LDR

- **We have transitioned innovation from our LDR Initiatives into BAU:** e.g. innovative LV losses modelling techniques developed under LDR have been incorporated into the new LV analysis tool NAVI.
- **We have reviewed wider industry innovations ready for adoption in RIIO-ED2:** e.g. we have investigated the MAAV, an innovative technology being used by UKPN, to understand the benefit in our own network.
- **We continue to seek new innovations:** e.g. we are in early discussions with OEMs and generators to investigate power factor correction at the point of connection through innovative new reactive power control technology.

6.1 Innovation Adopted as BAU in RIIO-ED1

We have developed a number of innovative processes throughout the LDR with the following adopted as BAU.

6.1.1 Suite of modelling tools

Enhanced Network Modelling

Major progress has been achieved on the NAVI tool to better measure losses. The consideration of losses has been an additional activity under the LDR.

Initially, we identified and developed an approach to determine service cable losses from smart meter data under Initiative 1. This has demonstrated how smart meter data can be combined with GIS data to determine a range of typical service losses values, enabling the quantification of potential losses savings. We then built this work into our ongoing Smart Meter project NCEWS and discussed our intentions for this to become a BAU process available to network planners. Since tranche two, our losses-enhanced NCEWS analysis functions have now been successfully integrated into our new LV network analytical platform called NAVI and is now integrated into business systems for use as BAU.

Our innovative tool for modelling complex networks in HV+ networks, developed under Initiative 4, enables much more granular analysis of larger network models and their behaviour patterns. This is in contrast to the traditional approach that made use of smaller, fragmented network models that were only analysed in detail at times of peak demand and peak generation. The tool has been adopted for BAU and is being used to consider losses when undertaking major investment/policy decisions during the remainder of RIIO-ED1 and forward into RIIO-ED2.

In their tranche two decision, Ofgem requested detail on how these schemes will deliver clear benefits in terms of management of losses. In Section 5 of this report, we discuss the specific loss management actions for which our enhanced network analysis and modelling are now being used and the benefits that this will have.

6.1.2 Theft Reduction

In tranche one, we presented a highly innovative working relationship and shared process with Merseyside Police, which involved embedding a staff member, with knowledge of energy consumption patterns, into their business to support their Cannabis Dismantling Team. As reported in tranche two, this approach has been adopted as BAU in SPM. The process used to identify suspicious activity (using the Theft Propensity Model) is under ongoing development. Discussions with Police Scotland are also ongoing to implement a similarly innovative working partnership in Scotland.

Our activity with the Electralink TIG has demonstrated the use of smart meter data analysis to identify demand outliers. We have supplied an innovative approach to combine smart meter data with weather data to provide a degree-hour metric as an additional consumption comparator to be used by the TIG. This is now included in our detection processes as BAU.

6.2 Innovation Identified for RIIO-ED2

Under the LDR, we have also reviewed wider industry innovations ready for adoption in RIIO-ED2. We continuously seek new innovation and have identified further opportunities. The following innovations have been identified from our work on LDR initiatives.

6.2.1 HV Rural Network Phase Imbalance Losses

Our modelling approach using GIS data to model potential phase imbalance and consequential losses, which reduces the need for monitoring. Results will be validated to develop the business case for BAU deployment within RIIO-ED2 planning and asset management functions.

6.2.2 MAAV (Mobile Asset Assessment Vehicle)

In tranche two, we reported a new initiative, intending to undertake a business case review to assess the viability of using the Power Survey Company (now part of Osmose Utilities Service) Mobile Asset Assessment Vehicle (MAAV) – a mobile system for detecting the electric field emitted by faults, and hence losses, caused by a live contact voltage. This is an innovative technology that has been adopted widely in the United States and in the UK by UKPN.

LV system faults can result in publicly accessible structures, such as streetlights, becoming live. Typical faults, such as the loss of the neutral within a service joint, can result in contact potentials of anything from a few volts to over 230V. These voltages can correspond to stray currents (losses). A report by Princeton University, commissioned by UKPN, estimated that there could be over 81GWh/yr of contact voltage loss in SPD and 31GWh/yr in SPM, amount to a societal cost of about £5.5m in total using Ofgem's value for the societal cost of losses.

Whilst UK trials were being conducted with UKPN, we organised a circa 40-mile trial survey in Liverpool City Centre. The system identified a number of issues for further investigation (Appendix 5 includes details on the priority issues). However, the business case review has some significant, unanswered questions that led us to pause with the progress of this technology.

The level of loss-reduction seen in the trial did not correspond to the levels expected in the literature or forecast by the provider. Many of the faults discovered by the technology were within customer premises and although we informed asset owners in all instances, there is no DNO process or funding mechanism to resolve customer-side faults. The rate at which investigations could progress does not allow the MAAV to operate at full capacity. Given that the prospective costs of the technology, a supportive business case could not be developed at this time, though we are willing to investigate further trials in the SPD area.

We are supportive of all successful network innovations and will continue to consider the application of this technology within the business.

6.2.3 TEPCO

In tranche two, we reported on a losses workshop with TEPCO (Tokyo Electric Power Company) at our Prenton office. We followed two investigations as follows:

- Central Voltage Control System: TEPCO reported on a field demonstration of voltage optimisation to reduce losses. Their findings aligned with our LDR tranche one investigations, which built on LCNF project learning to explore how the use of smart meter data can help us recognise network losses alongside capacity. We have been considering the network impacts of adjusting the 11kV voltage using the Automatic Voltage Control (AVC) at the primary substation to reduce losses downstream, and of using smart meter data to explore the degree to which we may expect high loadings during periods of high solar PV. When smart meter data becomes available from our network, this work can proceed.
- Seasonal Normal Open Points (NOPs): TEPCO had analysed how they may optimise HV network loadings by moving the NOPs to reflect seasonal loading. Initial shared research indicated that up to 6% of technical losses might be saved on the parts of the HV network where this can be deployed. Upon more detailed analysis of the GB business case, the effect of the seasonal demand changes in Japan is greater than in the UK at present, largely attributed to a much higher adoption of photovoltaics. There is currently not the required level of evidence for making a BAU change towards seasonal NOPs. However, with photovoltaics, EVs and heat pumps all on course for significant increases in coming years, this is something that will be considered for RIIO-ED2.

6.2.4 Novogrid

In late 2019, we met with Novogrid, who presented the report of a study commissioned to investigate the potential benefit of a visualisation platform (GridViz) and reactive-power control (Q control) automation software at an existing 33kV connected wind farm. The technology estimates in real-time the network conditions at the remote end of the line, and then controls the reactive power output of the wind farm to minimise energy losses whilst maintaining voltage within limits.

The results suggested that the majority of remote network conditions at the nominated site could be estimated with good accuracy. In this case, it is very likely that loss reduction can be achieved by the Q control technology. Based on 2018 data, the report showed a potential loss saving of 430MWh, whilst maintaining the voltage within permissible limits. At the current capitalised cost of losses, this represents a saving of upto £20k per annum.

Trials, additional studies, and monitoring need to be conducted to demonstrate effectiveness. Moreover, there is no mechanism to recoup the costs of this technology until a sufficient period of data monitoring (12 months) has demonstrated its effectiveness, and even then approval of the analysis methods would also need to be established. As discussed in Section 4, we have instigated discussions with Elexon on this matter. We would look to undertake trials to support and work with customers to minimise their losses. This builds on the work of initiative 12 for the remainder of RIIO-ED1 and into RIIO-ED2.

6.3 Beyond LDR

For the remainder of RIIO-ED1 and continuing to RIIO-ED2, we commit to being a fast follower of innovation. Many of the LDR initiatives were new and innovative by nature. Where they have not been adopted, we have reviewed the benefits case and will continue to observe the possibilities of adoption. We also intend to pursue some specific innovations actively. Our continued efforts are as follows:

- Completion of the business case for deploying our new modelling approach for phase imbalance and consequential losses as BAU.
- Continuing to observe the business case for the MAAV and report to the business if this becomes a viable investment.
- Keeping abreast of developments to Central Voltage Control System technologies whilst awaiting smart meter data, and of developments to NOPs routines as the network changes as a result of connection of low carbon technologies.
- Actively investigate and seek to reduce the barriers to adoption of newly discovered losses management innovations, specifically including the reactive power control technology of which we are aware.

7 | Conclusion

This submission provides evidence of our progress in line with LDR expectations on the portfolio of initiatives we presented in our tranche one and tranche two submissions. We have also included details of other activities undertaken with regard to better understanding and managing network losses. We include many examples of how our new knowledge has been translated into action and BAU. Some of our actions in networks loss management are our innovations whilst others are a direct application of new knowledge from understanding best practice elsewhere. We have not completed this work on our own, but have worked with others, including the other DNO groups, NGET, suppliers, other industry parties and our international colleagues.

A final overview of progress of our LDR programme against the Ofgem LDR criteria is given below:

WORKSTREAM		Understanding	Stakeholder	Processes	Innovation
LOSSES DISCRETIONARY REWARD					
Initiative 1	Smart Meter Data analysis systems to reduce non-technical losses	Used example datasets to estimate LV network usage		Developing processes ready for arrival of smart meter data	Innovative methods now incorporated for use as BAU
Initiative 2	Smart Meter Data analysis systems to reduce technical losses	Used example datasets to estimate LV network usage	Liaising with suppliers and our parent company	Developing processes ready for arrival of smart meter data	
Initiative 3	Voltage Optimisation to Improve Network Losses and Load	Better understand potential for voltage optimisation	Held workshops with international network operators	Learning about international best practice	
Initiative 4	Improved Modelling of Complex Networks to Reduce Losses	Stochastic power flows in pockets of the network	Disseminated results extensively	BAU tools to make better losses informed design decisions	Innovative tool now used as BAU
Initiative 5	Improved Modelling of Rural Networks to Reduce Losses	Understand suitable equipment upgrades		Developing processes to plan phase-phase line reconnections	Innovative tool now ready for use as BAU
Initiative 6	Assessment of Power Factor to Improve GB Losses	Initial understanding of level of loss due to power factor was successful. This work is now progressing under Open Networks Workstream 1b.			
Initiative 7	Improved detection of theft through revenue protection	Continually improving understanding of theft patterns with detection	Police, Fire & Rescue, Suppliers, Councils, Housing Associations	Internal process for theft detection is best practice	Innovative approach has become BAU
Initiative 8	Improving Network Loading by Stakeholder Engagement		Proactively engaging across all initiatives		
Initiative 9	Substation Efficiency – Alternative uses for waste heat	Proactively engaging across all initiatives			Improved understanding about the technology
Initiative 10	Substation Efficiency – Monitoring and self-sufficiency	Better understand self-sufficiency measures, but no retrofit PV		Change to processes as a result of business case review	
Initiative 11	Consider case for Mobile Asset Assessment Vehicle (MAAV)	Understand contact voltage faults, further trials to understand loss impact	Learning from UKPN		Relatively new technology in US, very new to UK market
Initiative 12	Early viability of Loss Adjustment Factors (LAFs)		Driven by engagement with generators and Elexon	(Very) early beginnings of future process for site-specific LAFs	Requires cutting edge technology
Initiative 13	SCADA based near real-time losses calculations			In early/preparatory stages	
INDUSTRY COLLABORATION					
ENA Technical Losses Task Group		Impact of Low Carbon Transition	SPEN coordinate and lead ENA Technical Losses Task Group	Standards & Technical Recommendations (& ED2 incentives)	
ENGAGEMENT EVENTS					
Engaging with Stakeholders		Ofgem and Industry Teach-In Sessions	Presentations and Workshops: CIRED, CIGRE, LCNI		

In conclusion, we are proud of the progress we have made in understanding and managing losses since the start of the RIIO-ED1 period. The work done under our original initiatives and as chair of the TLWG pave the way for better losses consideration for the remainder of RIIO-ED1 and into RIIO-ED2.

The LDR has proved a useful mechanism for change and industry has transformed its approach to, and attention on, losses. To meet Net Zero, future losses innovations must now take place as part of the wider business and we have led industry in the development of reporting mechanisms that ensure this is managed and rewarded appropriately.

Appendix 1 | Glossary

Term	Definition
ALARP	As Low as Reasonably Practicable
AVC	Automatic Voltage Control
BAU	Business As Usual
BSCP128	Balancing and Settlement Code Procedure 128
BSP	Bulk Supply Points
CBA	Cost Benefit Analysis
CIRED	International Conference on Electricity Distribution
CO2	Carbon Dioxide
DG	Distributed Generation
DNO	Distributed Network Operator
DSO	Distribution System Operator
EHV	Extra-High Voltage (33 kV)
ENA	Energy Networks Association
ENWL	Electricity North West Limited
EV	Electric vehicles
GB	Great Britain
GIS	Geographic Information System
GW	Gigawatt
HP	Heat Pumps
HV	High Voltage (11kV)
ICE	Incentive on Connection Engagement
IDNOs	Independent Distribution Network Operator
ICPs	Independent Connection Provider
kV	Kilovolt
LAFs	Loss Adjustment Factors
LCNI	Low Carbon Network Innovation (conference)
LCNF	Low Carbon Network Fund
LCTs	Low Carbon Technologies
LDR	Losses Discretionary Reward
LEAN (LCNF project)	Low Energy Automated Networks (LEAN) (SSEN project)
LV	Low Voltage (425V)
MAAV	Mobile Asset Assessment Vehicle
MPAN	Meter Point Administration Number
MV	Medium Voltage
MW	Megawatt
NAVI	Network Analyse and View
NCEWS	Network Constraint Early Warning System
NGESO	National Grid Electricity System Operator
NGET	National Grid Electricity Transmission
OEM	Original Equipment Manufacturer
OHL	Over-Head Line
PLC	Power line carrier
PV	Photovoltaics
RIIO-ED1	RIIO Electricity Distribution (Price Control) 1
RIIO-ED2	RIIO Electricity Distribution (Price Control) 1
SLC	Standard Licence Condition
SO	System Operator
SPD	SP Distribution plc
SPEN	SP Energy Networks
SPM	SP Manweb plc
SSEN	Scottish and Southern Energy Networks
TASS	Transformer Auto Stop Start
TEPCO	Tokyo Electric Power Company
TIG	Theft Issues Group
TLWG	Technical Losses Working Group
TOs	Transmission Owner (Operator)
TRAS	Theft Risk Assessment Service
UKPN	UK Power Networks

Appendix 2 | Enhanced Modelling of Complex Networks

Our losses modelling traditionally used a 'top-down' approach to quantify losses across voltage levels. This used metering data to calculated Losses as Energy In minus Energy Out. This simplistic technique is prone to various sources of inaccuracy as outlined in the table below. It is also unable to test the impact of loss interventions in detail. With this approach the network cannot be accurately disaggregated into subsections and a portfolio of assets cannot be ranked based on the losses incurred on each asset. Where losses interventions needed to be studied in more detail, network analysis and modelling studies were restricted to small scale models with a limited number of network operating conditions, typically reflecting times of peak demand or peak generation.

More advanced tools were developed as part of our LDR tranche one . One new tool employs a 'bottom-up' modelling approach. A 'bottom-up' model automates modern power systems analysis tools to assess the network in a much more granular manner to assess losses in each individual asset. It applies half-hourly demands at all available locations in the network where these are known. Where half-hourly demands are not available, the tool can either use defined profiles, or disaggregate the supply in-feeds. The advantage of a 'bottom-up' approach is that it gives a much more detailed information on the network, which facilitates the identification of high loss circuits and network components amongst other things.

A comparison of 'bottom-up' and 'top-down' modelling tools is summarised in the table below, indicating clear benefits of our enhanced modelling capability.

	Bottom-Up Modelling	Top-Down Modelling
Benefits	• Uses more network metrics so more accurate • Enables validation with network measurements • Enables identification of high loss network components • Detailed modelling of loss intervention methods • More accurately captures impact of generation and customer profiles • Captures power flows and losses of complex networks and configuration changes • Suitable for networks with limited available data	• Simple model to use • Rapid assessment of losses • Suitable for networks with limited available data
Disadvantages	• Greater complexity • Significantly more data required • More time consuming and much more computationally intensive • Set up and model connectivity crucial	• Susceptible to metering uncertainty • Small changes in metering volumes or accuracy introduce significant inaccuracy in losses • Very sensitive to inaccuracies due to billing and settlement or time shift • Limited representation of variability of losses across the network • Not always able to capture impact of embedded generation • Interdependencies not captured e.g. operating conditions • Not possible to test impact of loss interventions in detail

[10] *https://www.spenergynetworks.co.uk/userfiles/file/Improved_Modelling_of_ Complex_Networks_to_Reduce_Losses.pdf*

Using the Model in Our Networks

The model has full detailed coverage of the SPM 132 kV / EHV networks down to the LV side of the 33/11 kV transformers (performing 17,520 individual power-flow analyses, using circa 35 million data elements). In SPD a range of the 33 kV GSPs have been selected and studied in detail. A range of both interconnected, and radial HV networks have also been studied. From these tranche one studies, we now have losses information by network group and down to an individual asset level – some highlights are presented in the body of this report.

Our ability to consider our planned network throughout all operating periods in a year is expected to deliver a reduction in network losses through our ability to optimise how we operate our assets. This will include changes to network configuration and the target set points on power flow controllers and voltage control devices. This tool has been adopted for BAU use and will be used to consider losses when undertaking major investment/policy decisions during the remainder of RIIO-ED1 and forward into RIIO-ED2.

The tool has also been to assess the impact of distributed generation in our networks. An example sensitivity analysis was presented at CIRED 2019 (see Figure 1 for a summary poster). Two types of substation were considered: a heavily interconnected substation group, common to SPM, and a radial 33 kV network, common to SPD. The SPM network includes around 70 MW of embedded generation, the SPD network around 60 MW, both predominantly wind. On a case by case basis (highly dependent on network configuration), there were some times in the year when losses were reduced as a result of increased embedded generation. However, both cases predominantly saw increase in losses throughout the year with the generation on. The losses with generation connected to the network were also found to be highly stochastic. Throughout the year, the losses reached up to 200% compared to with the generation off, with the situation becoming more prevalent during typically high-demand periods such as the winter months of November to January, as can be expected.

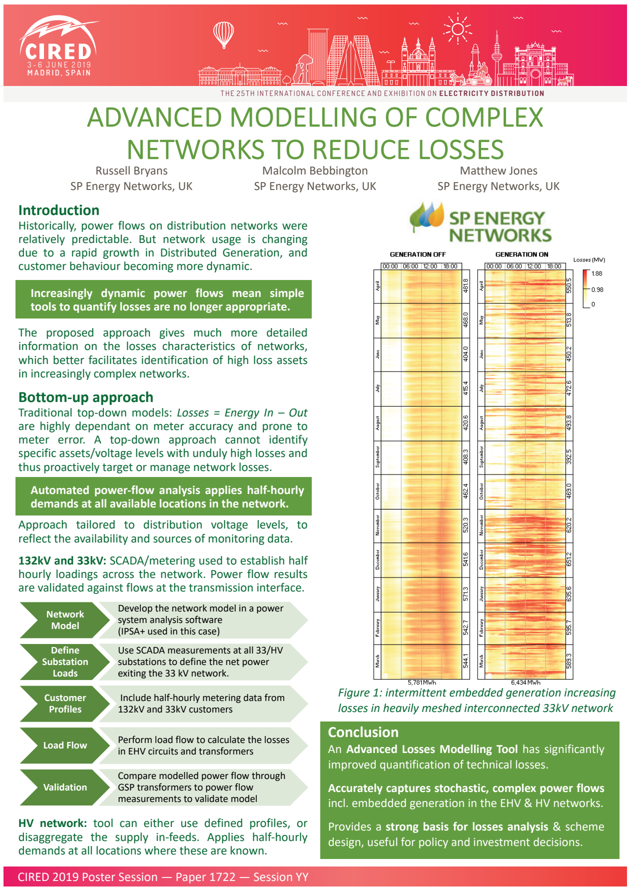


Figure 1: Summary poster of CIRED Advanced Modelling of Complex Networks to Reduce Losses paper

Appendix 3 | Smart Meter Data

This appendix is a refresher of our tools that rely on smart meter data, which have been used to build up our understanding of losses and can now be used with smart meter data as it becomes more prevalent to inform network policy in RIIO-ED2.

Demand Profile Outliers

This work was completed as part of our Initiative 2 "Development of Smart Meter Data analysis systems to reduce technical losses". For this work, we analysed meter data to establish whether smart meter data can be used to improve losses understanding and decision making for the LV networks.

The analysis conducted makes use of the UKPN Low Carbon London dataset – it is relatively large (it includes metering data from over 4000 customers recorded at 30 minute intervals for over one year) and available under the Open Government Licence.

The data was reduced to one calendar year (2013) and excluded any with missing hourly records to avoid 'false positives' in our filter where meters showing low annual consumption may be erroneously included as outliers. The two vertical red lines are drawn at the 5th and 95th percentiles for our dataset to remove the small population of customers who consume a lot less or a lot more than the typical customers in this dataset. The median annual consumption of our sample dataset is 2965 kWh and it is expected that most of the customers in this dataset use mains gas for space and water heating. The data is shown in Figure 2.

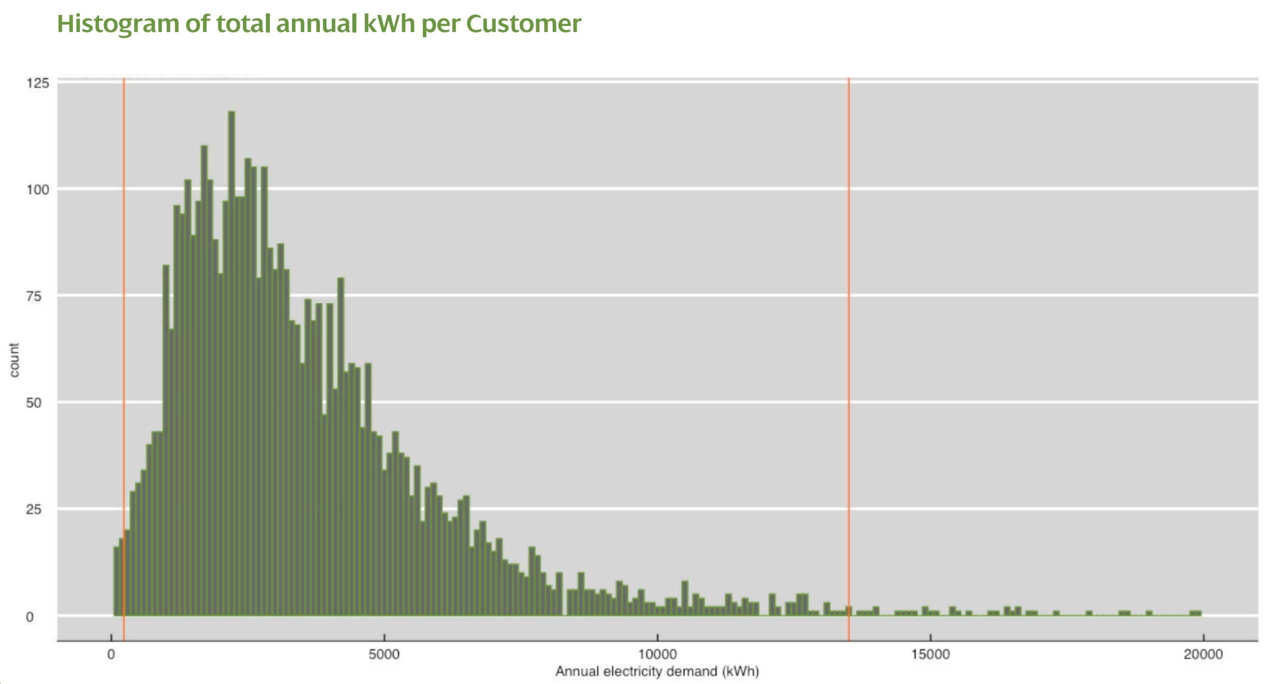


Figure 2: Histogram of total annual kWh per Customer

Simplistically, customers who exhibit much higher than normal annual demands (i.e. those at the RHS of the graph) are likely to be the cause of higher than normal losses on the LV network. Similarly, customers with very low annual demands (LHS of graph) may include those involved in non-technical losses.

For technical losses, the level of smart meter deployment will influence whether the measurements of typical LV and HV feeder demands will continue to rely on Elexon profile data instead of accurate half-hour readings.

High Demand Outliers

High demand customers are likely to result in high losses on their individual service cables. We investigated the annual demand profiles for three high demand outliers; this data is shown in Figure 3. Each graph shows the hourly load over a year where days of the year are arranged on the y-axis and hours of each day on the x-axis.

Annual profiles of highest kWh consumers
Colours indicate kWh demand per hour (Source of data: UKPN LCL dataset)

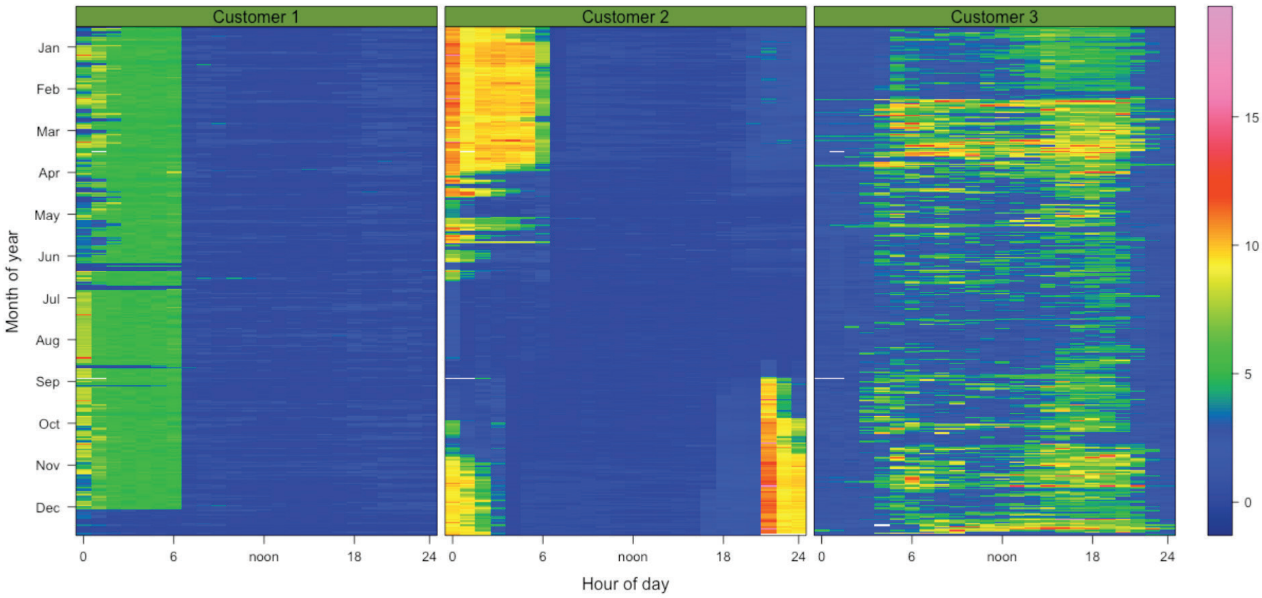


Figure 3: Annual profiles of highest kWh consumers. Colours indicate kWh demand per hour (Source of data: UKPN LCL dataset).

These examples show how some consumers incur high night-time demands consistent with high levels of Economy 7 heating demand. Customer 1 (left) appears to have little or no seasonal variation, whilst night-time demand for Customer 2 (middle) appears lower during the summer months. However, Customer 3 (right) appears not to have the same night time demand requirements. With this type of analysis, behavioural signatures can be used to help identify where customers have, for example, adopted low carbon technologies. Load profile analyses are expected to support DNOs in the early identification of hot spots in electric vehicle charging, heat-pump demand or roof-top solar PV generation. Clusters of low carbon technologies can significantly increase network utilisation and can lead to significantly increased losses.

Service Cable Loss Analysis

Initiative 2 also looked at technical losses on service cables, and how we can use disaggregated smart meter data to identify and prioritise for replacement the service cables with the highest losses. Service cables are the distribution network cables that connect individual customers to the LV network – they are the final bit of distribution cable between the distribution network and individual customers.

For the analysis, this initiative made use of disaggregated smart meter data available from our EnergyIP system and asset data from our NCEWS system. The initiative works by combining these two data sets – when the known energy consumption from a smart meter is combined with the known technical characteristics (e.g. resistivity and length) of the service cable that suppliers that meter, then the annual technical losses for that service cable can be calculated. This identifies services that may experience higher than average losses, depending on either each customer's individual load profile or on a probabilised load profile for predictions. This information can be used to make losses-informed replacement and design decisions.

The web-browser view for service resistance is shown in Figure 4, using a synthesised dataset for LV services connected to LV feeders, each associated with one HV feeder.

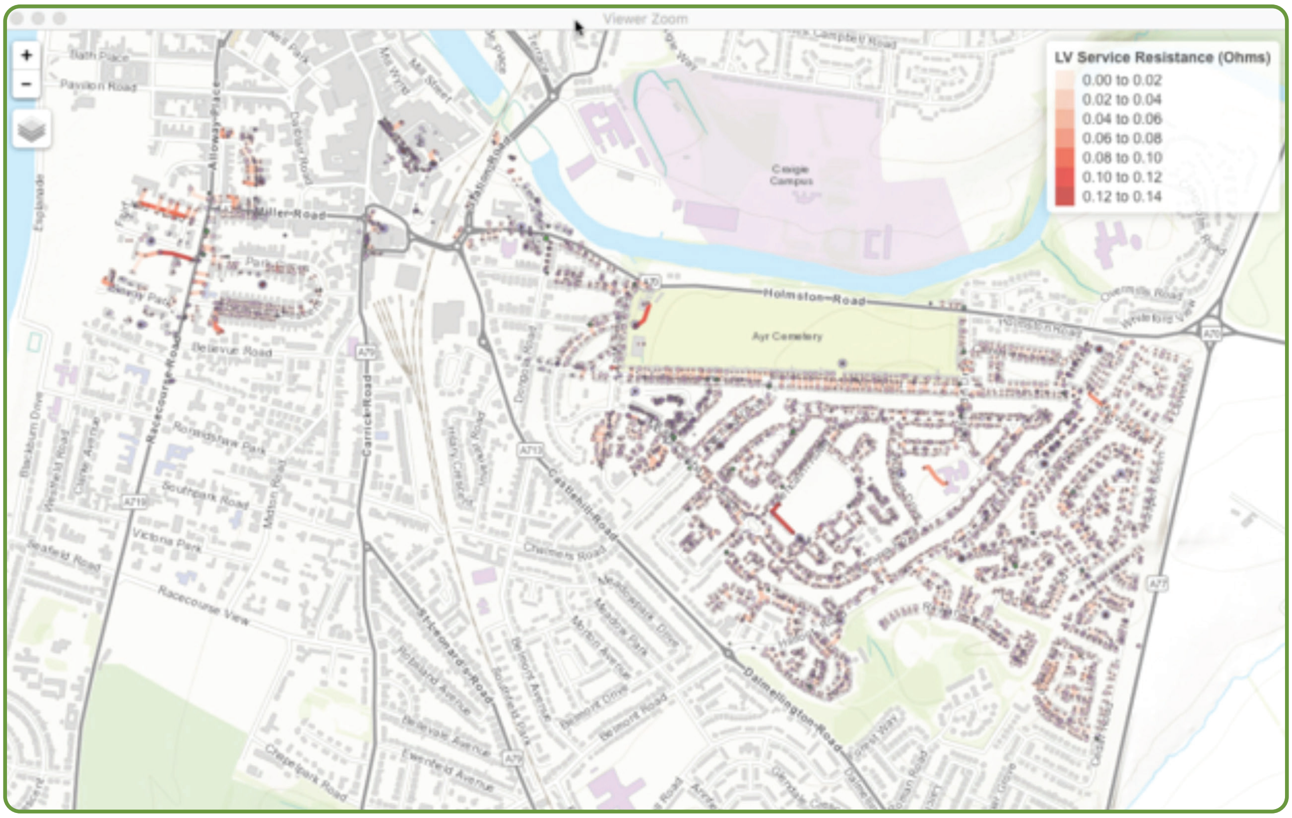


Figure 4: View of tool that shows service cable losses

Fuse Failure Detection

Another indented use of smart meter is to reduce losses through better fuse failure detection.

In the SPM interconnected LV network, each LV feeder may be supplied via up to three different 11 kV/LV substations. LV fuse failures do not necessarily interrupt supplies, but do increase losses and reduce supply security. As no customers are affected, fuse failures can go undetected for extended periods. Earlier detection and resolution of these fuse failures would reduce losses and improve supply security.

Interconnected LV feeders typically exhibit lower variations in voltage along their whole length. A fuse failure at one infeed will cause the voltage drop on that part of the LV feeder to increase beyond a 'normal' range. Our smart meter data processing systems will enable the monitoring of the voltages reported by smart meters near each of the HV/LV substations. These are the locations closest to the fuse failure where the voltage variation is expected to be greatest, and therefore these present the best opportunity for detection.

The voltage boxplots shown here indicate how a fuse failure may be detected as a change in characteristic voltage, shown in the graph below to occur between months 9 and 10 at one site. Algorithms to monitor the variation in voltage must consider sufficient duration to be able to differentiate between typical network reconfiguration and fuse failures, and must be able to adapt to variations in customer behaviour.

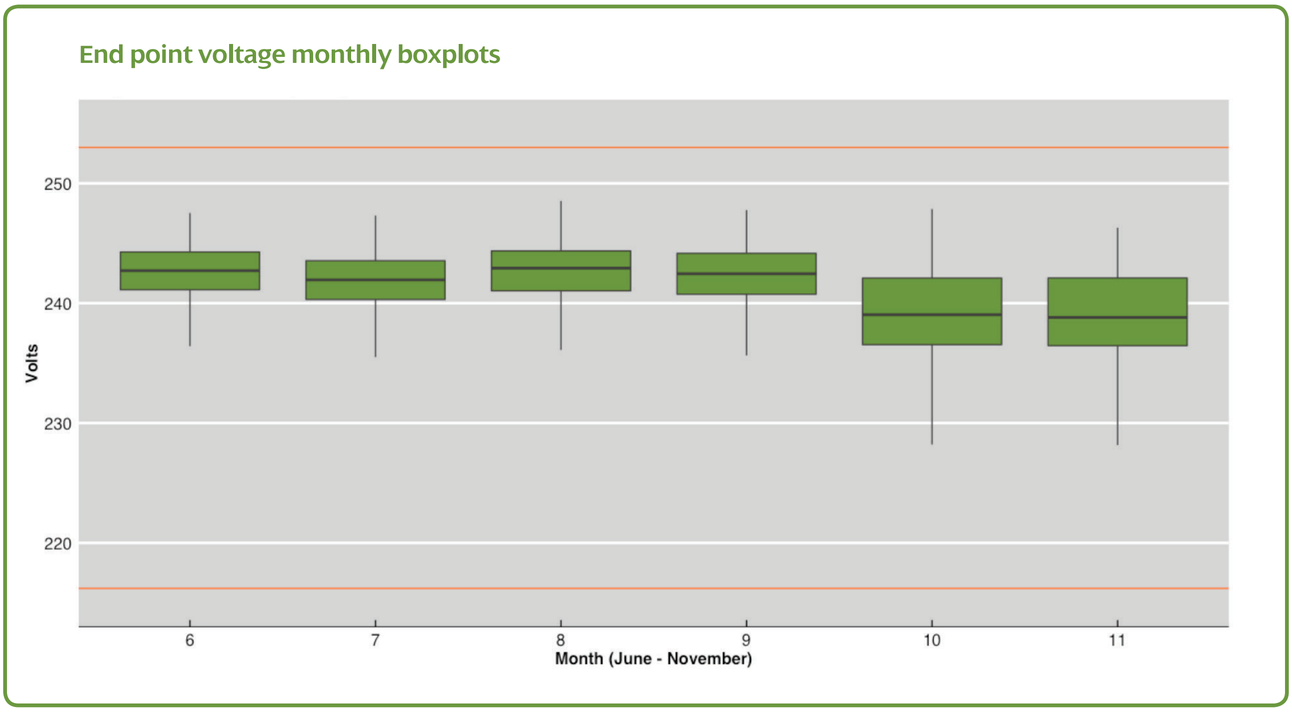


Figure 5: End point voltage monthly boxplots – UKPN dataset

We have established a prototype methodology based on smart meter data from the UKPN LCL project. Application and refinement of this methodology will occur as smart meter data becomes available, specifically at locations in close proximity to the HV/LV substations.

Degree-Hour Outliers

Research shows that dwellings that have the poorest energy efficiency tend to have the greatest increase in electricity consumption as ambient temperature decreases . By comparing hourly electricity consumption with ambient temperature, we can use this known relationship to identify those dwellings that exhibit the poorest energy efficiency. This knowledge can be used to provide targeted information to customers on how they can increase their energy efficiency. If these customers improve their energy efficiency their electricity consumption will reduce, which will result in reduced technical network losses. There will be a direct customer benefit in the form of a lower energy bill, and it may also reduce network peak demands, which may help defer or avoid demand constraint driven network reinforcements. This knowledge can also be used by a DNO for network planning purposes (for example, knowing how much DSR might need to be contracted to be ready for a cold weather period).

We have shared this analysis method with the TRAS Expert Group for consideration as an additional means of identifying some meter tampering behaviour (possibly in response to high energy bills) and also assist with tracking customer energy efficiency where this assists with ECO obligations. In addition, those low-efficiency, high demand customers generally contribute to network peak demands; consequently any improvement in energy efficiency may help defer or avoid network reinforcement.

[11] The background to degree-day analysis is summarised at: Degree-days: Theory and application, TM41:2006, CIBSE. There is also an earlier Fuel Efficiency Booklet published by the Government Energy Efficiency Office (1993) available at: http://www.cibse.org

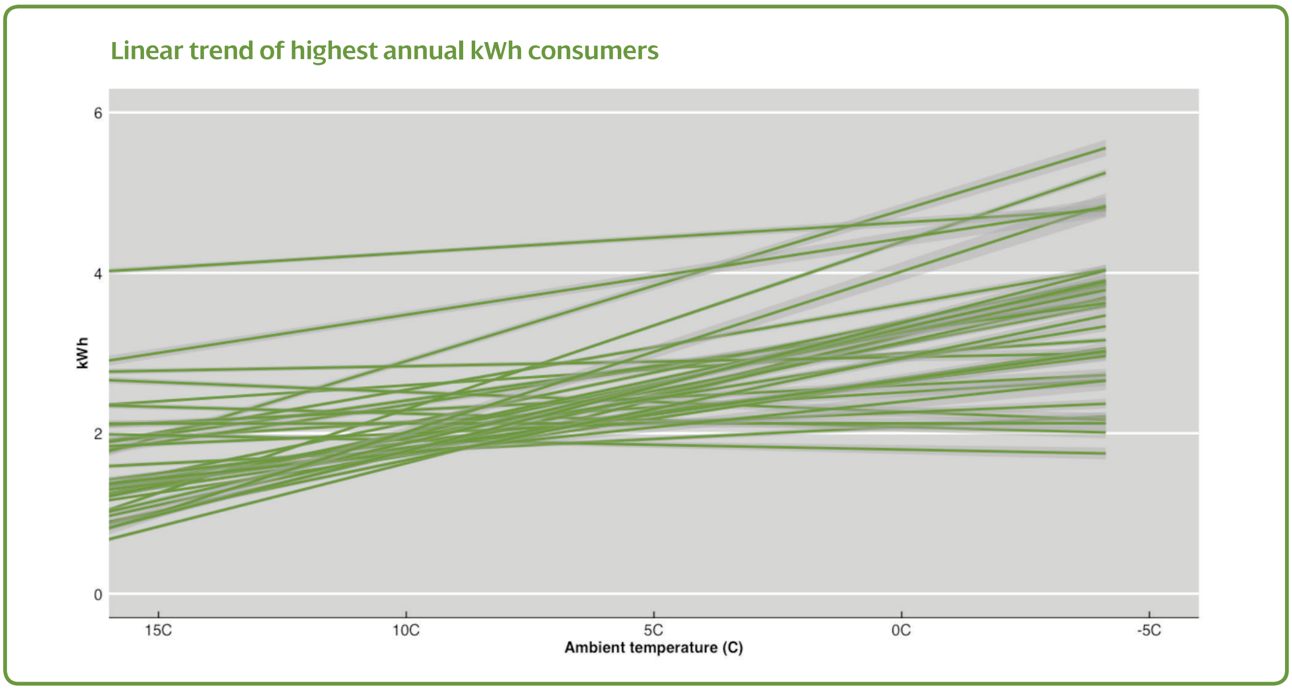


Figure 6: Linear trend of highest annual kWh consumers

This graph shows rising electricity consumption compared with reducing ambient temperatures. Each line represents an individual customer. For this work we selected customers with highest annual kWh demands as it is those customers who cause some of the highest losses on our LV network.

Each of the lines represents a linear regression of the hourly consumption compared with the hourly ambient temperature. The steepest of these lines indicates a customer whose consumption increases significantly as ambient temperature decreases. Some of these customers show an hourly consumption of about 5 kWh during the coldest periods. These periods are also likely to coincide with peak electricity demand on our LV and HV networks so that any improvement in energy efficiency and/or other demand-side management method will be most effective if deployed at these consumers' premises.

Appendix 4 | Regulatory Mechanisms

As discussed in the body of the report, independent technical experts WSP have worked with the ENA Technical Losses Working Group (TLWG) to produce a report that investigates best practice and makes independent recommendations as to future loss incentive mechanisms. Through the stakeholder engagement and literature review carried out, a list of four possible incentive mechanisms was identified, as summarised Table 1 below.

Incentive Mechanism	Description	Examples
Reputational	DNOs assessed against a written submission which describes the actions taken to improve network losses and gives a scoring	• GB Losses Strategy • GB Environmental Discretionary Reward (Electricity Transmission)
CBA Based	CBA tools used to include financial & environmental cost of losses within network investments and to establish design policy. Allows DNOs to make investments based on life time cost.	• Australia • Sweden (TSO) • GB (RIIO ED1 Submissions)
Measured Output Based	Targets set for each DNO for losses (% of MWh) during a price control period. Financial incentive or penalty applies depending on the measured performance against the target	• Sweden • France • GB (DPCR4) • UK (NTS Shrinkage) • Denmark
Procurement of Losses	DNOs incentivised to reduce the price negotiated to procure energy to cover network losses (£/kWh0.	• Norway • France

Table 1: Summary of possible losses incentive mechanisms (Source: WSP report)

The viability of each of the incentive mechanism described above was evaluated against a set of criteria based upon the following guiding principles in agreement with the TLWG:

- Incentivise the economic and efficient management of losses;
- Balance between today's and tomorrow's customers;
- Harmonious with other incentives and revenue streams;
- Efficient to operate and practical to implement.

The full results of the evaluation are provided in the Report.

[12] WSP, CEP023 Technical Losses Mechanism Study, Development of a Losses Incentive Mechanism: Phase 1 Final Report. Produced for ENA, September 2019 (https://www.energynetworks.org/assets/files/CEP023%20Technical%20Losses%20Mechanism%20Study%20Final%20Report.pdf)

CBA Approach Options

The following extract is taken from the summary report :

It is suggested in the Report that if a CBA based approach is used to incentivise a reduction in network losses it must generate informative and accurate results whilst also being practical to implement for GB DNOs. Furthermore, it should be consistent across all DNOs, where possible, to allow performances to be benchmarked and compared during RIIO-ED2. A CBA calculation and testing methodology is proposed in Section 7 of the Report. It is also proposed that a flexible CBA tool, based on a modified Ofgem template, is developed.

It is proposed in the Report that the CBA incentive mechanism would use CBA tools to indicate which network investments have a positive Net Present Value (NPV) and represent value for money for GB electricity consumers.

Regulatory governance could be created that clearly sets out the process that DNOs must follow to secure any additional funding required to make the network investment that results from the new CBA tool suggest would be optimal. A reputational incentive approach would play an important role in this as well, providing evidence and reasoning behind investment scenarios. Two potential options for funding mechanisms include:

- A funding pot to be made available within the price control period, which can be used to fund increased capital costs for projects that are shown to have a positive full lifecycle cost;
- A reopener within the price control period that can be used to submit a modified business plan to Ofgem for consideration for a specific area of investment.

The value of funding required would be dependent on a number of factors, including availability of funding and level of appetite to invest to reduce network losses. The funding requirement could be informed by the results of the CBA testing methodology.

Reputational

The following extract is taken from the summary report:

A reputational incentive could be selected alongside a CBA based approach. The potential options for a reputational incentive mechanism are provided below. Further discussion on these approaches is provided in the Report.

[13] *https://www.energynetworks.org/assets/files/CEP023%20Technical%20Losses%20Mechanism%20Study%20Summary%20Report.pdf*

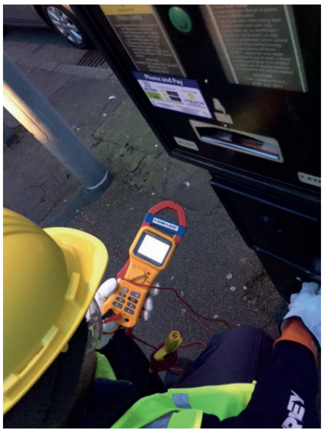
Name	Description	Output	Pros	Cons
Published Losses Strategy – No Scoring	This should be based on transparency, allowing interested stakeholders to form their own views (i.e. progress reported versus the losses strategy).	Report detailing progress against the losses strategy.	No scoring or comparison between DNOs.	On its own, may not provide a sufficient incentive for DNOs to optimise their performance.
Published Losses Strategy – With Scoring	The performance of DNOs could be monitored versus the Losses Strategy and this could be scored (e.g. red, amber, green scoring)	RAG showing how well the DNO met their Losses Strategy commitments.	A measurable incentive without specific financial penalties.	The published losses strategy between the DNOs are likely to be quite different. There will be comparison between DNOs, which has drawbacks.
Published Losses Strategy with agreed areas and elements	The DNO could be monitor versus a set of agreed areas for example understanding of losses, engagement and knowledge sharing BaU integration. Could include output from the CBA incentive mechanism.	Score showing how well the DNO has performed against each of these areas.	A measurable incentive without specific financial penalties. Elements can be obtained from previous incentive schemes.	Difficult to associate elements with a physical number based scoring system, and some of the elements may not be applicable to certain DNOs.

Table 3: Comparison of different reputational incentive mechanism approaches (source: WSP report)

The design of the reputational incentive is to be determined through further discussions with Ofgem.

Appendix 5 | Liverpool Trials of the MAAV

The Mobile Asset Assessment Vehicle (MAAV) is a mobile system for detecting the electric field emitted by faults caused by a live contact voltage, these in turn contribute to network losses. The technology has been developed by Power Survey Company (now part of Osmose Utilities Service) and has been adopted widely in the United States and in the UK by UKPN.



Under our policy of reviewing emerging innovative technologies we organised a ~40mi trial survey in Liverpool City Centre, which identified 27 issues for further investigation. Some examples are observations made during the trial are provided below:

Location 1

At this location, a lost neutral connection on a service cable supplying a street lighting column was identified. The resulting investigation concluded that this was likely at the service joint. The fuse to the lighting column was pulled removing any safety risk and remedial works to the cable joint were completed.
There were no significant losses because of this fault.

Location 2

As above, a street lighting column was identified with a lost neutral connection in the SPEN service joint to the street light. Again, the fuse to the lighting column was pulled and remedial activity scheduled.
There were no significant losses because of this fault.

Location 3

At this location a fault was identified on the steel shutters of a small commercial business. Subsequent investigations determined the fault was on the customers side of the meter.
The inadvertent energy consumed by this incident did not therefore contribute to network losses, though were able to remove the safety risk.

Location 4

As with the first two incidents, there was a fault at a street lighting column on a footpath. The subsequent investigation identified the issue to be internal to the column, the fuses were removed, a caution notice attached, and the local council were informed. The annual losses resulting from this issue were estimated to be in the region of 70MW by the service provider.
This fault was not attributed to the SPEN network.

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