Northern Powergrid

Losses Strategy, October 2023

Executive Summary

Losses are simply the difference between the amount of energy entering the network and the amount of energy drawn out of it. No system can be 100 per cent efficient and losses are unavoidable in distributing electricity. The two main types of losses are:

- technical losses resulting in electricity converted into heat on the network, and
- non-technical losses, generally resulting from metering errors and theft.

For Northern Powergrid, the magnitude of losses equates to roughly two terawatt-hours (TWh) per year, and the associated carbon emissions equates to roughly 94 per cent of our total business carbon footprint (when considering scope 1, 2 and 3; and over 98% when considering only Scope 2 emissions[1]). When expressed as a percentage of the total energy entering the network, losses are approximately six per cent. This energy that is 'lost' needs to be generated, and therefore has a financial and carbon impact. We take our role seriously in ensuring losses are as low as reasonably practicable.

There are aspects of losses management that we can control, and aspects that we can only influence. Recognising that the amount of losses is dictated primarily by the loading placed upon network equipment, and secondly (but to a lesser extent) by the characteristics of the network; it is clear that losses are mainly determined by the energy requirements of our customers. The general rule-of-thumb is that the higher the loading, the higher the losses.

Decarbonisation will result in a significant increase in network loading, and when taking into account that the majority of our existing network[2] will continue to operate well into the future, losses will generally increase[3]. We will therefore only be in a position to directly control/influence a small percentage of losses, primarily when we make changes to our network and install new equipment. Forecasting of losses is challenging; given the key driver of losses is our customers' energy needs; which are subject to significant uncertainty and can vary year-on-year in line with economic activity and weather. As a result, we do not forecast losses.

The most economic and efficient manner of facilitating net zero will generally be to increase network utilisation, and therefore an increase in losses will occur. Facilitating decarbonisation at lowest cost will benefit society and our customers, where an overall reduction in carbon intensity that is supported by decarbonisation will reduce the emissions associated with losses. Network losses are therefore not something that we seek to minimise, but to optimise as part of a holistic asset management approach; which will generally see losses increase in the coming decades, whilst emissions will ultimately tend to zero.

Given that the primary driver of any future change to the overall level of network losses is the changing energy needs of our customers, we recognise there is a significant opportunity for influencing customers and their energy usage (and therefore losses). We will work closely with our customers and stakeholders as part of our commitment to provide support to communities to become more energy efficient. The actions to educate and inform customers about energy efficiency are detailed in the consumers and network - customer service section of our 2023-28 business plan, specifically customer outcomes CO3.1 and CO3.2.

[1] 94% reported as part of regulatory reporting, which includes scope 1, scope 2, and a sub-set of scope 3 emissions.
[2] Consisting of 63,000 substations and over 96,000 kilometres of network.
[3] ENA working group project: Impact of Low Carbon Transition – Technical Losses.

Our track record illustrates our commitment to managing losses. We have undertaken a range of innovation projects that have sought to better understand losses, and have explored new technologies (such as very low loss amorphous core transformers) that could produce a step change in losses performance. We have undertaken actions that are improving losses performance now, and will continue in the future, such as: the use of lower resistance cables at low voltage (LV) and 11 kilovolt (kV), and; the implementation of static voltage optimisation to reduce energy use behind the meter which can also reduce losses[4]. We will be upgrading this to dynamic voltage optimisation during 2023-28 as part of our enabling whole system solutions approach. Whole systems solutions are covered in more detail in the 'decarbonisation – enabling whole system solutions' section of our 2023-28 business plan (see also 'annex 4.3 whole systems strategy').

Our over-arching vision for managing losses is to optimise whole system losses while facilitating net zero:

- **Optimise.** Fully integrating losses into asset management decision making and planning processes means that management of losses does not always mean minimising losses, but instead, optimising losses.
- **Whole System.** A whole system approach is imperative, where increasing distribution network losses to obtain a reduction in transmission losses and overall carbon emissions reduction is a positive outcome.
- **Facilitating net zero.** Through our transition to distribution system operation (DSO), we are committed to a flexibility first approach. The use of customer flexibility and smart solutions will often lead to an increase in network losses, as these solutions typically result in higher network utilisation. From a whole systems perspective this is the right outcome as this in turn unlocks wider decarbonisation at the lowest cost to customers. In turn, the carbon impact of network losses will diminish over time, as we facilitate increasing volumes of low carbon generation required for net zero.

Our Losses Strategy for 2023-28 has taken into account a wide range of stakeholder engagement, and has evolved to reflect the significant challenges and opportunities presented by decarbonisation, DSO, and the new data and technology improvements available through programmes such as our 2015-23 smart grid enablers programme and the national smart meter rollout. Our vision to optimise whole system losses whilst facilitating net zero embodies this evolution.

For our 2023-28 Losses Strategy, we have considered 46 actions to optimise both technical and non-technical losses, along with improving our understanding of losses to further contribute to the evidence base of what we can influence or control. We categorise these actions as potentially having either 'high', 'medium' or 'low' impact on our network during 2023-28, and the estimated range of losses quantification for these impacts is depicted in Table 1. It is worth noting that calculating absolute losses impact or savings are difficult for many of these actions. Where we feel that these savings can be quantified with high confidence, we have included them in this document.

Losses impact categories	Range of losses quantification
High	More than 100 Megawatt-hours (MWh) per annum (p.a.)
Medium	Between 10 MWh and 100 MWh p.a.
Low	Less than 10 MWh p.a.

Table 1: Estimated losses impact of high, medium of low losses impact categories of our actions to optimise both technical and non-technical losses.

We have shortlisted 28 'medium' or 'high' impact losses actions out of the total of 46 actions within our Losses Strategy, which we considered as our main actions, and these are summarised in Table 2. We have also characterised these actions into different action types (continue, consider, expand or adopt), to reflect that some of the actions are already embedded into the business, whilst others are not and may need further development. The full list of our losses actions and action types are presented in Appendix 1, where the '2023-28 Losses Strategy' section of this document provides a more detailed description of all of the actions.

[4] In absolute (MWh) terms, but not in percentage terms.

Ref.	Initiative Group	Initiative	Action Name	Action Type	Losses Impact
1.1.1	Accelerated asset replacement	Accelerated asset replacement	Pre-1958[5] ground-mounted transformer replacement	Continue	Medium
1.1.3			Upgrade unbalanced networks	Adopt	Medium
1.1.4			Upgrade small-section LV overhead conductors	Adopt	Medium
1.1.5			Replace pre-1987 PCB-contaminated pole-mounted transformers	Adopt	High
2.1.1	Data and analytics	Data	Enhanced monitoring	Expand	Medium
2.1.2			Data improvement	Adopt	High
2.2.1		Analytics	Modelling improvement	Adopt	High
2.2.3			Optimising network configuration for a specific loading condition (single time step)	Expand	Medium
3.1.2	Design policy	Specification	Lower loss HV overhead line (OHL) conductors (i.e. AL3 to AL5)	Continue	Medium
3.1.3			**Install Ecodesign Tier 2 transformers** (see note 2)	**Adopt**	**High**
3.1.4			Service connection review	Consider	Medium
3.2.1		Optimal asset sizing	**Install low-loss (i.e. higher capacity) low voltage (LV) cables**	**Continue**	**High**
3.2.2			**Install low-loss (i.e. higher capacity) high voltage (HV - 11 kV) cables**	**Continue**	**High**
4.1.1	Network operation	Static network operation	Static HV voltage optimisation	Continue	Medium
4.1.3			Multi-objective system optimisation of network operation	Expand	Medium
4.2.1		Dynamic Network operation	**Dynamic voltage optimisation**	**Expand**	**High**
5.1.1	Non-technical losses	Energy efficient substations	**Improve the energy efficiency of our substations**	**Adopt**	**High**
5.2.1		Theft	Theft - monitoring data	Consider	High
5.2.2			Theft - tamper alerts	Consider	Medium
6.1.5	Research and development	Investigation / Trial	Alternative transformer technologies	Consider	Medium
6.1.6			Losses price signals driving flexibility	Research	Medium
7.1.1	Stakeholder	Customer energy efficiency	Power factor advice	Expand	Medium
7.1.2			**Community energy coaching (advisors)**	**Adopt**	**High**
7.2.1		Education and engagement	Losses educational material	Continue	Medium
7.2.3			Collaboration, sharing and adopting best practice	Continue	Medium
7.3.1		Expert stakeholder collaboration	Internal stakeholder engagement	Continue	High
7.3.2			Collaborations with academia	Continue	Medium
8.1.1	Whole system	Flexibility optimisation	Embed losses costs in optimising flexibility assessments	Expand	High

Table 2: 28 main actions for our 2023-28 Losses Strategy

Note 1: The 'key actions' are shown in bold-underlined text. The 22 actions that are not covered as part of the key actions will be reported on as part of the higher level appraisal of our Losses Strategy implementation.

Note 2: Action 3.1.3 was originally to install super low-loss amorphous core transformers. We undertook a robust analysis using the Ofgem cost benefit analysis template and this analysis supported the use of amorphous technology in 80% of cases. Because the use of lower loss (amorphous) transformers would provide a net benefit to our customers in that the 29 GWh reduction in losses over RIIO-ED2 2023-28, and the compound loss benefits thereafter, offsets the higher cost, we proposed an ambitious adoption of this technology as part of our 2023-28 business plan submission. We, therefore, increased the unit cost of our secondary transformer replacement to cover the incremental unit cost of amorphous core technology when compared with Ecodesign Tier 2 transformers. Although our Losses Strategy was 'approved' by Ofgem, the increased unit cost was not funded in Ofgem's final determination. Without the appropriate funding to enable the use of amorphous core transformers, it has been necessary for us to revert to installing Ecodesign Tier 2 transformers during 2023-28. Replacement with Tier 2 transformers will still provide an incredible 72 GWh benefit over this price control period (2023-28) and we will continue to investigate the use and benefits of amorphous core transformers in ED2 and consider submitting this as a request in a future price control.

[5] Ground-mounted distribution transformers manufactured before 1958 (termed as pre-1958 transformers throughout this document) have significantly high no load losses, with up to six times more for BS171 type transformer built in 1936 compared to the minimum efficiency level requirement by The Ecodesign Directive from the European Commission known as Tier 2 throughout this document, which took effect in July 2021.

Table 3 below lists the four 'key' actions that will be reported on alongside our wider environmental action plan (EAP), with two of the actions being reported in other sections of our 2023-28 business plan. For simplicity, the LV and high voltage (HV) cable actions have been merged into a single reportable action. The fifth action (regarding community energy advice) is being delivered and reported on as part of the consumers and network - customer service section of our 2023-28 business plan[6]. The sixth action (dynamic voltage optimisation) is being delivered and reported as part of the decarbonisation – enabling whole system solutions section of our 2023-28 business plan (see also annex 4.3 whole systems strategy) and within annex 1.5 detail on our consumer value propositions (CVPs).

Action	Measure (output)	ED1 2015-23 complete	ED2 2023-28 target
EP2.1) Develop and report on our Losses Strategy annually	*Updates issued*	*4*	*5*
EP2.2) Install super low-loss amorphous core transformers (funding for this not provided in ED2 2023-28)	*Units*	*5*	*Action closed (see Note 3)*
EP2.3) Install low-loss (i.e. higher capacity) LV and HV cables	*Circuit km*	*2,909*	*3,400*
EP2.4) Improve the energy efficiency of our substations	*% major substations assessed*	*n/a*	*100%*
Community energy advisors **(see CO3 in the 2023-28 business plan, consumers and network – customer service section)**			
Dynamic voltage optimisation for domestic energy efficiency **(see 'whole systems: dynamic voltage optimisation for domestic energy efficiency' CVP (annex A1.5 detail on our CVPs) and decarbonisation – enabling whole system solutions section of our 2023-28 business plan)**			

Table 3: Key actions and associated performance measures.

Note 1: The Action IDs are those used in our environmental action plan (EAP), and are listed above to enable cross-referencing.
Note 2: The targets with respect to installation volumes of transformers and cables are not driven by losses, and therefore there could be variation against this target during 2023-28. This should not be seen as failure to manage losses, where our commitment is to install the asset that has the lowest whole life cost when including losses.
Note 3: The ED2 2023-28 target for the installation of amorphous core transformers has been reduced to zero due to the funds essential for this work not being granted for the ED2 2023-28 price control. We still plan to replace c15,000 existing transformers (mainly PCB contaminated designs) with Ecodesign Tier 2 transformers.

Our Losses Strategy is a live document, and we will continuously improve it as we undertake further engagement activity, progress our actions and develop our knowledge from the actions we propose.

[6] Specifically, customer outcomes 'CO3.1' and 'CO3.2'.

Summary of losses savings quantification for activities in 2023-28

We originally proposed total cumulative losses savings of up to 320.6 GWh over the course of 2023-28 from our activities that we intended to undertake during 2023-28. These savings are grouped into three main category of activities:

1. activities that are **not driven by losses**, where the activity assumes the minimum specifications are utilised if losses was not a consideration (which includes non-load related and load related drivers; for example, replacing a transformer with an increased size transformer for a load-related driver);
2. the (incremental) **opportunistic** benefit provided from using losses-inclusive specifications for activities that are not driven by losses (for example, using an amorphous core transformer instead of a standard transformer for the transformer being replaced); and finally
3. **proactive** losses activities that we carry out to manage losses (for example, replacing pre-1958 transformers with an amorphous core transformer, where both the driver for the activity and the incremental benefit from the technology choice are both losses-driven).

Given the inadequate unit cost allowance (set by Ofgem in its final determination) for secondary substation transformers, and the resultant decision to no longer use amorphous core transformers, to ensure we can align with the Ofgem allowed unit cost, there is now a lower cumulative losses savings of 291.4 GWh for 2023-28. This is 29.2 GWh lower than with amorphous core transformers included, and this reduction in benefit will also compound beyond the price control for the lifetime of the transformers, typically in excess of 50 years. The proposed activities are summarised in Table 4 below. The benefit from these activities beyond the 2023-28 period was predicted to be up to 107 GWh per annum (with amorphous core transformers), and this future benefit is now expected to be up to (the lower figure of) 97 GWh. This benefit is dependent on the volume of activity undertaken during the 2023-28 period; for example, the number of LV reinforcements that occur, and are subject to change as a result of uncertainty mechanisms. The quantified benefit is aligned to the Northern Powergrid Planning Scenario volumes, where the majority of the cumulative losses savings during 2023-28 is provided by the decarbonisation investment.

Category of activity	2023-28 cumulative losses savings (GWh)
Not driven by losses	184.6
Opportunistic	88.6
Proactive	18.1
Total	**291.4**

Table 4: Summary of losses savings for activities to be carried out in 2023-28.

Introduction

In this section, we will:

- state our vision for our Losses Strategy and discuss how we will realise this;
- summarise the Losses Strategy for 2023-28;
- provide an overview and context for our Losses Strategy; and
- discuss the quantification of losses, which includes the overall distribution across the network and the issues regarding measurement of losses.

Our vision

Our over-arching vision for losses is that we will optimise whole system losses whilst facilitating net zero. There are several key parts to this vision, and we define what each means as follows:

- Optimise. We will seek to find the optimum balance between overall costs, and overall benefits. Figure 1 below shows a simplified example (where only losses is considered as the variable), which highlights that the optimal level of losses mitigation is where the total cost is minimised; and not simply the lowest loss option, which would result in a higher overall cost to our customers. This approach is central to good asset management, and aligns with our asset management system for which we are ISO55001 accredited.

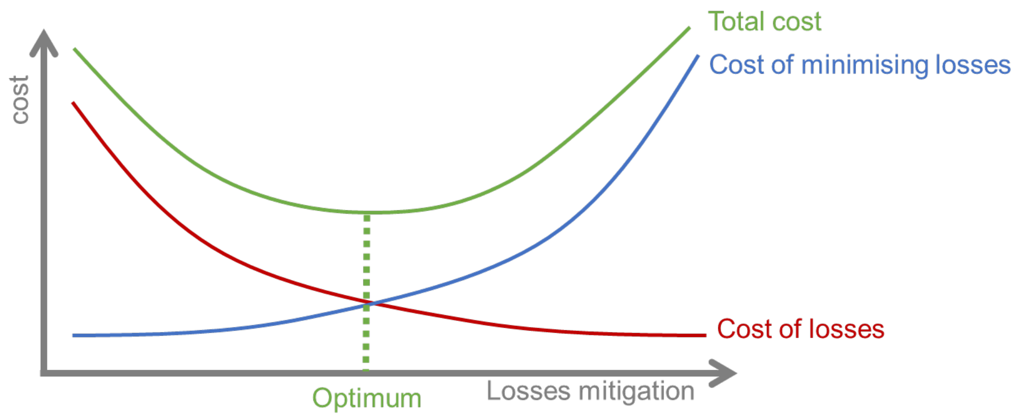

Figure 1: Losses optimisation, balancing cost of losses against cost of losses mitigation.

- Whole System. We will seek to make decisions that take into account all aspects of the electricity system which will ultimately impact our customers. For example, we may take actions that increase distribution network losses slightly; where other benefits outweigh the cost of losses (such as facilitating connection of low carbon technology (LCT) for customers onto the network with minimal network reinforcement). Similarly, we recognise that actions we take can impact others (such as voltage optimisation can improve behind-the-meter energy efficiency), and actions others take can impact network losses (such as customers taking energy efficiency and demand shifting actions can reduce network losses). We therefore believe it is a critical time to educate and engage our customers and stakeholders to ultimately optimise whole system efficiency.

- Facilitating net zero. The most important challenge that we face is to ensure we reach net zero, and to do so in the most cost effective way. All potential decarbonisation pathways are ones which will place distribution networks centre stage, consisting of electrification of transport and heat, together with increasing volumes of renewable generation, and novel technologies such as storage or energy (vector) conversion. In many instances, this is likely to result in a significant increase in utilisation of our network, as customers connect new sources of load (e.g. electric vehicles and heat pumps). Given the plausible range of pathways through which the net zero target could be achieved, we recognise that our role is to facilitate the transition along with the uncertainty (of which pathway will be taken). The outcome of this is that as utilisation increases, losses will also increase. However, the facilitation of net zero takes precedent, and we will take steps along the way to better optimise losses (particularly as the pathway becomes more certain)[7]. Ultimately, facilitation of net zero supports low carbon technologies, where the decreasing carbon intensity of generation will result in less carbon emitted for every unit of energy lost. For a net zero system, there will be no carbon emissions associated with losses.

Our vision for losses is to optimise whole system losses whilst facilitating net zero; this will therefore be incorporated in our business, and embedded in each and every decision we make.

Realising our vision

To realise our vision, we need to embed losses management into our business and general way of working. Specifically this means we will:

- Develop and commit to implementing a Losses Strategy to efficiently manage both technical and non-technical losses on the network over the long term. This includes specific actions and performance measures to track the impact of actions during 2023-28. We will report on our progress against our wide range of 'main actions' (detailed in Table 2) at a high level annually.

- Report on the focussed list of 'key actions' and associated performance measures regularly as a way of transparently showing the impact of our actions during 2023-28. The key actions and performance measures are detailed in Table 3.

- Manage losses across the full range of our engineering activities that aligns with our net zero ambition, underpinned by the actions detailed within this Losses Strategy.

- Expand our engagement and education activity with our customers and stakeholders, whereby enabling our customers to become energy efficient not only saves them money, but also has subsequent whole system (including losses) benefits.

- Fully incorporating the societal cost of losses (cost of energy and cost of carbon) into our decisions, from investment, to network operation. This means that decisions made by us will automatically embed losses optimisation into the decision making process.

- Continue our strategy of not bringing forward work programmes solely to target losses reduction. We do not believe it is justified by the cost benefit analyses (CBAs) we have undertaken. Instead, we will justify improvements in losses as part of investment with other primary drivers. We adopted this approach during 2015-23 to justify targeted asset upsizing, and this will be our approach during 2023-28. The CBA 'inputs' are specified by Ofgem and based on a pre-defined rate of decarbonisation. The (future) energy prices and carbon intensity are based on this rate of decarbonisation and are therefore an important focus area.

- Continue to take on board input and feedback from our enhanced stakeholder engagements to steer and inform our losses management strategy during 2023-28, and building on work done by ourselves and other distribution network operators (DNOs) during 2015-23.

- Continue (and significantly expand) working with our customers, fellow DNOs, partners, academia, industry stakeholders and the wider communities, to:

[7] We will do this by having a 'flexible' business plan to support achieving the net zero target in line with a range different pathways, facilitated by uncertainty mechanisms which will allow us to meet new investments as their value to existing and future consumers becomes clearer.

- better understand losses, particularly when considering decarbonisation, and further developing the evidence base on the proportion of losses that network companies can influence/control; and
- continuing to research, innovate, collaborate and share best practice to optimise whole system losses whilst facilitating net zero.

Continuous improvement is important to us, and we know we can, and should do better. Losses are a complex area that will become more complex and more important as we decarbonise and transition to net zero. Our commitment to optimising losses will strengthen during 2023-28. We explain in this document the measures we are taking now, and the additional measures we believe are necessary.

Overview of losses

What are losses?

Losses are simply the difference between the energy measured as injected into a network (energy in) and that extracted from it (energy out), as depicted in Figure 2. No system can be 100 per cent efficient. Losses (i.e. inefficiency) are therefore an unavoidable phenomenon of distributing electricity, governed by the laws of physics. Actions can be taken to impact losses, but the impact is often limited. It is important to recognise that the majority of the network in place today will be in place for years to come – noting typical asset lives are in excess of 40 years. We cannot expect significant losses improvements in the short term from short term actions. It is therefore imperative that what we do today is right not just for today, but for the future.

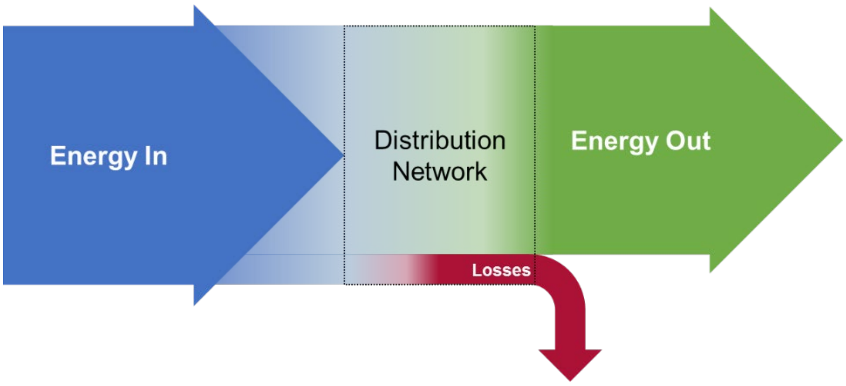

Figure 2: Distribution network losses

Quantification of losses – overall

Total losses across all DNOs in the UK in 2019 was around 17.8 TWh; about 5.1 per cent of the total UK electricity demand of 346 TWh, and this accounted for about 67 per cent of total UK electricity network losses[8]. This represents the largest component of the carbon footprint for all DNOs.

For Northern Powergrid, the magnitude of losses equates to roughly 2 TWh p.a., which is approximately six per cent of our total electricity demand of roughly 34 TWh p.a.. This energy that is 'lost' needs to be generated, and therefore has a financial and carbon impact. The financial and carbon impact of losses on our network are approximately £200m[9] and 400 kilotonnes of carbon dioxide equivalent (ktCO_2e)[10] respectively, which is about 94 per cent of our total business carbon footprint (BCF including Scope 3, and 98% of Scope 2 emissions). These are significant financial and environmental impacts and we take our role seriously in ensuring losses are as low as reasonably practicable. The different categories of losses that together make up the total network losses are explored further below, which gives the

[8] Digest of UK Energy Statistics (DUKES) 2020.
[9] Assuming a typical wholesale electricity price of £100/MWh for 2 TWh.
[10] Assuming a typical carbon intensity of c200 kilograms of carbon dioxide equivalent (kgCO_2e)/MWh for 2 TWh.

context around why a significant amount of our effort focuses on the LV and HV networks; given that over two thirds of the total losses on our network occur at these voltages.

Quantification of losses – distribution across the network

Figure 3 gives an indication of how the total system losses are distributed across the network assets. It can be seen that over two thirds of the energy lost on the system is at HV and below.

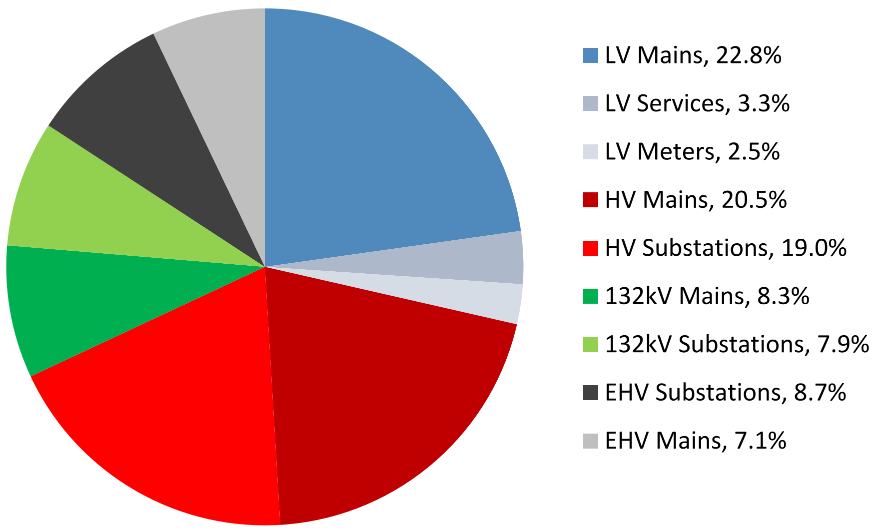

Figure 3: Typical overall distribution of percentage losses (adding up to 100%)

Note: With reference to Figure 3, the fixed losses are predominantly within transformers, and are roughly 30 per cent of the total technical losses; where the typical ratio of fixed to variable losses within our transformers is roughly 75:25.

The different 'types' of losses

The definition of losses provided in the preceding paragraph is often termed 'technical losses'. There are also a number of other types of losses that are categorised under the heading 'non-technical losses'. These types of losses are related to unidentified, misallocated, and inaccurate energy flows, in which the end user is unknown or the amount of energy being consumed is uncertain. Both technical and non-technical losses are described below.

- **Technical losses**: Losses as a result of electrical energy being converted to heat that occur naturally in power systems, associated with the passage of current through a resistance (where the laws of physics apply). There are two sub-categories:
  - **Fixed losses**: Losses that are incurred as a result of an asset being energised (switched on), and are largely independent of network loading, contributing to roughly between a quarter and a third of the total technical losses on distribution networks. This is also known as 'no load losses'. The most significant source of fixed losses is transformer core losses (also known as 'iron losses')[11]. In Figure 3, 'substations', relates to transformer losses (both 'fixed' and 'variable').

[11] Transformer core losses are associated with hysteresis and eddy currents. Other forms of fixed losses include dielectric (insulator) losses, as no insulator is a 'perfect' insulator.

  - **Variable losses**: Result from equipment being loaded (utilised), and vary with the square of the loading. Variable losses are often referred to in their equation format of 'I^2R' losses[12], or by the terms 'resistive' or 'Ohmic' losses. The most significant source of variable losses are overhead lines and cables (i.e. circuits), particularly those that are heavily loaded (high 'I'). The square relationship is a key takeaway; where doubling the load would quadruple the variable losses. Variable losses are roughly between two-thirds and three-quarters of the total power system technical losses. This is also known as load losses (or copper losses for transformers).

- **Non-technical losses**[13]: Losses that are primarily related to unidentified, misallocated, and inaccurate energy flows, in which the end user is unknown or the amount of energy being consumed is uncertain[14]. There are four sub-categories:

  - **Metering error:** Meters are not 100 per cent accurate. In addition there is energy consumed by the meter itself[15]. This is energy that is consumed but not metered and is therefore a subset of losses.

  - **Metering energy use:** Meters require energy to function, which is generally consumed from the network and not the customer's side of the meter. This 'parasitic load', whilst typically only several watts per meter, results in tens of gigawatt-hours (GWh) p.a. of 'losses'.

  - **Theft, unregistered connections, unmetered supplies and urgent metering services**: Ultimately, unmetered energy that is consumed which is not paid for directly by individual consumers.

  - **Electrical energy consumed by network operations:** Our substations take auxiliary supplies which powers network equipment such as: circuit breakers; transformer cooling; substation heating and lighting; and electronics, such as relays and communications equipment. This energy usage is not metered and is instead estimated.

External landscape impacting the energy system

External factors impact our losses management decisions. These factors will continue to steer, influence and affect our Losses Strategy, notably:

- 2050 net zero target. The Committee on Climate Change (CCC) responded to a request from the governments of the UK, Wales and Scotland and recommended a new emissions target for the UK of net zero greenhouse gases by 2050. This resulted in the UK government introducing legislation to implement this target, which has implications for our role as a DNO, our investment planning, and our valuation of a carbon price, in supporting such a target.

- The ten point plan for a Green Industrial Revolution. The plan brings together and delivers ambitious policies and significant investments by 2030 across energy, buildings, transport, innovation and the natural environment, driven by low carbon technologies and services. This has implications for our role as a DNO to support this ambition.

- National infrastructure strategy (NIS) outlines how transport, industry, energy and the built environment will be transformed to reach net zero, describing the government's intention to deliver an infrastructure revolution that is tied to net zero. This includes record level of investments on roads programme, the High Speed 2 (HS2)

[12] I^2R, where I is the current (proportional to the power, loading or utilisation) and R is the resistance.
[13] Internal Northern Powergrid policies related to non-technical losses include: REG/008 – policy in respect of the relevant theft of electricity; REG/008/001 – code of practice for the investigation of theft in conveyance; and REG/008/002 – code of practice for the management of unregistered customers.
[14] CIRED WG CC-2015-2: Reduction of Technical and Non-Technical Losses in Distribution Networks.
[15] For example, a typical customer with both a gas and electricity smart meter will continuously consume 7W, which is not metered, and therefore is a part of losses.

project, broadband and flood defences, reiterating the commitments of the ten point plan. Our role as a DNO complements the NIS strategy.

- The energy white paper builds on the ten point plan for a green industrial revolution and the NIS, outlining plans to transform the power and heating systems in supporting the net zero emissions target for 2050. It outlines commitments to renewables and green buildings, providing a great detail of certainty for businesses and green groups as to how the national energy and electricity mix will change over the next 20 years. Our role as a DNO to support this transformation is very important.

- The sixth carbon budget published by the committee on climate change (CCC) recommended that the UK sets a sixth carbon budget to require a reduction in UK greenhouse gas emissions of 78 per cent by 2035 relative to 1990; a 63 per cent reduction from 2019. While power sector decarbonisation is leading the way, future UK emissions reductions must come from transport, industry, buildings and agriculture, as well as phasing out gas-fired power. Our role and strategy as a DNO is central to this target.

- Brexit continues to result in considerable uncertainly around what rules and regulations we will have to comply with in the future. However, we will continue to adopt some regulations. For example, the EU Ecodesign directive and EU regulation on polychlorinated biphenyls (PCBs) will be incorporated into UK law post Brexit.

- Transport decarbonisation plan (TDP). The government is developing an ambitious plan to accelerate the decarbonisation of transport, setting out in detail what government, business and society will need to do to deliver the significant emissions reduction needed across all modes of transport, putting us on a pathway to achieving carbon budgets and net zero. Whilst there have been recently published strategies[16] to reduce greenhouse gas (GHG) emissions in individual transport modes, the journey to net zero demands that transport as a whole sector moves further, and faster. We have been updating our distribution future energy scenarios (DFES)[17] to align with these targets. Our role as a DNO is central in the electrification of transportation.

- Smart meter delays. The smart meter programme has been delayed several times, which means that any benefits of the time of use (ToU) tariffs have also been delayed. The minimum level of aggregation of consumption data required for data protection purposes will also reduce the utility of smart meter data to calculate losses[18]. The potential benefits of smart meters arise from the adoption of time of use tariffs, which will generally result in a decrease in the peak demand, and more generally, a flatter load profile; which in turn will result in lower losses than what would otherwise occur.

Impact of DSO and decarbonisation on losses

In the short term as increasing volumes of low carbon technologies connect to the network (renewable generation, EVs, heat pumps and battery storage), utilisation of the network will increase. Subsequently, losses will generally increase[19]. As we transition to DSO, we are committed to a flexibility first approach. The use of customer flexibility and smart solutions will often lead to an increase in network losses, however from a whole systems perspective this is the correct outcome as this in turn unlocks wider decarbonisation. Further, the carbon impact of this increase in network losses will diminish over time. Should network reinforcement be the optimum solution, network losses will be reduced by installing new assets that will have lower losses (e.g. larger cables and modern low-loss transformers).

We remain committed to whole system optimisation and will continue to incorporate losses into our decision making process. As an example of this in an industry wide context, we and other DNOs have been working together as part of the ENA open networks project on flexibility services[20] in developing a common evaluation methodology (CEM). This tool enables DNOs to make investment decisions when comparing flexibility products to traditional network interventions.

[16] Which includes the Road to Zero Strategy.
[17] https://odileeds.org/projects/northernpowergrid/dfes/
[18] CIRED 2017: Analyzing the ability of Smart Meter Data to Provide Accurate Information to the UK DNOs (http://cired.net/publications/cired2017/pdfs/CIRED2017_0654_final.pdf).
[19] Energy Networks Association (ENA) working group project: Impact of Low Carbon Transition – Technical Losses.
[20] https://www.energynetworks.org/creating-tomorrows-networks/open-networks under the section 'Flexibility services'.

The CEM considers some of the wider network and societal impacts of the different network interventions, which includes the impact of network losses.

The link between utilisation and losses

Applying the principles of fixed and variable losses we can explain why a network with high utilisation will have higher losses than a network with low utilisation:

- Losses could be reduced to zero if the network was completely switched off, or if there was no network.
- Starting with a simple section of the network (e.g. one circuit and one transformer), upon energisation, there will be fixed losses present.
- Once power is flowing to customers, there will be the introduction of variable losses, rising in a square relationship with the amount of load.
- As more of the network is energised and supporting additional load (increasing utilisation), the fixed losses and variable losses will increase.
- As customers connect more load (e.g. EVs) to the existing network, the variable losses will increase further (non-linearly).
- As the network expands to facilitate new connections, new sources of fixed and variable losses will be introduced, and the total losses will increase further still.
- The amount of losses is largely dependent on the network loading, and therefore changes in customer behaviour can produce increases and decreases in losses.

Controlling versus influencing losses and the impact of our 2023-28 Losses Strategy

There are certain elements of losses management that we can control, and certain elements that we can only influence. A brief overview of areas we can control that are historically the focus of losses management, and generally result in using higher efficiency assets:

- Fixed losses: Install assets with lower fixed losses (e.g. lower loss transformers).
- Resistance (variable losses): Install assets with lower resistance, *'R'*, to reduce the variable losses (e.g. lower resistance cables), noting that the load (or current, *'I'*) is broadly defined by the needs of our customers.
- Network design and operation (fixed and variable losses): Design and operate the network so far as is reasonably practicable and economical to reduce losses. Examples of this are to utilise higher voltages (e.g. 33 kV instead of 11 kV) for bulk power transfer, limiting the number of customers connected to a given section of the network (and therefore limit the loading), or installing higher capacity (thus lower resistance) assets on the network to reduce losses. Generally, the driver is to ensure other parameters are optimised (e.g. thermal limits, voltage drop, fault level, security of supply), and in optimising these other parameters, losses are often optimised.

A brief overview of areas we can influence (or control to a limited extent) that are historically the focus of losses management:

- Loading (variable losses). Limit the amount of current, *'I'*, through a given asset or section of the network. This requires significant investment in infrastructure to ensure utilisation remains low; i.e. a higher capacity network. Once the network is built, the key determinant of variable losses is the loading. This loading is driven by our customers' needs, and therefore this variable is one we can only influence, and not fully control.

- Power factor. Industrial and commercial customer who consume reactive power may have poor power factor resulting in higher than necessary energy bills, and this will lead to an increase in losses on our network. Although we can guide customers who we identify as those that could benefit from power factor advice, again, we can only influence this and not fully control the power factor on the network (with the exception of making significant, and uneconomincal investment in reactive power equipment such as statcoms).

In isolation, it seems reasonable that network operators like us would seek to minimise losses as this should minimise our customers' energy bills and the associated emissions. To minimise these losses in any significant manner typically requires significant investment in network assets; which are also ultimately paid for by our customers. We therefore seek to optimise losses, by ensuring we balance the cost of losses with the cost of the network.

We have over 63,000 substations (i.e. over 63,000 transformers), and over 96,000 kilometres of circuit (i.e. overhead line and cable) on our network. We have some assets that are a century old, and much of the network was installed in the 1950s and 1960s. Assets we install now will be in place for over 40 years, and therefore any asset investment decisions we make now will only marginally impact total network losses in the short term, but will have a long term legacy.

Although we cannot materially change the physical properties of the assets that are already installed, we can operate the network in a smarter, more flexible way. We have invested heavily in smart grid enablers; and these are fundamental to optimising how we operate the network.

For new assets that we are installing on the new network, the losses are in the order of half of that of the assets they are replacing. The upper end of our planned performance improvement was our pre-1958 transformer replacement programme, where a typical 315 kilovolt-ampere (kVA) pre-1958 transformer (with annual losses in the region of 17 MWh) would be replaced with the most modern, amorphous core transformer. Subjected to the same loading, the new amorphous core transformer would have annual losses under 3 MWh; i.e. an 83 per cent reduction. Across our original ED2 2023-28 anticipated programme of investments covering cable and transformer replacements, we estimated that the total reduction in losses as a result of the more efficient assets would be in the region of two per cent. However, due to inadequate unit cost allowances set by Ofgem, our plan of installing super low loss amorphous core transformers has been paused for 2023-28, and we will revert to use of more 'lossy' Ecodesign Tier 2 transformers. These Ecodesign Tier 2 'cold-rolled grain-oriented' (CRGO) transformers have annual losses of 4 MWh, lower than the pre-1958 transformers but higher than the amorphous core transformers, resulting in less reduction in losses. It must also be noted that, given that losses is highly sensitive to network loading, where a one per cent increase in network loading could increase losses by roughly two per cent, it becomes clear that losses in total cannot be controlled.

The majority of our network has been installed for many decades, and will continue to be in place for many more decades. We will typically upgrade in the region of one to two per cent of our network every year, where a typical upgrade may result in a halving of losses. Subsequently, it is evident that the impact of our network upgrades could reduce losses in the region of half a per cent to one per cent every year. At the extreme, if we were to replace our entire network (during 2023-28) with the modern, equivalent technology that is more energy efficient, we could expect that losses could roughly halve. This approach would be more costly to our customers (costing £bns, but only providing a losses reduction of tens of £ms p.a.). As a result, losses do not drive our investment plan; they only drive the option selection for assets that we have determined requiring an intervention for another driver (e.g. over-loaded assets).

Noting that a one per cent increase in loading on our network will typically increase overall losses by two per cent, it is clear that the overall level of losses is dominated by the (loading) requirements of our customers, and our actions only have a secondary impact on losses. Given that we do not control losses, but can only influence the overall level of losses, we are increasingly recognising the benefit of educating and engaging with our customers and stakeholders. We recognise that energy efficiency and customer behaviour will increasingly have a more significant impact on our network. Given the likely increase in loading between now and 2050 of roughly two to three fold, it is important more than ever to place energy efficiency at the forefront of our strategy to optimising losses. For example, if our engagement with customers could reduce loading by one per cent, or even shift loading to off-peak times when the carbon intensity is lower, the overall level of losses and carbon emissions will be reduced by more than one per cent. That is, the impact of engaging with our customers could play just as (if not higher) a significant role on losses than our 2023-28 actions.

In addition to our increasing focus on educating and engaging customers and stakeholders, it is important to also re-iterate that the most economic and efficient manner of facilitating net zero will generally be to increase network utilisation, and therefore an increase in losses will occur. Facilitating decarbonisation at lowest cost will benefit society and our customers, where an overall reduction in carbon intensity that is supported by decarbonisation will reduce the emissions associated with losses. Network losses are therefore not something that we seek to minimise, but to optimise as part a holistic asset management approach; which will generally see losses increase in the coming decades, whilst emissions will ultimately tend to zero.

Regulatory treatment of losses

We have an existing licence condition[21] that requires DNOs to:

- ensure that losses are as low as reasonably practicable; and
- maintain and act in accordance with our Losses Strategy.

DNOs do not pay for electrical losses on their networks. Hence, Ofgem seeks to ensure that DNOs maintain an appropriate focus on losses management activities.

During the 2015-23 price control review, Ofgem incentivised DNOs to undertake additional actions to better understand and manage losses. The mechanism for this was the losses discretionary reward (LDR). The LDR scheme was split into three tranches, and DNOs were required to produce an LDR submission for each of the three tranches. Tranche one was in 2016/17 and we received a reward under the incentive. No DNOs received a reward in tranche two (2018/19) or tranche three (2020/21).

Our existing initiatives for improving our management of losses are incorporated in both our Losses Strategy and our tranche three submission under the LDR. Our Losses Strategy for 2023-28 incorporates and builds on the 2015-23 initiatives with further activity and ideas.

During 2015-23, we have worked with other DNOs and Ofgem on losses incentive arrangements for 2023-28 that best deliver the right outcomes for customers based on what we have learnt during the 2015-23 period. As a result, for the 2023-28 period, Ofgem will remove the LDR and replace it with a reputational incentive[22]. Table 5 below summarises the previous losses incentives by Ofgem[23].

Losses incentives	Description
2000-05 losses incentive mechanism	• This was the first Ofgem price control review to include an incentive mechanism to reduce losses.
2005-10 losses rolling retention mechanism	• Ofgem implemented a mechanism known as the losses rolling retention mechanism (LRRM). DNO allowed revenue was adjusted according to performance against a losses target, using Settlement data. • Ofgem finally determined that this approach was ineffective, due to concerns raised on inconsistencies and issues with Settlement data.
2010-15 distribution losses reporting requirement	• Ofgem initially implemented an updated version of LRRM to address issues from the 2005-10 price control review. • Two years into the 2010-15 period, Ofgem suspended the mechanism and replaced it with the distribution losses reporting requirement (DLRR), to ensure that actions taken to reduce losses were documented sufficiently to allow the information to be used to inform future strategies to reduce losses.

[21] Standard Licence Condition 49 'Electricity Distribution Losses Management Obligation and Distribution Losses Strategy'
[22] Ofgem Sector-Specific Methodology Decision, December 2020.
[23] ENA CEP023 Technical Losses Mechanism Study - Development of a Losses Incentive Mechanism: Phase 1 Final Report

Losses incentives	Description
2015-23 Losses Strategy and losses discretionary reward	• Ofgem introduced a strategy to manage losses, which included four elements: ○ licence obligations; ○ loss reduction expenditure in business plan; ○ annual reporting; and ○ the LDR. • Licence conditions required DNOs to produce a Losses Strategy to ensure losses are as low as reasonably practicable.
2023-28	• Losses Strategy will be incorporated into the environmental action plan (EAP), along with other associated reporting. Losses also form part of the Scope 2[24] GHG emissions, and will therefore be reported as part of DNOs' annual BCF reporting requirements.

Table 5: Timeline of Ofgem losses incentives

How our Losses Strategy fits in with our 2023-28 business plan

Our Losses Strategy is a supplementary document to the 2023-28 EAP. We will report annually on the implementation of the key actions and associated performance measures detailed within this Losses Strategy as part of EAP reporting.

Our whole system approach to losses means that there is significant linkage with the following areas of our 2023-28 business plan:

- asset resilience;
- connections;
- customer service;
- communities;
- decarbonisation;
- EAP; and
- vulnerable customers.

Other related information

The code of practice for the methodology of assessing losses states our approach and provides guidance for the methodology of calculating losses and carbon emissions associated with the operation of the distribution system. This document can be accessed here.

For further information on our initiatives and activities to manage losses, please visit our losses webpage at https://www.northernpowergrid.com/losses or email us at losses@northernpowergrid.com.

[24] Scope 2 emissions: indirect emissions being released into the atmosphere associated with the reporting company's consumption of purchased electricity, heat, steam and cooling. These are indirect emissions that are a consequence of the reporting company's activities but which occur at sources they do not own or control. This includes losses of electricity for electricity transmission and distribution companies.' - RIIO-ED2 Methodology Decision: Overview.

Stakeholder engagement: influencing our Losses Strategy

In this section, we will:

- outline the existing stakeholder engagement activities that we have been carrying out throughout the 2015-23 period and how these influenced our Losses Strategy; and

- discuss the stakeholder engagement activities that we are starting now and will continue to carry out to continuously improve our Losses Strategy during 2023-28.

2015-23 stakeholder engagement activities

Our stakeholder engagement during 2015-23 focused on clear, open and honest communication and cross-cutting approach to manage losses, which we will continue and expand during 2023-28. We have been utilising various stakeholder engagement platforms to address losses and energy efficiency, sharing best practice and engaging with stakeholders to develop strategic partnerships, as well as engaging closely with our local communities.

Our engagement activities with our stakeholders is summarised in Table 1 of Appendix 2 of this document. Below are the highlights of the activities.

Stakeholder-led consultation and dialogue with our range of stakeholders

General engagement: We ran a consultation on our 2015-23 Losses Strategy as well as creating online communities for more targeted campaigns with regards to our losses management actions in our losses strategies and LDR. We learned that the response from interested stakeholders, mainly the general public, was limited in these approaches. In response, we looked at different methods, and re-designed our losses webpage to be more informative as well as using social media for our campaigns. We continue to use these digital routes for updating our stakeholders and general public with more information and latest news on our activities and actions to manage losses. We feel that this approach is more engaging and relevant, gives more impact and is more effective in capturing the interests of a wider range of stakeholders. We also used social media platforms in addition to the usual trade media to reach out to our stakeholders and audience, and will continue to do this. We believe that an effective strategy to engage with stakeholders is to tie in the theme of 'losses' into other related areas, for instance energy efficiency, sustainability or decarbonisation.

Visuals and animations: We created our 'losses animation'[25] to educate our stakeholders on network losses, and provide simple explanations on the background of network losses, their impact and solutions. We had positive feedback via Scottish and Southern Electricity Networks (SSEN) on the usefulness of this approach to frame the issues[26]. Simple yet interactive animations like these are effective in educating and creating awareness on network losses.

Low carbon network innovation (LCNI) 2019: We and other DNOs carried out a joint panel session which was chaired by WSP Global Inc. (WSP) at the 2019 LCNI event in Glasgow. We carried out an interactive discussion with stakeholders from various backgrounds on our joint project with regards to the LCT impact and the regulatory approach on losses.

Energy-saving advice and measures: One of the conclusions of our report on the impact of domestic losses[27] stated that focusing on improving the efficiency of UK domestic appliances would reduce the loading of the energy network. This would avoid both the need for additional generation and electricity network infrastructure, which ultimately will reduce losses. We have identified a cross-cutting approach to relate losses with energy-saving advice by working internally within our Powergrid Care Team and with our partners to engage with communities in advocating energy efficiency initiatives. Part of our Priority Service Register (PSR) package that we sent across our licence area (just over 900,000 customers) contained some advice on being energy efficient.

[25] Our losses animation can be found at http://www.youtube.com/watch?v=M9v_2HDnMLI or on our losses webpage.
[26] This is mentioned in page nine of the report 'Low Energy Automated Networks (LEAN) SDRC 9.4 Initial Learning from Trial installation and Integration'.
[27] A study commissioned by Northern Powergrid to WSP: 'Impact of voltage and harmonic variations on domestic losses'. The report can be viewed on our losses webpage: https://www.northernpowergrid.com/asset/1/document/4121.pdf

We worked with a range of partners across the region where the outcome of those conversations could manifest itself in cost savings for our customers, arising from reduced consumption, and the subsequent reduction in network losses:

- Infrastructure North: We work in partnership with Northern Gas Network (NGN), Yorkshire Water (YW) and Northumbrian Water (NW) to help serve our customers in the north of England. Part of our initiative as a group was to advise customers on ways to use electricity, gas and water more efficiently to reduce energy bills whilst helping the environment.

- Citizens Advice: Offeeg advice and support to those in fuel poverty – partnering with offices in Bradford, Calderdale, Kirklees, Leeds, Newcastle and Wakefield.

- Green Doctor: Offered energy-saving advice and measures in homes: North and West Yorkshire, North and South Tyneside, Hull and East Riding.

- Ahead Partnership: Originally offered employability skills to pupils but evolved to form a youth consumer panel to assist with stakeholder engagement.

- Energy Heroes: Energy-saving advice and measures for schools, pupils and communities.

Reactive power (volt-amperes reactive (var)) advice: We have engaged and worked with our non-domestic customers to help them to improve their power factor and included this action into our incentive on connections engagement (ICE)[28] initiatives. We published guidance on this on our losses webpage. Customers that improve their power factor could save money on energy bills, and reduce the carbon footprint associated with their electricity supply by reducing network losses. Improving power factor could also relieve voltage constraints on our network, which in turn can allow connection of more low carbon technologies. We also advised our customers on other measures available that could improve their power factor, such as installing newer machinery, or operating their site more efficiently.

2019 stakeholder summit: Over one hundred delegates attended from local authorities, environmental organisations, civic leaders and the energy industry. This summit was centred on the considerable challenge of energy, decarbonisation and climate change. The event consisted of a mix of presentations and direct interactions with our stakeholders via exhibition of innovation and decarbonisation projects. We engaged with the delegates by discussing and educating them on the concept of network losses, its impact towards the environment, our role and obligation as a DNO on losses and our activities to manage losses, which include our enhanced understanding of network losses project with Newcastle University, our amorphous transformer trial (proposed at the time and now complete, and var advice.

In-depth dialogue with expert stakeholders

Impact of variable cost of electricity on losses*:* We built on one particular stakeholder's comment on how the cost of losses should take into account the variable electricity price during the day rather than an average price over the year. More details on this are given in the next section ('our existing approach to managing losses') of this document.

Engagement with independent distribution network operators (IDNOs): We raised our concerns with Ofgem and IDNOs via the ENA low-carbon technology group about the policy of IDNOs using small cross section low voltage mains cables on connections for new developments. In our view, this wiould produce a distribution network with higher losses and less capacity for the electrification of heat and transport, and facilitation of the LCTs. On the other hand, for the same new connection, the local DNO would use higher capacity larger cross section cables. The market conditions and financial incentives would drive IDNOs towards this type of shorter term decision-making on asset selection which is at odds with the wider pressure on electricity networks to facilitate the move to the net zero and whole system thinking. We therefore welcomed the consideration by the Department for Business, Energy & Industrial Strategy (BEIS) engineering standards review with regards to the adoption of minimum cable sizes.

CIRED 2019: We engaged with academic and technical audiences at the 25th International Conference and Exhibition on Electricity Distribution (CIRED) 2019, where we presented our conference paper on 'enhancing the understanding of

[28] ICE was introduced by Ofgem in the 2015-23 price control review to drive DNOs to understand and meet the needs of these types of larger customers.

distribution network losses' from the enhanced understanding of network losses project. This high profile conference and exhibition event had a worldwide perspective and participation and it was a perfect platform for us to highlight our project while having a broad range and in depth engagement and interactions with the electricity distribution community.

Industrial advisory board (IAB): We have started collaborating with the University of Bradford by becoming a member of their IAB. We will continue to support their academic programme which could align with industrial needs in areas such as losses management in order to equip students with skill sets required by the industry.

Engagement with National Grid Electricity System Operator (NGESO) and Electricity Transmission (NGET)

NGESO: Variable losses (I^2R) are a function of the current squared, and therefore reducing reactive power flow on our network could significantly reduce losses. Reactive power control plays an important role in maintaining a secure voltage profile, especially on the transmission network. Although we have no obligations to provide reactive power (var) support to NGESO, we acknowledged that our systems are interconnected and our network activities impact the var flow in the transmission network which will create a high voltage issue during low load periods. The system needs to control high voltage as we have seen an increasing need to absorb vars in recent years, resulting in increased costs to voltage management overall. We engaged with NGESO to address and manage this through the ENA open networks project. The open networks project is a collaboration that plays a major role in transforming the way that both local distribution networks and national transmission networks operate and work for customers towards a holistic and coordinated approach to network management and solution as we transition to DSO roles.

NGET: We also engaged with NGET to share best practice on managing the network, which includes our Losses Strategy. We acknowledged that having a Losses Strategy is also a licence condition for National Grid, and will continue to work closely with NGET to ensure our Losses Strategy activities are optimised from a whole system perspective.

International engagements

We engaged with a DSO in Norway, Lede AS, on processes and methods to manage losses. Although we have a different structure, economic regulation and incentives, we believe that both Northern Powergrid and Lede AS apply the simple principles of good asset management in terms of selecting options with the 'lowest annualised whole life cost'. During 2020, there was a significant amount of activity developing whole life cycle frameworks within Norway.

We also engaged with our sister companies in the US and Canada that are part of the Berkshire Hathaway Energy (BHE) Group. This dialogue allows us to leverage the international experience of five significant utility operators in areas such as conservation voltage reduction and reactive power support.

Collaborative activities

ENA Technical Losses Task Group (TLTG) was a platform for us to engage and collaborate with other DNOs and stakeholders on all aspects of losses. We contributed to the group in our initiatives. Some key activities carried out by the group were as follows:

- Ofgem teach-in session (October 2017): This presentation provided an introduction to losses, an overview of the current approach on losses and discussions on factors that will influence future regulatory approaches to losses.

- LCNI presentation (December 2017): This presentation summarised the work that the group commissioned WSP on 'the impact of low carbon transition on technical losses'.

- 'The impact of low carbon transition on technical losses' WSP (March 2018): The aim of this study was to understand the impact of low carbon and smart grid transition on technical network losses to inform losses strategies and the regulatory approach to losses. The key findings in this report concluded that the LCT uptake and how networks accommodate this will significantly impact losses, that calculation of losses are complex and will become increasingly complex, and losses are difficult to measure, and vary significantly based on regional topology and loading patterns (e.g. LCT uptake).

- 'Technical losses mechanism study' WSP (September 2019): Development of a losses incentive mechanism. The group recommended a reputational incentive option with a CBA approach for the 2023-28 period, which is the approach that has been adopted by Ofgem.

- LCNI panel discussion (October 2019): The 'deep dive' session was an interactive discussion with the audience focusing on an overview of the project that the group commissioned WSP on the 'technical losses mechanism study', with key topics including the complexity of network losses, the impact of LCT and the regulatory approach on losses.

- Knowledge-sharing: Some key areas of successful collaborations, learning and sharing of best practice are as follows:

  - Amorphous transformers (AMT): We agreed to focus on installing ground-mounted AMTs, with UK Power Networks (UKPN) to focus on pole-mounted AMTs. Scottish Power Energy Networks (SPEN) shared the specification where they had installed pole-mounted AMT as part of business as usual (BAU) activities. The learning from this was shared amongst the group members and the wider industry.

  - Losses assessment methodology and CBA: We and other DNOs shared best practice on the approach to assess losses for policy and design decisions. In general, all DNOs applied the concept of loss load factor (LLF) to estimate losses, with our methodology being at the more comprehensive end of the available guidance[29].

  - Mobile asset assessment vehicle (MAAV) and contact voltage losses (CVL): UKPN (and Power Survey) shared their knowledge and experience based upon their trial work. We built on the work by Princeton University Report on CVL[30] and analysed the CVL on pole leakage, which we discuss further in the 'innovation and enhanced understanding of losses' section and the CVL action (6.1.3).

  - Transformer waste heat recovery: We built on UKPN's Bankside Project with the same consultancy (Arup) to look into the roll-out of this technology into BAU by retrospective design of the system onto our existing transformers. We will discuss our project further in the next section of this report.

Engagement with academic partners, consultancies and other industry players

Throughout the 2015-23 period, we engaged and collaborated with various organisations. For example, we collaborated with Wilson Power Solutions (AMT manufacturer) and Freedom (our service provider, i.e. installer) in our AMT trial. We also engaged with fellow utility companies, YW and NGN, when we considered processes and methods to manage losses, including both technical and non-technical losses. We engaged with other ENA working groups (e.g. ENA LCT working group, ENA open networks) to generate ideas and share knowledge, with our academic partners and consultancies in research and innovation projects as well as the energy suppliers on non-technical losses area along with our smart meter development.

Shaping our 2023-28 Losses Strategy

Losses is a complex topic and we need to tailor our engagement to the people we are talking to. Stakeholder engagement experience during the 2015-23 period on losses indicated that our role was more about educating a wide range of stakeholders on what losses are and how both DNO and customer actions can impact losses. Therefore an important strand of our 2023-28 Losses Strategy is around energy use education, with a particular focus on vulnerable customers, as we believe that this education could provide a net positive social return on investment (i.e. energy efficiency or behavioural changes made, will save customers more money than was invested in the education provision), which includes the knock-on reduction in losses that can result from reduced network loading.

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[29] CEP023 technical losses mechanism study – development of a losses incentive mechanism: Phase one final Report.
[30] 'Analysis of contact voltage Losses in low voltage electricity distribution systems of the U.K.', by Princeton University. The report can be downloaded from the UKPN losses webpage at https://www.ukpowernetworks.co.uk/losses/static/pdfs/analysis-of-contact-voltage-losses.f7e1d56.pdf

Our approach will be to weave losses into other engagement activity such as decarbonisation and only hold specific losses engagement with specialist stakeholders.

Our engagement regarding the actions that customers can take will be primarily focussed on the actions that would be beneficial from a customer financial and wider environmental perspective (for example; replacing a 60W halogen spotlight with a 6W light-emitting diode (LED) spotlight). There is danger that over complicating the messaging to focus primarily on losses could reduce the effectiveness of communications.

Continuing our initiatives from the 2015-23 period

These are some of the initiatives that we will continue during 2023-28 and beyond.

General stakeholder engagement:

- Our targeted approach on this will be to continue utilising the mainstream social media and visualisation platforms.

ENA:

- We are continuing our contribution and engagement within the ENA and its members for continued collaborations and sharing of best practice.
- The group is working on an ENA recommendation document on losses. This is still at an early stage, and the key aim of this is to ensure best practice becomes common practice across the industry (including IDNOs).
- We will also continue working and engaging with communities on energy efficiency measures and will increase our effort in educating them on the benefits of energy savings towards optimising network losses and decarbonisation, not just saving them money on their energy bills.
- We are also learning the best practice from SSENs Solent achieving value from efficiency (SAVE)[31] project on how they evaluate the potential for domestic customers to actively participate in improving the resilience of the network, which looks into energy efficiency, data, price signals and community energy coaching.

Academic and energy market experts:

- Engagement with academic partners, consultancies and other industry players will continue to be our on-going strategy during 2023-28 to keep us ahead in our journey to pursue net zero.
- For our analysis on variable cost of losses, we are planning to discuss our analysis with academia and the learning from this will improve our understanding on how we value losses, particularly in the world of DSO when we will gradually see the transition of consumers into prosumers.
- In terms of our collaboration with the University of Bradford IAB, we are also looking forward to working with them and exploring the possibility of embedding a decarbonisation and sustainability theme in the programme, where losses will fit in.

NGESO and NGET:

[31] https://save-project.co.uk/

- Although losses are not the primary aim of our engagement with NGESO on the management of reactive power flow, we realise that the outcome of this engagement might result in increased losses on our network and this is something that needs to be addressed.

- However, from a whole system view, we are facilitating a holistic and coordinated approach in managing our network as we transition to DSO roles. We will continue to engage with NGESO and be part of the initiative of the ENA open networks project via its work streams to develop a good practice for conflict resolution, management and co-optimisation (in our case DNO-NGESO), and aligning DSO and ESO var flexibility services to manage the reactive power flow.

- We will continue to share best practice in managing losses with NGETas this will progress whole systems thinking and sharing of best practice between key stakeholders.

International engagements:

- BHE group: We will continue to engage with and seek value in areas of power system operation and management from the BHE group.

- Lede AS: By continuing to engage with Lede AS, we are also taking this opportunity to get a useful insight into the future of electric vehicles (EVs), as Norway is leading the world in the uptake of EVs. They have also been keeping up-to-date with the DSO strategies amongst the DNOs in the UK, including us, to share best practice.

Stakeholder input

Stakeholder engagement is very important to us in all aspects of our business and has shaped our 2015-23 Losses Strategy. Hence, in developing our Losses Strategy for 2023-28, we have been carrying out several programmes of stakeholder engagement, as summarised in Table 6 below. On-going engagement is crucial to continuously improving our Losses Strategy.

"You said"	**"We did"**
Stakeholder message	***How we improved our Losses Strategy***
	Customer Engagement Group (CEG)
"It would be good to understand more about how losses relate to other areas of the business plan. For example, if LAEP drives towards more localised energy flows...Likewise for DSO strategy — as well as its role in local energy markets, DSO has potential to influence losses through the way it dispatches flexibility to reduce peaks and suchlike. Where does this figure in NPg's plans?"	In the 'Overview of Losses' section, we provided more explanation of the link with other plan sections, particularly decarbonisation, DSO, and flexibility, and how increasing utilisation will impact losses on some areas of the network, whilst reducing losses on other areas of the network. We have also introduced several actions that relate to this, in particular the actions within the initiative groups of 'network operation' and 'whole systems'.
"...tease out what is within NPg contract and achievable in ED2"	We expanded the detail regarding the regulatory treatment of losses, and focussed on better explaining our vision. We undertook an analysis of what is achievable in 2023-28 by undertaking a full review of our investment plans to determine that the impact of our business plan, which will result in a c2-3% reduction in losses (in absence of other changes; where 2-3% is of the c2 TWh total). We have also provided more context that the overall level of losses will be impacted more materially by the energy needs of our customers.
"...potential for reduced losses through customer behaviour change and links to DSO/ Net Zero proposals"	We agree that there is a significant role for customer behaviour and the links with net zero and DSO (e.g. flexibility), and therefore have shifted our future focus to expanding our activity with respect to education and engagement of customers and stakeholders. This is one of our key actions (cross referenced against Customer Service). In addition, we have a wider range of initiatives relating to DSO, flexibility, and customer/stakeholder engagement. This is in recognition that future losses will be impacted significantly by the transition, and we need to proceed with losses as part of the agenda.
"One area where I think we could do with greater clarity is the treatment of Northern	We have included a specific action on this (energy efficient substations), where further detail is provided on this topic. Following this engagement we have reviewed SPT's findings (from their innovation project), together with a detailed discussion with SPT to

"You said" ***Stakeholder message***	"We did" ***How we improved our Losses Strategy***
Powergrid's own use of energy in the system"	further explore their learning; and as a result, we are now proposing to progress this area given the potential benefits of doing so.
"a missing key piece of information to aid understanding is the split of fixed and variable losses "	To better understand and explain losses, we reviewed learning from others and undertook some analysis to determine that fixed losses is c30% of total technical losses. We have included this learning within our Losses Strategy.
"I don't understand why losses will become more important as we go towards NZ (net zero), or why increasing local generation increases losses"	We have expanded the explanation of how losses will generally increase as network utilisation increases (in line with decarbonisation of heat and transport), but have better explained the nuance of decarbonisation enabling lower emissions from losses. This helped to shape our vision for the Losses Strategy.
Technical Panel	
Why should consumers care about losses, particularly when accounting for the future system of zero marginal-cost generation?	Following a detailed follow up on this topic, including reviewing our research on 'losses correction factors', we agreed that further work is required to better quantify the impact of losses in a future world of potentially plentiful, low cost, low carbon intensity generation. This is reflected in Action 6.1.1 (losses correction factors).
"What proportion of losses can actually be influenced by strategy, what is reasonably practicable and what can be achieved?"	This feedback echoed similar feedback from the CEG, and this resulted in analysis and further information provided within the Losses Strategy to explain the level of impact our actions can have within 2023-282 (2-3% of the c2 TWh p.a. losses for our 2023-28 business plan).
"Losses need to be factored into investment decision-making rather than considered to be the primary driver."	We have improved the clarity within our Losses Strategy to confirm that our investment is not driven by losses as a primary driver, but that losses simply impact the chosen solution for an investment where the driver is either asset risk, or a load related driver.
Consumer Panel	
Consumer Panel participants in both areas were largely unaware of losses (roughly half), and the amount of energy losses across the network and the costs associated with this. Many were shocked and even "alarmed" by the extent of these losses.	We will continue to produce educational material, and will ensure that electrical losses are appropriately covered as part of our 2023-28 proposal to educate and inform customers and stakeholders on energy efficiency and behaviour. This approach of covering losses as part of broader energy efficiency dialogue was seen as important.
Incentivising consumers to use electricity at off-peak times was seen as the most suitable approach to reducing losses, although most participants recognised that no one approach would work for all customers.	We will jointly develop 2023-28 energy advice and behaviour material alongside the Customer Service propositions. This is a new action within our on-going commitment to manage losses, and is a key area of focus. We have explained this focus within our Losses Strategy.
Most participants felt that messaging intended to encourage customers to reduce losses should focus primarily on the costs to consumers.	Alongside the energy efficiency advice action, we will continue to produce new, informative and appropriate losses educational material. We recognise the increasing importance of high quality educational material and messaging, and this will underpin our new energy efficiency advice actions, and are therefore committed to continuously improving.
Community Energy Forum	
The community energy forum members were supportive (>85%) of the vision, and a higher percentage (>90%) agreed that customer actions should play a role within NPg's Losses Strategy, and that NPg had a key role (>90%) in engaging and educating customers to both reduce demand and shift demand (to greener, lower loaded periods).	At this point, our Losses Strategy had been improved from prior engagement with the CEG and technical panel, and therefore the key feedback was on levels of support for the Losses Strategy.
97% of community energy forum members voted that when educating and engaging customers (regarding energy efficiency) that we should also discuss network losses. The majority (c60%) of the members identified that we should only discuss losses 'a little bit', rather than in much detail.	Discussions identified that the key to ensuring customers adopt improved energy behaviour is to lead with the benefits to the individual, where losses are generally a second order benefit. We are therefore progressing the education and engagement of customers (for energy efficiency) as part of our customer service plan. Losses will appear as part of this engagement, but only to a small extent, based on feedback from both the community energy forum and the consumer panel.
National Grid Electricity Transmission (NGET) bilateral	
It was agreed that on-going engagement is required on losses, amongst other considerations to ensure whole system optimisation.	We are keen to engage further on losses with NGET (particularly given the increase complexity of the network).
University of Bradford - Smart Grids and Energy Systems MSc postgraduate students	
There was particular interest regarding the application of cost benefit analyses (CBAs) to determine the optimal solutions, with a clear recognition that this is an important aspect of engineering (asset management) that is not presently part of syllabi across UK colleges and universities.	Alongside continuing engagement with regional universities (for which we are a member of University of Bradford IAB to better align syllabi with the needs of industry), we improved the Losses Strategy to better explain what we mean by 'optimisation' (c.f. Figure 1), alongside explicitly explaining how CBAs are used, and the specific outputs of these CBAs.

"You said"	"We did"
Stakeholder message	***How we improved our Losses Strategy***
Stakeholder Panel	
There was overall support for whole system energy efficiency, rather than simply focussing on network losses. There was particular interest in BEET, and how new (low carbon) technologies could interact with, benefit from, and complement BEET. Further engagement was requested, specifically for BEET.	We have enhanced the messaging around energy efficiency and the linkage with losses within our Whole Systems annex (which provides the specific details regarding the rollout of BEET during 2023-28), and we also incorporated losses into our messaging for the BEET project stakeholder engagement literature. As part of BEET, we will engage further with our stakeholder panel, exploring the areas of interest identified in more depth.
Internal Engagement	
Focussed' engagement has been undertaken regularly as part of business as usual, and specific engagement was undertaken to support the production of the 2023-28 Losses Strategy. Because losses is not an isolated consideration, separate from other activities, but is instead integral to how we plan, design and operate the network; this focussed engagement has shaped both the Losses Strategy, whilst simultaneously shaping other strategies. For example, losses are incorporated into relevant engineering justification papers. Continuous improvement is critical to ensuring we continue to optimise whole system losses, and therefore we will continue to engage internally. This continuous engagement also ensures losses remains part of how we plan and operate the network.	

Table 6: Stakeholder engagement for the 2023-28 period

We are also working with local authorities (LAs) and other stakeholders in our region to explore local area energy plans (LAEPs) with regards to future energy needs across our region. We are also discussing the use of localised generation to support local energy requirements, with the aim of lowering whole-system losses. Working with local stakeholders supports a joined-up approach to driving regional decarbonisation.

Our approach to managing losses 2015-23

This section is intended to provide an overview of our approach to manage losses in 2015-23, and is written with the intention that it could be read in isolation of other sections. As a result, some of the material in this section is repeated to some extent in the next section, which details our Losses Strategy for 2023-28.

Our business as usual approach to managing losses is embedded within our objective in developing the network to achieve economic and efficient operation of a distribution system, delivering greater utilisation without compromising our network resilience. This is achieved by fully integrating the whole system understanding of losses within all asset management decision-making and planning processes.

We have produced and maintain an internal code of practice for the methodology of assessing losses (IMP/001/103). This document, together with our Losses Strategy, training provision, and on-going internal stakeholder engagement, resulted in the adoption of the actions detailed within our Losses Strategy.

Our strategy was in line with our vision for the Losses Strategy in 2013-28 that we stated at the beginning of this document. However, we took a step further in strengthening our focus on the whole system aspect and taking a leap to pursue net zero by looking at our future energy scenarios (DFES) when we carried out our CBA instead of organic load growth assumption that we adopted for our 2015-23 strategy.

Categories of existing management actions

Our 2015-23 initiatives were categorised into seven management actions (or areas), which are summarised below[32]:

- Product specifications for our transformers and underground and overhead conductors.
- Design policy on sizing and selection of underground and overhead conductors and transformers.
- Network investment and asset replacement strategy.
- Network operations.
- Promoting energy efficiency.
- Innovation and enhanced understanding of losses.
- Managing non-technical losses and electricity theft.

Each of these seven management actions are explored further below.

Product specifications

Transformers

The specifications for our transformers included a requirement that the manufacturer calculated the total cost of ownership of the transformer using the following formula: -

Lifetime cost = Purchase price + (no load losses kW x no load losses £/kW) + (load losses kW x load losses £/kW)

[32] Our RIIO ED1 Losses Strategy and Losses Discretionary Reward submissions can be obtained from our losses webpage at https://www.losses.northernpowergrid.com

The no load losses £/kW and load losses £/kW are the capitalised unit losses values of the transformer throughout its life span of 45 years. These values were determined by the cost benefit analysis (CBA) using the Northern Powergrid losses CBA template (a modified version of the Ofgem CBA), as explained in the Code of Practice for the Methodology of Assessing Losses (IMP/001/103) and are also presented in Table 2 in Appendix 2 of this document.

Ecodesign tier 2 requirements

The Ecodesign Directive (2009/125/EC) established a framework to set efficiency requirements for energy-using and energy-related products sold in all 27 EU Member States[33]. The directive provided minimum energy performance and product information requirements, by applying a 'tier' system. Our transformers are bound by this directive although the UK is no longer an EU Member. The energy performance was measured in terms of the maximum allowable load losses (variable losses) and no-load losses (fixed losses) values for different categories of transformers.

Before the implementation of this directive, we assessed the economic value of losses over the life of our assets, including transformers, to inform wider procurement and design processes, driven by the financial incentive for losses from Ofgem in the price control period prior to 2015-23[34].

Tier 1 requirement, started in 1 July 2015 and underwent a review in 2018, resulted in an amended version published in November 2019[35]. Tier 2 commenced 1 July 2021, with a review planned in 2024 to decide if there will be a tier 3 requirement. All new transformers to be procured in 2023-28 will comply with tier 2 requirements unless they are applicable for derogation of the directive[36].

Energy savings is the key behind this directive. It was estimated that using more energy efficient transformers would lead to energy savings in the EU, of an estimated 16 TWh per year (after 2020). This is equivalent to 3.7 million tons less of CO_2 being emitted each year[37], or about 4.6 per cent of UK's total annual electricity consumption (346 TWh[38]).

We estimated that the tier 2 technology would result in a cost uplift of 15 to 20 per cent compared to our existing tier 1 transformers. In addition, the increased weight and dimensions would have operational and practical implications, which would result in further cost increase in the supply chain. The learning from our amorphous transformer trial[39] indicated that tier 2 1000 kVA ground-mounted transformers would require new plinth design.

Underground and overhead conductors

Our underground and overhead conductors are procured to our standards[40], referencing relevant national standards. At low voltage (LV), we adopted 300 mm^2 aluminium underground cables as a standard cable size for all mains other than tees carrying less than 120 A per phase[41]. The standard HV underground cable size used on distribution feeders at 11 kV was 300 mm^2 aluminium. For our 20 kV standard underground cables, the size remained at 185 mm^2 for distribution feeders[42]. For high voltage (HV) overhead lines, we specified 'AL5' grade alloy (all aluminium alloy conductor) AAAC in sizes 100 mm^2 and 175 mm^2 for main line circuits and 50 mm^2 and 100 mm^2 for tail end circuits. 'AL5' conductor was

[33] The document published in May 2014 can be viewed at https://op.europa.eu/en/publication-detail/-/publication/9124a197-e17f-11e3-8cd4-01aa75ed71a1/language-en/format-xhtml
[34] IMP/001/103 – Code of Practice for the Assessment of Asset-Specific Losses. This document is superseded by IMP/001/103 – Code of Practice for the Methodology of Assessing Losses.
[35] The amended version published in 2019 can be viewed at https://op.europa.eu/en/publication-detail/-/publication/0009a44b-f735-11e9-8c1f-01aa75ed71a1/language-en/format-xhtml
[36] The ENA Transformer Assessment Panel (TAP) are currently working with BEIS to define the categories of transformers included in the derogation.
[37] https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/energy-efficient-products/power-transformers_en
[38] Digest of United Kingdom Energy Statistics 2020, Chapter 5 Electricity.
[39] We trialled the installation of five units of 1000kVA super low-loss amorphous core as part of our Losses Discretionary Reward initiative in RIIO-ED1.
[40] NPS 001 007 - Technical Specification for Overhead Line Conductors. NPS 002 019 – Technical Specification for LV Distribution and Service Cables. NPS 002 020 – Technical Specification for 11 & 20kV Power Cables. NPS 002 021 – Technical Specification for 33kV Power Cables. NPS 002 022 – Technical Specification for 66kV Power Cables. NPS 002 023 – Technical Specification for 132kV Power Cables.
[41] IMP/001/911 – Code of Practice for the Economic Development of the LV System.
[42] IMP/001/912– Code of Practice for the Economic Development of the HV System.

chosen because it had significantly lower resistivity to achieve higher ratings for a given size of conductor, resulting in lower losses. The choice of these conductor sizes is dependent on the load of the circuit.

Design policy

We have embedded a low loss policy in designing and operating an efficient power network, with the two asset class considerations below being of particular importance.

Conductor selection:

From a losses optimisation perspective, the selection of conductor sizes as dictated by the design policy had a greater impact than the equipment standard. The benefits of low loss design were usually in the form of increased sizing of conductors[43], taking into account the whole lifetime cost. The incremental cost of higher capacity (larger) conductor was compared with the benefits of having bigger capacity, lower resistance conductor, i.e. lower losses, creating the extra network capacity required to facilitate net zero and improving network performance (i.e. voltage drop, current carrying capacity and earth loop impedance). During 2015-23, we determined from our CBA modelling that:

- LV (underground) circuits should utilise 300 mm^2 cable instead of the slightly cheaper 185 mm^2 cable.
- 11 kV (underground) circuits should utilise 300 mm^2 cable instead of the slightly cheaper 185 mm^2 cable.
- 20 kV (underground) cables should continue utilising the slightly cheaper 185 mm^2 cable instead of 300 mm^2 cable.

Transformer sizing and selection:

Our IMP/001/911 code of practice for the economic development of the LV system provided maximum economic loading guidance for new distribution transformers resulting in the use of higher capacity assets, depending on load/generation type. System transformers on our EHV and 132 kV network are sized to match the load and selection of cables and overhead lines shall be based on IMP/001/913 – code of practice for the economic development of the EHV system.

Network investment and asset replacement strategy

Besides optimal sizing of our assets as part of our design policy to optimise losses, we took losses into account when we carried out CBAs on our network investment options and asset replacement strategies.

Voltage rationalisation

We decided to invest in reinforcement and equipment reconfiguration at Darlington and Rise Carr 6 kV networks to the standard 11 kV system (supplied from Darlington 132/6 kV and Rise Carr 33/6 kV substations) to fully mitigate fault level issues, as well as to address the long-standing condition issues that cause operational difficulties at this site. This is the highest capital cost option considered (about 4 times the capital cost of other investment options). However, it has the best NPV when considering losses as a factor for the like for like cost comparison with other investment options.

Analysis on the Darlington/Rise Carr 6 kV network showed that the losses incurred on the 6 kV network were approximately 2.1 MW at full load, and at 11 kV these would be reduced to approximately 0.6 MW (as the voltage is increased about twice from 6 kV to 11 kV, the current is reduced to about half, and due to the squared relationship between current and losses, the losses is reduced to about a quarter). Using the Northern Powergrid losses CBA template for design solution and applying the process as set out in IMP/001/103 – code of practice for the methodology of assessing losses, the cost savings that would result from upgrading the 6 kV network to 11 kV, along with the associated EHV reconfiguration of the network, which would also result in marginally lower losses, would equate to approximately

[43] The cost benefit analysis (CBA) for the increased sizing of conductors is described in our RIIO-ED1 Losses Strategy. This policy has also been adopted by other DNOs.

£128,000 per year. This is a perfect example how investment in voltage rationalisation not only solves the fault level issues and improves network performance, but also optimises losses on our network.

Replacement of pre-1958 ground-mounted distribution transformers

Pre-1958 ground-mounted distribution transformers have significantly high no load losses, with up to six times more for BS171 type transformer built in 1936 compared to tier 2. We prioritise the replacement of pre-1958 distribution transformers as part of our existing asset replacement work programmes based on our CBA.

Network operations

We have carried out several activities to operate our network efficiently. Although we learned that smart solutions and low-carbon transition could increase losses, an optimised network operation is to focus on a whole system approach to balance different priorities to achieve the net zero target.

Voltage optimisation

In general, for our HV network, the voltage downstream of the primary is not actively managed. Therefore, the voltage at this site must be suitable for a range of conditions. However, as our customers sought to connect generation (e.g. solar PV), voltage rise has become an on-going issue. We therefore analysed and implemented voltage reduction at our primary substations. Our voltage optimisation activities help to unlock our network, allowing connection of more low-carbon generation. So far, we have reduced the voltage (typically from 11.3 kV to 11.1 kV) at 482 sites, which frees up the potential to connect about 4.3 GW of embedded generation, such as residential solar PV.

Building on from the success of our HV voltage reduction, we extended the concept to our EHV network. The primary driver for this initiative was to ensure that we continue to maintain Grid Code Operational Code 6 compliance, which is critical for ensuring system frequency stability. We ensure that the network is re-balanced to take into account the significant volume of embedded generation, both connected and yet-to-connect to our network, and to optimise network losses. This initiative ensured on-going compliance and was a key enabler of our HV voltage reduction. We implemented optimised EHV voltages at 12 supply points.

Initial assessment of the impact of our EHV voltage optimisation on network losses indicated that in the broader context of net zero, and in facilitating connection of renewable generation, this initiative would provide benefits (potentially in the order of £m), far outweighing the small increase in losses (potentially in the order of £k).

The preliminary studies for our Boston Spa Energy Efficiency Trial (BEET)[44] were conducted. The BEET project aims to use smart meter data in (near) real-time to optimise the voltage at the customer's meter and thereby decrease energy consumption – an evolution of a technique known as conservation voltage reduction. The reduction in energy our customers use will save them money, reduce the power flow on the network, and could therefore reduce losses. The project layers intelligent use of data on top of existing investment in smart meters, metering data flows and voltage control improvements to benefit the customer. The energy bill savings are expected to be approximately £35 per household per year, and overall are expected to far outweigh any capital and operational expenditure, given that other programmes such as the national smart meter rollout and our 2015-23 smart grid enabler programme already provide the bulk of the investment/infrastructure needed.

We will be continuing our voltage optimisation activities and investigate its impact on losses in our 2023-28 Losses Strategy.

Optimising network configuration to optimise customer numbers

[44] Boston Spa Energy Efficiency Trial (BEET), NIA_NPG_032.

Open points on the HV network are positioned to optimise customer numbers and load, but also to reduce switching operations under first circuit outages. Balancing customer numbers on circuits could reduce the respective customer interruptions (CIs) and customer minutes lost (CMLs). Load on these circuits is also reduced, which will reduce load losses as well as mitigating voltage and thermal constraints. This is currently undertaken on the basis of an optimal 'long-term' configuration, which is then typically not reviewed for several years following the optimisation modelling, unless there is a significant change on the local network (e.g. a new connection, or additional automation on the network).

Substation ambient temperature

In all major substations (primary substations, bulk supply points and grid supply points), indoor equipment rooms are temperature controlled. This is usually in the form of dehumidistats, to allow switchgear and associated control equipment to function correctly. We have also installed dehumidifiers at major substation sites where specific issues have been identified, usually in the form of partial discharge.

Promoting energy efficiency

Power factor correction

Customers are encouraged to aim for a power factor of between 0.95 lagging and unity on their electrical systems[45,46] in order to reduce reactive power flows and hence load losses across the wider network. Our Statement of Use of System Charging stipulates that half hourly metered customers are charged for excess reactive power consumption (kvarh)[47]. The excessive reactive power charge was introduced for HV and LV half hourly metered customers in April 2010. Our application guide for modelling generator reactive power control (IMP/001/007/002) also set out guidance on power factor arrangement for generation connections on our network.

We are also required (under the connection and use of system code) to make a request for a statement of works (SoW) to National Grid Electricity Transmission (NGET) in relation to the potential impact of connection of embedded generation on the national electricity transmission system (NETS). This includes a requirement to operate at a specific power factor to improve the reactive power flow between our network and the NETS.

We have engaged and worked with our non-domestic customers to help them to improve their power factor and included this action into our ICE[48] initiatives. We published guidance on this on our losses webpage, and also undertook analysis to shortlist the customers that could most benefit from personal contact; and then contacted several hundred customers. Unfortunately, during our communications activity, the COVID-19 pandemic took hold, and we took the decision to postpone the dialogue on this initiative.

Customers that improve their power factor can save money on energy bills, and reduce the carbon footprint associated with their electricity supply by reducing network losses. Improving power factor can also relieve voltage and thermal constraints on our network, which in turn allows connection of more low carbon technologies. We continue to recognise the significant benefit that this initiative can offer. As of October 2023, this activity is to recommence during 2023-28.

Power quality

Non-linear connected devices draw non-sinusoidal currents which in turn create harmonic voltages distortions for other customers and increase losses (for example triplen harmonics causing significant losses in transformers).

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[45] IMP/001/ 010 – Code of Practice for Standard Arrangements for Customer Connections
[46] This is also a requirement in the Distribution Connection and Use of System Agreement (DCUSA), section 39.14
[47] NPg (2013). LC14 – Statement of Use of System Charging – NPgN & NPgY.
[48] Incentive on Connections Engagements (ICE): Introduced by Ofgem in 2015-23 period to drive electricity distribution network operators (DNOs) to understand and meet the needs of these types of larger customers.

As such, we stipulated that where this is likely to occur, the connection design should take into consideration the requirements of engineering recommendations G5/5[49] as appropriate to mitigate any issues.

Harmonic distortion is not a significant cause of losses, compared to poor power factor[50]. However, with higher penetration electric vehicles (EVs) and solar photovoltaics (PVs) and other potential power electronic applications, for example power electronic transformers and soft open points (SOPs), this might change in the future. This is when the application of LV monitoring is beneficial to monitor the impact of harmonics on power quality and losses on the network.

Energy-saving advice and measures

One of the conclusions of our report on the impact of domestic losses[51] states that focusing on improving the efficiency of UK domestic appliances will reduce consumption, thus the loading of the network, avoiding both the need for additional generation and electricity distribution as less power is flowing on the network. This will ultimately reduce losses.

In 2015-23, we identified losses reduction opportunities within our existing effort to discharge our social obligation and responsibility, by working internally within our Powergrid care team and with our partners to engage with communities in advocating energy efficiency initiatives. Part of our priority service register (PSR) package that we sent across our licence area (just over 900,000 customers) contained some advice on being energy efficient.

Innovation and enhanced understanding of losses

Innovation and activities that we carry out to enhance our understanding of losses are key elements towards implementing a successful losses management strategy, now and in the future. Salient points of our activities and achievements are highlighted below. More information can be obtained from our losses webpage https://www.northernpowergrid.com/losses.

Amorphous transformer (AMT) trial

From our Ecodesign directive (tier 2) discussions with other DNOs on the ENA transformer assessment panel (TAP), there was some reluctance to adopt very low loss amorphous core transformers on certain technical grounds. We therefore collaborated with Wilson Power Solutions (AMT manufacturer) and Freedom (our service provider) to install 5 units of 1,000 kVA ground-mounted AMTs on our network using standard working procedures.

We also collaborated with UK Power Networks (UKPN), where they focused on pole-mounted amorphous transformers. This trial helped to allay technical concerns around size, weight, brittleness of the core material, harmonics and noise in preparation for Ecodesign tier 2 maximum loss levels which came into force in 2021.

The replacement of older transformers with the new ground mounted AMTs has the potential to produce annual losses savings of up to 3 GWh. Due to the success of this trial, we considered AMT as BAU in our 2023-28 plan, however the unit cost allowance in Ofgem's final determination was not sufficient to enable us to proceed with AMT during 2023-28.

Contact voltage losses (CVL) investigations

UKPN undertook an innovation project that sought to detect energised assets (e.g. lighting columns) which could potentially pose a danger to public health. The root cause of such hazards can sometimes be related to defects on the distribution network; specifically failure of cable insulation between a phase conductor and the outer sheath (and thus 'contact'), coupled with a defect in the sheath between the point of 'contact' and the upstream substation. Although

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[49] Engineering Recommendation G5 Issue 5 - Harmonic voltage distortion and the connection of harmonic sources and/or resonant plant to transmission systems and distribution networks in the United Kingdom.
[50] Based on results from Losses Investigation innovation project by Western Power Distribution (WPD) (WPD_NIA_005).
[51] A study commissioned by Northern Powergrid to WSP: 'Impact of voltage and harmonic variations on domestic losses'. The report can be viewed on our losses webpage: https://www.northernpowergrid.com/asset/1/document/4121.pdf

health and safety was the driver for this project at first, it was recognised that the inadvertent energisation – and thus presence of a voltage – of an object that is not supposed to be energised, will result in current flowing where it is not intended to flow. This current flow (I), coupled with the resistance (R) through which the current flows, results in electrical losses (I^2R). UKPN subsequently instructed Princeton University to investigate the potential magnitude of losses cause by these situations referred to as 'contact voltage losses' (CVL).

Following the findings by UKPN on CVL, we reviewed the report produced by Princeton University, to improve our understanding of losses due to what is commonly known as 'leakage current'. We subsequently engaged with UKPN to further improve our understanding of CVL. We are keen to undertake further work on CVL, and there is additional research needed to validate the assumptions and calculations used in the report; including whether or not different network topologies, different cable and earthing types (and thus failure modes) will have an impact on the assessment.

Building on UKPN's work, we examined CVL from the perspective of pole leakage current in our HV network, learning from the Princeton University report and following our previous work with EATL[52]. We concluded that the losses impact due to pole leakage current is small (less than 0.01% of total annual losses of our network), and thus can be considered negligible. The primary concern for the pole leakage detection is safety.

Time series analysis of losses using scripting method

We carried out a time-series analysis in our current software modelling tool (IPSA), to quantify network losses by using a scripting method. This powerful tool can accurately calculate variable losses for any assets in the network or for the network as a whole, by carrying out load-flow half-hourly for any set duration of time using half-hourly loading data available from our Plant Information (PI) system. This will allow us to assess the impact of losses for any set of conditions in the network.

The flexibility and capability that this method can offer will allow us to analyse the impact of any changes in the modelled network on losses, which will inform our design optioneering and decisions. For instance, we can analyse the impact of changing transformer sizes, network configuration or voltage set-points on network losses more easily and accurately. We are currently undertaking a major upgrade of our power system analysis simulation tool. Known as the 'distribution system analysis tool' (DSAT) project, this will facilitate the time-series capability to cope with the complex modelling of our network and to obtain better assessment of network losses. We will then update our code of practice for the methodology of assessing losses to reflect this.

MicroResilience – providing microgrid solutions

Our innovation project, MicroResilience[53], is providing microgrid solutions that will increase resilience for low voltage (LV) customers whilst offering flexibility to support the wider HV network, with potential added benefit of losses reduction. We will be implementing any learning into our Losses Strategy.

Enhanced understanding of network losses project

Our enhanced understanding of network losses project with Newcastle University started in April 2018, and is now complete. The project was broken into five work packages, with an aim to enable us to better understand, and make decisions pertaining to, the unavoidable losses which take place in our network. We produced several reports and disseminated the initial learning at the CIRED 2019 in Madrid, Spain.

[52] EATL STP reports related to pole leakage include 1) 'Leakage current measurements on eleven unused wood poles' 2) 'In-situ Megger Testing of Wood Poles on De-energised High Voltage Overhead Lines' 3)'Field Trials of Prototype Pole Leakage Detectors' 4) '"Call-out" Leakage Current Measurements on Suspect 11kV Poles' 5) 'Leakage Current Measurements On Poles With Defective Insulators'

[53] Delivering distribution system flexibility through MicroResilience – CIRED 2020 Berlin Workshop

Impact of battery energy storage system (BESS) on losses

We built on two of our innovation projects by carrying out two case studies to understand the impact of BESS on losses in our network: i) BESS from the DS3[54] project which are connected to domestic premises on our LV network; ii) BESS connected to the Rise Carr 6 kV network. Both types of BESS are of different sizes and were installed on different voltage levels of our network for different purposes, and acting under different operating regimes. Since the BESS for our DS3 project were connected on domestic properties, we could assume that the monitoring data of these properties would be analogous to the smart meter-derived data.

We learned that BESS could either reduce or increase network losses, depending on its scale and mode of operation. Understanding this would mean that we can utilise BESS to manage losses as well as factoring in the cost of losses into investment decisions for future BESS, for instance in the loss adjustment factor (LAF) charging. However, both case studies also demonstrated that the operation of the BESS is complex, and is outside of DNO control. The quality of data (including time resolution) for both case studies has an impact on the level of accuracy of the analysis and quantification.

Impact of variable cost of electricity on losses

We analysed the impact of wholesale energy prices and carbon intensity on losses over the course of a year (from 01 November 2018 to 31 October 2019) on our network. We calculated the losses impact correction factors to be applied to the standard assumptions around the cost of energy and carbon footprint by comparing three annual values based around how the average is determined:

- un-weighted average;
- weighted average based on demand profile; and
- weighted average based on losses profile.

The cost and carbon impact correction factors were then determined using this data.

An important learning from our work was the recognition that the correction factor for the energy costs will become more important as the penetration of renewables increases in the future. This is because high cost and high carbon plants will become operational for fewer settlement periods. Marginal plants will increasingly become marginalised, which in turn will require revenues to be recouped for less energy provided. Besides, high penetration of zero-marginal and renewable energy sources will introduce more 'green losses' compared to 'carbon losses'. This would make the analysis more challenging and complex. We plan to discuss our analysis with a wider range of energy experts (including energy economics), to determine the next steps that will enable us to better reflect the societal value of losses for the different circumstances in which they occur.

Research and development - measurement of data and losses analysis

We addressed the issue of measuring network data and the subsequent estimation of losses in several projects that we carried out in the price control period 2015-23.

In the ENA technical losses task group (TLTG) project on 'impact of low carbon transition – technical losses', we learned that although variations in losses would occur due to the nature of network characteristics and operation, the accuracy of the measurement used in our network components would also have impact on the evaluation of losses. Distribution losses are normally calculated as the difference between the energy into the network and the energy out of the network. The accuracy of energy measured into our network is affected by the different metering accuracies employed by the mix

[54] Distributed Storage and Solar Study DS3 (NIA_NPG_011): https://www.northernpowergrid.com/innovation/projects/distributed-storage-solar-study-nia-npg-011

of transmission network and embedded generation connected to our distribution network. Thus, trying to determine a consistent accuracy level when measuring losses is not straight-forward[55].

In our enhanced understanding of network losses project with Newcastle University, we looked at how data resolution, missing data, data uncertainty, and the correlation between demand values and the accuracy of losses estimation. Higher variability within the network demand led to higher errors in loss estimation and specifically underestimation. As load variability is proportionally lower in high voltage (HV), because of the higher diversity arising from supplying a large number of customers, loss estimation errors would tend to be lower than at low voltage (LV). The impact of losses estimation errors associated with measurements (which include time resolution, measurement accuracy, and data unavailability) was more severe at LV network.

The potential measurement errors encountered on real networks were a compound value encompassing the error from several discrete processes, namely:

- Error in the current transformers (CTs) and voltage transformers (VTs) used to transform the voltage and current on the real network to lower values which can be safely measured by a transducer.
- Error in the transducer on the secondary coil of the CTs and VTs is used to measure the current or voltage and pass this data onto a relay.
- Quantization error in the conversion of scaled analogue measurement into a 7-bit digital signal.

Our smart meter data project with University of Sheffield[56] concluded that reducing the time resolution of customer demand data could underestimate losses. On the other hand, aggregating customer demand data could overestimate losses.

What do all these mean in terms of measuring losses in our Losses Strategy?

- It is difficult to determine the level of accuracy when measuring losses. As losses are a small proportion (about 6%) of the total energy entering our network, even a small percentage of errors in measurement can have a significant effect on the accuracy of the losses estimation[57]. Hence, measuring losses is a challenging task.
- This would mean that any attempt to establish a target to reduce losses against a benchmark is not an effective and practical incentive or strategy. Besides, customer behaviours in influencing peak demand and duration, which would impact losses in our network, is outside of our control.

We will expand our data capabilities (using new sources of data made available by projects such as our LV monitoring programme, along with that made available via smart meters), and with our modelling capabilities (using new tools, such as DSAT) to better understand losses. This will become increasingly important as we have already identified that losses will become more complex, and will likely increase as we transition to net zero.

Forecast losses movement and the impact of load growth on losses

[55] ENA Working Group Project: Impact of Low Carbon Transition – Technical Losses.
[56] 2017 CIRED publication 'Analyzing the ability of Smart Meter Data to Provide Accurate Information to the UK DNOs'. The publication can be viewed at http://cired.net/publications/cired2017/pdfs/CIRED2017_0654_final.pdf
[57] It is reported in 'Electricity Distribution Systems Losses Non-Technical Overview', by Sohn Associates that the errors or measurement uncertainties attributed to up to 0.3% of the electricity distributed, which is up to about 6% of the losses themselves. This report also highlighted various issues regarding measuring losses as an incentive.

The potential losses pathways (particularly with respect to emissions) are covered separately in our science based targets[58] (SBT) section of the EAP[59]. This modelling consisted of using load growth as a proxy for losses growth (applying a ratio of 1%:2% respectively), and using the appropriate carbon intensity pathway consistent with each decarbonisation pathway, as depicted in the graph below, taken from our EAP. The key driver behind the spread is the difference in carbon intensities for each pathway. This modelling demonstrated that emissions associated with losses depend primarily on the rate at which power generation decarbonises, and are not directly within our control. The losses emissions pathways produced are therefore to be treated as rough guides for each decarbonisation scenario, where the overall level of emissions is dominated by the carbon intensity of generation. These pathways are not to be used as forecasts, and to be used only for the purpose of modelling SBT alignment.

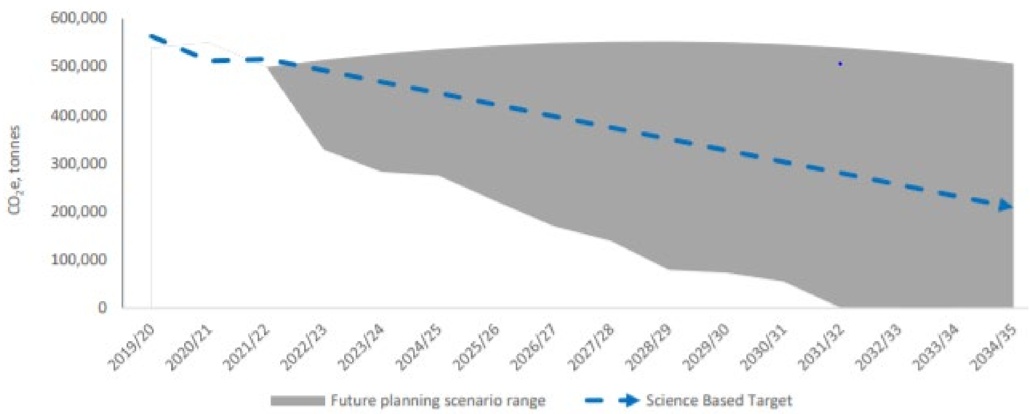

Figure 4: Scope 1 and 2 emissions SBTs (including losses) showing a range of future pathways for losses

We have historically provided a high level losses forecast. We have learned that our forecast losses movement as reported in our 2015-23 Losses Strategy is subject to significant uncertainty since it is highly sensitive to variables that are outside our control, resulting in inaccuracies and does not really provide us with meaningful target as we originally thought. High penetration of LCTs as part of the transition to net zero future of low carbon energy and the influence of political incentives and market trends which are difficult to predict would mean that forecasting losses is a challenging task. Hence, we will no longer consider losses forecasting as an appropriate activity in our 2013-28 Losses Strategy.

The uptake of LCTs will significantly impact losses. Smart solutions will generally increase the utilisation of existing network assets (as opposed to traditional network reinforcement), and will therefore generally increase losses. Again, the story is not always that simple, as future connections of LCTs will only increase losses depending upon the uptake level, the connection location and the balance between demand and generation. For example, small amount of solar PV will generally reduce network loading, thus reducing losses; however, once the penetration reaches a certain level, losses will start to rise again, until the point is reached where losses with solar PV exceed the level of losses if there was no solar PV.

From our enhanced understanding of network losses project with Newcastle University, we looked at how our forecast load growth impacted on losses for our studied primary network. We observed that as the projected load grows, losses increase significantly and with the intervention of customer flexibility, the increase in losses will be a lot lower. Some of these losses could be offset by network reinforcement and asset replacement, which will result in a network with greater capacity and more efficient assets.

[58] Science-based targets (SBT) provide a clearly-defined pathway for companies to reduce CO_2 emissions, helping prevent the impacts of climate change. Targets are considered 'science-based' if they are in line with the goals of the Paris Agreement – limiting global warming to well-below 2°C and pursuing efforts to limit warming to 1.5°C.

[59] Annex 4.4 Environmental Action Plan - see section on '**We have identified a range of potential pathways for scope 1 and 2 emissions (including losses)**'

In 2023-28, we will continue to look for innovative ways to optimise losses, and we will implement them where there is a clear benefit to our customers from doing so. We will also take the opportunity to engage with our stakeholders in looking at effective and meaningful benchmarking to track our progress in managing losses, and we will update our strategy accordingly based on input and feedback from this engagement.

Innovative options for further losses optimisation

We also considered options for further losses optimisation as summarised in Table 7 below. Some of these options are being included in our Losses Strategy for 2023-28, which will be discussed in the next section of this document.

Options	Description
Expand the existing losses reduction techniques	
Cables and plant sizing • Cables and overhead lines • Transformers	• Cost of copper is more than three times of aluminium – unlikely to be recovered in terms of losses over the lifetime of the cable. • Increasing the size (capacity) of transformers might reduce losses depending on the loading. Guidance on optimal size is provided in our IMP/001/911 policy. We are analysing this further in our 2023-28 Losses Strategy.
Power factor correction (PFC) installation	• The most cost effective location for PFC would likely be at primary substations. CBA indicated that a 5 Mvar capacitor banks installed at a primary substation, would be cost beneficial if the initial installation cost was the order of £20 000 per Mvar installed. • Initial analysis from our LV monitoring shows that our LV load has a power factor very close to unity. LV capacitors have been used by Electricity North West (ENWL) in their Smart Street project. We are not replicating their work.
Power quality • Harmonics • Load imbalance	• The effect of harmonics on losses is not thought to be as significant as poor power factor, however this is envisaged to increase as more load is fed via switched mode power supplies. • The roll out of LV substation monitoring will help us to quantify the harmonic and unbalance for future losses decisions.
New technologies	
Carbon neutral substations • Heat recovery from transformers • Solar heating at major substations • Use of local renewable generation to support substation auxiliaries • Design of energy efficient substation to be carbon neutral	• The waste heat recovery feasibility study project concluded that although heat recovery from our substations is technically achievable where local heat demands can be identified, it would not be commercially viable. We will continue to horizon-scan for opportunities for implementing waste heat recovery as local communities decarbonise heat, and potentially seek to implement heat networks. • By increasing the insulation U value to the substation buildings it is estimated that energy consumption could be reduced by up to 2.5 GWh over a licence area or a saving of £325k per year. • We are looking into this further in our 2023-28 Losses Strategy.
Transformer technologies • Reduced winding resistance • Cast resin transformers • Power electronic transformers	• Reducing winding resistance in transformers by having larger windings will increase core size, which in turn leads to increased iron losses in the core. This then influences the X/R ratio of the unit and can lead to more onerous network fault level requirements. • The use of cast resin transformer is not thought to be of any cost benefit to us. • We will investigate power electronic transformers further in our 2023-28 Losses Strategy.
Superconductors	• We believe that superconducting technologies are still maturing and are not cost beneficial in the near to medium term.
Changes to network operations	
Switching out under-utilised plant	• We see the transformer auto stop start (TASS) project by SSE Networks (SSEN) as some valuable learning, albeit a potentially niche application, as we need to consider the

Options	Description
	interactions of such schemes with network automation, voltage optimisation and active network management (ANM) schemes.
Smart meters	
• We will continue to develop our own processes, and help to develop the processes for the industry as a whole, to ensure that we are well positioned to collect data from smart meters as soon as they are installed, to manage our network, including losses.	

Table 7: Options for further losses reduction

Managing non-technical losses and electricity theft

The management of the impact of non-technical losses and theft on our networks is a primary concern for us. We have put in place a number of initiatives, which is summarised in Table 8 below.

Non-technical losses management	Description
Theft in conveyance	• Fully support the initiatives of the Crime Stoppers "Stay Energy Safe" campaign, the "Theft Risk Assessment Service" (TRAS) and the "Energy Theft and Tip Off Service" (ETTOS). • Full membership of the United Kingdom Revenue Protection Association (UKRPA). • Dedicated internal shared service function to support suppliers and to carry out site visits. • For sites with no registered supplier, we will ensure that all losses are minimised and will work within the relevant licence conditions and with other parties.
Unregistered connections (untraded MPANs)	• Error in registration process resulting in electricity not being paid and added to network losses (cost is spread across all customers). • We raised a formal Distribution Connection and Use of System (DCUSA) change proposal DCP209 'resolving un-registered customers' to improve communications with unregistered customers, set out best practice to manage unregistered customers (excluding registration process itself), and where necessary, place new obligations on other parties such as suppliers. • Internal shared service function to liaise with suppliers to support customers if necessary.
Settlement data – improving inaccuracies	• De-energised records – records where the energy should not be used at the property. We request the supplier to investigate the record and energise (reflecting that the supply is using energy) where necessary. • Incomplete registrations – We liaise with the supplier to request complete registration. • General data inconsistencies – We liaise with the supplier requesting to update the items.
Unmetered Supplies (UMS) Connections - ensuring accurate inventories	• Requirement for all unmetered customers to maintain a detailed and accurate inventory of all equipment and provide a copy to Northern Powergrid as agreed with the customer. • As the Unmetered Supplies Operator (UMSO), we have added a downloadable fact sheet[60] from our website that provides key information covering topics such as the accuracy of inventories to areas where efficiencies can be made.
Urgent Metering Services	• We provide a 'limited' urgent metering service for all electricity suppliers. The service is aimed at restoring a supply for vulnerable customers and rectification of other minor issues for all customers in the event of a metering equipment issue when our field operation team is already out at site.

Table 8: Summary of non-technical losses and electricity theft

[60] https://www.northernpowergrid.com/asset/0/document/572.pdf

Continuing our initiatives into 2023-28

While our strategy in 2023-28 is to contain new initiatives, we will focus our losses management initiatives that are proven to be successful in 2015-23:

- Increased sizing of underground cables and optimal sizing and selection of distribution transformers;
- using low loss overhead line conductors;
- embedding losses into our network investment and asset replacement strategy;
- operating the network to optimise losses;
- championing energy efficiency, with particular focus on vulnerable customers;
- apply or implement learning from our innovation and the enhanced understanding of losses projects;
- embedding more non-technical losses and electricity theft management activities; and
- considering options for further losses optimisation.

We will explore this further in the next section of this document.

2023-28 Losses Strategy

In this section, we will explore our strategy for managing losses during 2023-28, which consists of:

Objectives (outcomes for our customers) that we will seek to achieve to realise our vision. To achieve our objectives, we have developed:

- Initiative groups that categorise our initiatives, where underlying themes align. They span a wide range of themes, and each initiative consists of discrete actions. We will explain the actions that underpin these initiatives.

- Initiatives/actions that can be measured (to the extent that we can transparently quantify our progress and the associated benefits to customers), are then shortlisted, together with the associated scorecard metrics. We will report progress against the initiatives/actions for which we define up-front scorecard metrics.

Our Losses Strategy for 2023-28 builds on the initiatives and learning from 2015-23, and has been refreshed to take account of the significant challenge we face to facilitate net zero at least cost, together with the improvements available with new data and technology. We will continue those initiatives (from 2015-23) that add value, whilst also introducing new initiatives that we believe will, or could add value during 2023-28 and beyond.

Our Losses Strategy will be incorporated into the environmental action plan (EAP), along with other associated reporting. Losses also form part of our Scope 2 greenhouse gas emissions, and we will therefore report as part of our annual BCF reporting requirements. The associated reporting will consist of metrics on elements of losses management that we can control and are quantifiable[61], for example the losses benefits of replacing our pre-1958 transformers.

Objectives

The following objectives are the driving force behind each initiative, in that they link each initiative to its justification; i.e. what are we trying to achieve, or what the outcome is for our customers. The objectives are based on stakeholder engagement held for the purpose of both managing losses, and as part of wider stakeholder input that fed into 2013-28 business planning:

- minimise the overall environmental impact of the energy system (e.g. carbon footprint);

- minimise overall energy bills (for present and future customers);

- facilitate our region's decarbonisation;

- whole systems thinking;

- include our customers and stakeholders in our journey through enhanced engagement and education;

- seek to maximise value out of new assets (e.g. smart meters); and

- leading by example / force for good (e.g. our energy efficient substations).

Initiatives and actions

There are numerous actions that we can undertake to achieve the above objectives. To explain the strategy in a coherent manner, we have grouped the specific actions as follows (starting at the highest level):

[61] Based on our IMP/001/103 Code of Practice for the Methodology of Assessing Losses.

- Initiative group – a collection of initiatives with a similar theme (for example, I stakeholder initiatives), which are then subcategorised into;
    - Initiative – an overarching proposal of what we will deliver (for example, collaborating with expert stakeholders such as other DNOs, is a different initiative to working with our customers, but collectively they reside under the 'stakeholder' initiative group).
        - Action – description of individual actions that reside under the specific initiative (for example, educating and engaging with domestic customers regarding energy efficiency is a different action to educating and engaging with an industrial customer regarding poor power factor; but collectively, they reside under the 'Education and engagement' initiative).

The eight initiative groups are described below with the individual initiatives listed for each:

- Accelerated Asset Replacement – Together with other drivers (such as asset condition), reviewing the potential benefits of accelerating the replacement of assets when losses is taken into account. Initiatives: (1.1) Accelerated asset replacement.

- Data & Analytics – Utilising the more widespread and improved system data that is increasingly becoming available, together with new tools (such as new power system software 'DSAT'), to better model and understand losses on our network; and to ultimately improve the planning and operation of the network to optimise losses. Initiatives: (2.1) data, (2.2) analytics.

- Design Policy – Determining the most appropriate asset specifications for our network assets, together with application of the most appropriate size of asset for the intended application (e.g. optimal asset sizing). The use of the most appropriate specification and size can drastically impact the asset lifetime losses. Initiatives: (3.1) Specification, (3.2) Optimal asset sizing.

- Network Operation – Utilising the enhanced operability tools that are available (particularly, following the rollout of our smart grid enablers programme) to optimise the standard network operation arrangements (i.e. static network operation), and as a further ambition, to optimise the network in real-time (i.e. dynamic network operation). Key variables that we can control are:

    - network topology, hence network flows; and

    - network voltage.

  Initiatives: (4.1) Static Network Operation, (4.2) Dynamic Network Operation.

- Non-technical Losses – i.e. Non-network losses (those not directly related to losses in network assets) are an important area to focus on. Initiatives relating to metering inaccuracies are not considered appropriate for this Losses Strategy, however there are two initiatives that are:

    - Improving the energy efficiency of our substations (along with any consumption estimation errors) could reduce the level of energy consumed by our substations; and

    - using the modern data science techniques together with smart meter and LV monitoring data could potentially be used to improve theft reduction.

  Initiatives: (5.1) Energy Efficient Substations, (5.2) Theft.

- Research & Development – With a rapid pace of technology developments, there is a need for both horizon scanning (for future technology), and undertaking trials (for more mature technology). Coupled with the rapid change required by net zero, and the new market requirements (such as those for flexibility); there is a need to ensure that we remain focussed on research and development. Initiatives: (6.1) Investigation / trial, (6.2) Horizon Scanning.

- Stakeholder – We have a duty to educate and inform our stakeholders about losses, and will continue to do this. More importantly, we recognise that other stakeholders form part of the energy system, and therefore we need to think beyond just our network and collaborate with a wide range of stakeholders to optimise the entire system in order to achieve net zero at least cost. We will continue working closely with 'expert stakeholders' to share best practice, and we propose that customer energy efficiency should become central to our Losses Strategy. Initiatives: (7.1) Customer Energy Efficiency, (7.2) Education and Engagement, (7.3) Expert Stakeholder Collaboration.

- Whole System – Our whole systems approach is a key enabler to ensuring net zero is achieved at least cost. One of the key enablers to whole systems and DSO is the important role of enabling flexibility to compete against network solutions. We will be adopting a 'flexibility first' approach to future investment, and therefore it is essential that we take losses into account when considering flexibility to determine the optimum solution. Initiatives: (8.1) Flexibility optimisation, (8.2) strategic investment, (8.3) TO/ESO/IDNO, (8.4) Whole life-cycle sustainability.

Finally, for each initiative, we determine the actions that are appropriate to achieve the initiative. For each action, we consider the appropriate action type, and the relative losses impact. Where some of these actions have been described in previous sections of the document, we will refer to the sections instead of repeating them here.

First, the action type classifications are:

- Continue – continue undertaking the action, as we already undertake this action during 2015-23, and we believe this action will continue to achieve the objectives listed above.

- Expand – increase the application of this action, where we already undertake this action to a limit extent during 2015-23. Based on work done to date, we believe this action will achieve the objectives listed above.

- Adopt – a new action that we do not undertake (as part of BAU) at present, or have only undertaken as part of a limited trial / innovation project. Based on work done to date (potentially desktop-based), we believe this action will achieve the objectives listed above.

- Consider – a new action that we do not undertake (as part of BAU) at present, or have only undertaken as part of a limited trial / innovation project. It is likely that these trials are either a work in progress, or have been undertaken as part of an innovation project elsewhere. The net benefit of the action is therefore uncertain, and we will consider the application of the action during 2023-28.

- Research – a new action that is not BAU, and is not mature across the industry. Given the low maturity, we do not believe that the action will be applied during 2023-28, and instead, will be researched during 2023-28. Any positive outcome from such actions will likely only be realised during ED3 and onwards.

- Discount – where we have considered, but deemed it inappropriate for 2023-28. This does not mean that the action will not be assessed again should the landscape change whereby the action could provide value.

Second, the losses impact categories are:

- High – The potential benefit across the network is high relative to the other actions (estimated at above 100 MWh p.a.) and/or the action has been built into business-as usual or to be rolled out as part of our investment plan;

- Med – The potential benefit across the network is moderate relative to the other actions (estimated at between 10 MWh p.a. and 100 MWh p.a.); and

– Low – The potential benefit across the network is low relative to the other actions (estimated at less than 10 MWh p.a.), and/or the action has been not been built into business-as usual or is not to be rolled out as part of our investment plan.

The full list of losses actions considered (including those discounted, and low impact actions) is provided in Appendix 1. Each action explored in more detail below, with actions grouped by their 'initiative grouping'.

Accelerated asset replacement

Ref.	Initiative Group	Initiative	Action Name	Action Type	Losses Impact
1.1.1	Accelerated asset replacement	Accelerated asset replacement	Pre-1958 ground-mounted transformer replacement	Continue	Medium
1.1.2			Voltage rationalisation	Expand	Low
1.1.3			Upgrade unbalanced networks	Adopt	Medium
1.1.4			Upgrade small-section LV overhead conductors	Adopt	Medium
1.1.5			Replace pre-1987 PCB-contaminated pole-mounted transformers	Adopt	High

Action 1.1.1: Pre-1958 ground-mounted transformers replacement

Action	Pre-1958 ground-mounted transformers replacement (dual driver of poor condition and high losses).
Background	Distribution transformers manufactured before 1958 (termed as pre-1958 transformers throughout this document) have significantly high no-load losses; for example values for an 11 kV 315 kVA transformer could be approximately 2 kW, whereas a modern equivalent (CRGO Tier 2) has no-load losses of approcimately 0.2 kW.
Opportunity	Besides having deteriorating condition due to the age of these transformers, the no load losses for BS171 type transformer built in 1936 are six times more compared to tier 2.
Options	Replacing these transformers not only reduces the risk of having old assets with poor conditions, but will improve network losses by installing more efficient transformers.
Proposal	We prioritise the replacement of pre-1958 distribution transformers as part of our existing asset replacement work programmes based on our cost benefit analysis.
Action type	Continue from our initiative in 2015-23.
Losses impact	Medium.
Scorecard metrics	This was not proposed as a standalone metric, and a wider-ranging transformer metric was proposed instead, with respect to installation of amorphous core transformers (Action 3.1.3). However, the action to install amorphous core transformers was not appropriately funded by Ofgem, resulting in replacement of pre-1958 transformers with the Ecodesign Tier 2 transformers instead during 2023-28. This still yields significant benefit to customers.

Action 1.1.2: Voltage rationalisation

Action description	Voltage rationalisation (i.e. uprating 6 kV networks to 11 kV) for remaining legacy non-standard networks.
Background	We still have legacy 6 kV non-standard networks across our licences.
Opportunity	These networks are barriers to our long-term network performance and condition and decarbonisation efforts. Losses on 6 kV roughly quadruple those of 11 kV[62].
Options	Upgrading to our 11 kV standard voltage would not only improve interconnection, reliability and security, it will allow connection of more LCTs, future-proofing our network towards achieving net zero. However, we do not believe that optimising losses alone justifies upgrading these networks.
Proposal	Our approach will be consistent with how we decided to invest in rationalising Darlington/Rise Carr 6 kV network, i.e. considering losses as a factor to inform the decision to invest in this network via CBA, where the primary driver for the reinforcement and equipment reconfiguration was fault level and asset condition issues. We are proposing to replace poor condition transformers at Hebburn 66/6 kV and Wardley 66/6 kV with new 15/30 MVA, 66/11 kV units and upgrade the existing HV network from 6 kV to 11 kV. This work has the potential to reduce losses by approximately 73 per cent on this section of network, reducing annual losses from 1,248 MWh to 337 MWh
Action type	Expand voltage rationalisation activity to other legacy 6 kV networks, where the primary driver is re-inforcement and voltage uprating provides losses benefit.

[62] At 6 kV, current flows are roughly doubled compared to at 11 kV. Since variable losses is $I^2 \times R$ (where I is current and R is resistance), the losses on 6 kV roughly quadrupled those on 11 kV.

Losses impact	Low. The losses benefit can be quantified as part of our CBA when we carry out the network analysis.
Scorecard Metrics	Not proposed, this is a niche initiative.

Action 1.1.3: Upgrade unbalanced networks

Action description	Consider intervention on unbalanced networks - LV triple concentric replacement and single phase HV overhead lines uprating to three phase system.
Background	This initiative would facilitate decarbonisation by increasing the capacity of our network to cope with an increase in demand associated with the uptake of LCTs, in particular EVs and heat pumps (HPs).
Opportunity	Operating a balanced system not only unlocks the network to allow bigger capacity to connect LCTs, but it also helps to minimise network losses. On a worst case scenario, unbalanced conductor losses can be up to six times that of a fully balanced feeder. Harmonic currents can also be generated by rectifier and inverter equipment when subjected to unbalanced voltages, and this can further add to the losses in the network.
Options	Assessing the overall losses of the unbalanced LV and HV network can provide additional justification for the overall cost of the asset replacement works.
Proposal	We will adopt balancing the networks by replacing the LV triple concentric cables and single phase HV overhead lines with three phase equivalent where it is opportune and beneficial of doing so. For HV overhead lines, although losses will be reduced while uprating to three phase system, the reduction in losses will be very minimal and for now, will not be included in the criteria for the uprating. We are targeting the HV overhead lines replacement on future LCT hotspots.
Action type	Adopt.
Losses impact	Medium. To take into account losses in the CBA of replacing triple concentric cables only, and to be neglected in the HV overhead lines analysis.
Scorecard Metrics	Not proposed, losses is not the primary driver for this initiative.

Action 1.1.4: Upgrade small-section LV overhead conductors

Action description	Replacement of small section LV overhead conductors, targeting weak spots/bottlenecks to remove barriers to new connections, increase network flexibility post-fault whilst improving losses.
Background	A typical urban low voltage distribution network will be primarily constructed from underground conductors as opposed to overhead line. There is however parts of the urban LV network where historically the installation of an overhead line in an urban setting was commonplace.
Opportunity	As we move into the net zero future, we are likely to see a significant increase in demand on the LV network, in part due to the uptake of low carbon technologies including electric vehicles and heat pumps. Overhead lines can restrict the overall capacity of a circuit and this could prove a barrier to the connection of additional future demand.
Options	The cost of reinforcing the overhead LV network by undergrounding with 300 waveform cable is significantly higher than installing a larger overhead conductor. At the moment, 120 ABC (air bundled conductor) is the maximum conductor specified in our policy.
Proposal	To adopt increasing the conductor size to 185 ABC as an alternative to installation of a 300 waveform cable, although the losses benefit is less. Should the LV services require undergrounding then the existing overhead line should be replaced by underground cable due to the minor difference in cost.
Action type	Adopt.
Losses Impact	Medium. Losses is the added benefit in this initiative, not the main driver.
Scorecard Metrics	Not proposed, losses is not the primary driver for this initiative.

Action 1.1.5: Replace pre-1987 PCB-contaminated pole-mounted transformers

Action description	Accelerated replacement of pre-1987 PCB-contaminated pole-mounted transformers by 2025.
Background	Proposed changes to European Regulations on Polychlorinated Biphenyls (PCBs) have the potential to require all UK DNOs to test or replace all of their pre-1987, potentially contaminated, oil-filled assets (the vast majority of which are transformers) by 2025.
Opportunity	Whilst the related ground mounted items could be tested in situ without considerable cost and inconvenience, the pole-mounted units are essentially inaccessible.
Options	Replacing these transformers not only discharges our compliance to the European Regulations, but will improve network losses by installing more efficient tier 2 transformers (albeit, the net benefit is reduced by no longer proceeding with amorphous transformers).
Proposal	We prioritise the replacement of pre-1987 PCB-contaminated pole-mounted transformers as part of our existing asset replacement work programmes. This is a key part of our Environmental Action Plan.

Action type	Adopt.
Losses impact	High. We estimate around 10,000 units are still within our network. Replacing these will save around 1 MWh p.a. per transformer (£10 GWh total 2023-28 benefit).
Scorecard Metrics	Proposed, based on losses benefits of volumes replaced.

Data & analytics

Ref.	Initiative Group	Initiative	Action Name	Action Type	Losses Impact
2.1.1	Data & Analytics	Data	Enhanced monitoring	Expand	Medium
2.1.2			Data improvement	Adopt	High
2.2.1		Analytics	Modelling improvement	Adopt	High
2.2.2			ANM optimisation	Consider	Low
2.2.3			Optimising network configuration for a specific loading condition (single time step)	Expand	Medium

Action 2.1.1: Enhanced monitoring

Description	Enhanced monitoring in LCT hotspots and high-loss areas enables better and timely decision making on losses mitigation measures.
Background	Heavily loaded sections of the network have disproportionately high losses. Networks with pre-existing high utilisation, or areas for which loading will increase substantially driven by LCTs will be sections of the network for which losses will become material; and therefore most in need of losses mitigation measures.
Opportunity	Enhanced monitoring of LV and HV networks (e.g. using LV monitors, smart metering data, and for HV networks, data from devices such as pole mounted reclosers) provides the opportunity to: 1. understand the losses on the monitored sections of the network to enable the most appropriate losses mitigation actions; and 2. provides invaluable learning that can be applied elsewhere.
Options	Options include using only smart metering data, however this would not provide losses information given (a) the limited rollout of smart meters, and (b) losses is best calculated based on the 'energy in' and 'energy out'. Using the widest range of datasets is therefore best. Additionally, the enhanced monitoring is being progressed as a net zero enabler, hence this data presents an opportunity for losses as a synergy benefit.
Proposal	Take advantage of the natural synergies between heavily utilised networks and/or network which will become LCT hotspot requiring enhanced monitoring; and that these networks will typically be those with highest losses. We will determine enhanced monitoring requirements for specific network types that may not be triggered by net zero considerations (e.g. unbalanced networks that are not overloaded). We will use this enhanced data to improve our losses mitigation actions, together with improving our understanding of losses for application across the wider network.
Action type	Expand our existing practice of analysing network data.
Losses impact	Medium.
Scorecard Metrics	Not proposed – rollout is led by net zero facilitation.

Action 2.1.2: Data improvement

Description	Data analytics (statistical analysis and state estimation) - improving the quality and quantity of our data to enable subsequent analysis; including additional data sources such as that form LV monitoring and smart meters, and/or improving the existing data sources (E.g. PI data). Links with DSO proposition.
Background	We are in the process of increasing our level of network monitoring from only primary substations and above (i.e. c800 major sites), to tens of thousands of secondary (distribution) substations, together with smart metering data. Without application of data science techniques, we will not be in a position to turn this data (and the errors that may be present) into information that can drive suitable actions.
Opportunity	With the development of data science technique, we will be able to improve the quality of data, to a position that can enable us to turn the significant quantity of data we will be recording across highly utilised LV and HV networks into valuable information. This information can then enable us to better understand losses and determine the most appropriate losses mitigation strategies, both on the monitored networks, and for application across the wider network.
Options	The options are to either focus only on enabling net zero, or to focus on both net zero and high losses sections of the network (with regard to enhanced monitoring).
Proposal	As part of our DSO strategy and in line with our obligations to support net zero, we will continue with rolling out LV monitoring, and will expand our capabilities to analyse this data, together with

	other data sources such as smart meters and other network monitoring (e.g. pole mounted reclosers). The specific proposal with regard to losses is to i) ensure high loss networks are considered for enhanced monitoring (in addition to the natural synergy with highly utilised networks), and to ii) ensure data considerations include the need for improving losses understanding and actions.
Action type	Adopt
Losses impact	High – difficult to quantify.
Scorecard Metrics	Not proposed – rollout is led by net zero facilitation.

Action 2.2.1: Modelling improvement

Description	Distribution system analysis tool (DSAT) - to undertake more effective losses modelling; potentially including time series analysis if suitable.
Background	With the increasing volume of improved data (action 2.1.2) becoming available, it only becomes valuable information with improved modelling of the network. At present, it is difficult to undertake a robust losses analysis given that empirical methods are required to convert a single load flow (e.g. winter peak) into an annual losses estimate. As the power flows become increasingly complex, these estimates will become obsolete.
Opportunity	A key element of our DSO strategy is to invest in a future-ready modelling tool, (DSAT). This tool will enable us to no longer rely on empirical techniques/estimates (such as the use of loss load factors, LLFs), to robustly determine the losses on each section of the network; and to therefore better understand losses across the network and to better target intervention.
Options	DSAT is being delivered regardless of losses, however the full use of the tool to incorporate losses requires this to become part of how we use the tool.
Proposal	Ensure that DSAT is used in the most effective manner to help us better understand losses across our network, and to better target intervention.
Action type	Adopt
Losses impact	High – difficult to quantify.
Scorecard Metrics	Not proposed – rollout is led by net zero facilitation.

Action 2.2.2: Active Network Management (ANM) losses optimisation

Description	ANM losses optimisation
Background	The primary purpose of the ANM scheme is to avoid expensive reinforcement costs for customers by releasing previously unobtainable network capacity headroom using a monitoring and control scheme. ANM facilitates a greater utilisation of existing assets, which in turn can lead to increased system losses due to the higher currents flowing in the system for greater lengths of time.
Opportunity	Since the scheme controls a generator's output by issuing target set-points to ensure network capacity limits are not exceeded, there is an opportunity to explore adapting the ANM control algorithm to optimise reactive power flows and thereby reduce losses.
Options	The ANM scheme is based on a real-time load flow engine. Thus, it should be possible to manage both constraint issues and optimise losses at the same time when capacity exists and in a hierarchical manner when constraints are realised.
Proposal	Review ANM optimisation options with respect to losses considerations; and implement where appropriate.
Action type	Consider
Losses impact	Low. Quantifiable based on the algorithm applied. The impact is classed as 'low' for now because our existing ANM scheme does not focus on losses reduction and the confidence regarding this initiative is therefore low at present.
Scorecard Metrics	Not proposed – rollout is led by net zero facilitation.

Action 2.2.3: Optimising network configuration for a specific loading condition (single time step)

Description	Optimising network configuration using DSAT for automatic function to achieve a sole objective, for example optimisation of losses.
Background	Network reconfiguration can be defined as changing the topology of the network by opening and closing switches. The goal of network reconfiguration is to find a radial configuration which minimises a specific objective. Losses, load balancing, voltage deviation, and reliability have been commonly used as objective functions.
Opportunity	Our existing system analysis tool (GROND) has limited optimisation function that is not fit for purpose to deal with future energy scenarios in a complex network with LCTs.
Options	Optimisation of network configuration function will allow us to apply different weights (depending on our preferences) on the objectives and select the one with the best overall performance.

Proposal	We plan to improve the robustness and regularity to which this activity is undertaken, particularly as the level of automation on our network increased, and the number of configuration options also increases.
Action type	To expand this initiative in 2023-28 from the findings in the Enhanced Understanding of Network Losses project[63], in parallel with the development of DSAT.
Losses impact	Medium. Development of this initiative will optimise network losses on our network.
Scorecard metrics	Not proposed, this action requires DSAT to be fully operational.

Design Policy

Ref.	Initiative Group	Initiative	Action Name	Action Type	Losses Impact
3.1.1	Design Policy	Specification	Maximum economic loading guide for distribution transformers	Continue	Low
3.1.2			Lower loss HV overhead line (OHL) conductors (i.e. AL3 to AL5)	Continue	Medium
3.1.3			Install Ecodesign Tier 2 transformers	Adopt	High
3.1.4			Service connection review	Consider	Medium
3.1.5			Increased distribution transformer size	Adopt	Low
3.2.1		Optimal asset sizing	Install low-loss (i.e. higher capacity) low voltage (LV) cables	Continue	High
3.2.2			Install low-loss (i.e. higher capacity) high voltage (HV - 11 kV) cables	Continue	High
3.2.3			Install low-loss (i.e. higher capacity) high voltage (HV - 20 kV) cables	Consider	Low

Action 3.1.1: Maximum economic loading guide for distribution transformers

Description	Maximum economic loading guide for distribution transformers as part of our design policy.
Background	Historically for distribution transformers, the 'economic' sizing for a transformer is generally based upon not exceeding an initial maximum design loading of 95% of the nameplate rating for typical domestic load curves and transformers up to 1000 kVA.
Opportunity	The economic loading has been reviewed and guidance was included in IMP/001/911 Code of Practice for the Economic Development of the LV System, allowing design engineers to appropriately size transformers to optimise losses in a consistent manner.
Options	Our IMP/001/911 provides maximum economic loading guidance for new distribution transformers resulting in use of higher capacity assets, depending on load/generation type. System transformers on our extra high voltage (EHV) and 132 kV network are sized to match the load and selection of cables and overhead lines shall be based on IMP/001/913 – Code of Practice for the Economic Development of the EHV System.
Proposal	We will continue this approach in 2023-28, while we will update the loading and generation categories to align with our DFES assumptions.
Action type	Continue from 2015-23 and apply the output from the CBA for 2023-28.
Losses impact	Low. Losses is embedded in the economic loading guide.
Scorecard metrics	Not proposed, this is business as usual design policy.

Action 3.1.2: Lower loss HV overhead line (OHL) conductors (AL3 to AL5)

Action description	Changing the HV OHL conductor specification from AL3 to AL5.
Background	Historically, we specified AL3 grade alloy (all aluminium alloy conductor) AAAC for our HV overhead lines.
Opportunity / issue	AL5 grade has significantly lower resistivity to achieve higher ratings for a given size of conductor, resulting in lower losses.
Options	For high voltage (HV) overhead lines, we have upgraded to AL5 grade alloy (all aluminium alloy conductor) AAAC in sizes 100 mm^2 and 175 mm^2 for main line circuits and 50 mm^2 and 100 mm^2 for tail end circuits. The choice of these conductor sizes is dependent on the load of the circuit.
Proposal	We have changed our HV OHL conductor specification from AL3 to AL5.
Action type	Continue from 2015-23 and review the CBA.
Losses impact	Medium. It is an industry-wide decision to move to the more efficient AL5 conductor for HV OHL.
Scorecard Metrics	Not proposed, this is business as usual asset specification.

Action 3.1.3: Install Ecodesign Tier 2 transformers

Description	Utilise low-loss transformers to the latest Ecodesign standard (note: this action was previously amorphous core technology, which has a superior losses performance compared to Tier 2).

[63] Action 2.2.3, Action 4.1.3 and Action 4.2.5 – Refer to Enhanced Understanding of Network Losses:WP3-5 Report

Background	Modern transformers used 'cold-rolled grain-oriented' (CRGO) silicone steel (and often referred to as CROSS) cores. The no-load (or fixed) losses in these transformers are typically in the order of 1 kW for distribution transformers.
Opportunity	During 2015-23 we trialled the use of a different core material; amorphous steel. These transformers are referred to as amorphous core transformers, and typically have half the no-load losses.
Options	Recent EC legislation has resulted in significant progress of CRGO transformer losses, where as of early 2020, designs are still being finalised to comply with these latest legal requirements. The base-case option is to utilise the most modern CRGO transformers; whilst the most ambitious option is to adopt amorphous transformers.
Proposal	We have undertaken detailed analysis (consisting of several hundred cost-benefit analyses) to determine that amorphous transformers provide the highest net present value to our customers when incorporating the societal cost of losses. With the exception a handful of scenarios, we proposed to widely adopt amorphous core transformers, subject to confirmation of the long term asset integrity, when compared to the long lifespan required. This proposal, is however impacted by Ofgem's final determination late 2022, which did not appropriately fund such an ambitious losses initiative which would provide net benefit to customers. As such, the proposal is to revert to Tier 2 standard transformers, which will also provide significant benefit to customers when compared to the counterfactual of higher-loss legacy transformers.
Action type	Adopt.
Losses impact	High. There is, however an unfortunate missed-opportunity by note using AMT, where the weighted average (per unit) losses savings of AMT when compared to an Ecodesign tier 2 transformers is 0.25 MWh p.a., which across 12,000 units equates to 3 GWh losses saving. Despite this there is still a significant saving associated with simply replacing the high loss legacy transformer with a more modern 'Tier 2' unit.
Scorecard Metrics	In our Losses Strategy submitted with our 2023-28 business plan , we were working on the assumption that we were to replacing and/or install roughly 15,00 units of HV/LV transformers, and 80% were suitable for AMT, we proposed 12,000 units as a 2023-28 target. The funding for this, however, was not appropriate in Ofgem's final determination, hence we are instead proposing that 15,000 units of Tier 2 continues to be tracked as the benefits of this are still significant to customers. Note: The volume driver is not losses, and therefore the total number of HV/LV transformers is subject to change, and the final decision on the use of AMTs is subject to the final review of 2015-23 learning of AMTs, together with the outcome of competitive tender events.

Note: We will continue to investigate the use and benefits of amorphous core transformers in ED2 and consider submitting this as a request in a future price control.

Action 3.1.4: Service connection review

Description	Review of service connections (single phase vs. three phase).
Background	The existing standard for new (or replacement) service connection is single phase 80 amp infrastructure. This enables customers to draw up to 18.4 kW; which becomes increasingly likely to be reached, or exceeded as customers adopt low carbon technologies.
Opportunity	Three phase connections are commonplace across the EU, and there have been several customers requesting such connections in recent years. Three phase services could potentially better enable customers to facilitate LCTs whilst reducing losses and minimising issues (e.g. unbalance, voltage or thermal violations) on the LV network. Overall there could be a net benefit for new connections if three phase services were installed.
Options	Doing nothing is not a suitable option, given the need to remove any barriers to net zero, and to better serve our customers. At the other extreme, unilaterally imposing three phase services as a standard may also not provide net benefits (for example, three phase LCTs may be significantly more expensive given the majority of the UK is likely to remain single-phase). There is therefore a need to collaborate across our stakeholders and wider industry to determine the appropriate standard.
Proposal	Undertake more detailed CBA (including customer aspects, including EV chargers) and pan-industry collaboration to determine future requirements; with a view of this being mandated as part of a national standard (if determined to be an appropriate action). This will likely require further consultation with a wide range of impacted stakeholders.
Action type	Consider.
Losses impact	Medium – primary benefit is facilitating net zero.
Scorecard Metrics	Not proposed.

Action 3.1.5: Increased distribution transformer size

Description	Increased distribution transformer size
Background	Higher rated transformers typically have higher no-load losses, however they typically have lower load losses. There is therefore a point at which the loading of a site becomes sufficiently large to warrant 'upsizing' of the transformer.
Opportunity	We are replacing several thousand distribution transformers driven by either (a) load related drivers such as EV adoption rates, or (b) non-load related drivers such as asset health or PCB legislation. We therefore have the opportunity to determine the most appropriate transformer sizes based on the current and future load profiles at each site.
Options	We could determine a 'one-size-fits-all' approach for a given demand group (e.g. an existing 500 kVA transformer feeding 100 homes), however our analysis has shown that the appropriate size to select is highly sensitive to the specific load characteristics both now and in future. Rather than a one size fits all, we have determine that it is appropriate to take the specific site loading into account.
Proposal	Incorporate the selection criteria into our transformer selection process for each site. This will ensure that the most appropriate sizing option is selected, which best balances cost, load-losses and no-load-losses.
Action type	Adopt
Losses impact	Low. Marginal impact on the basis of the decrease in load losses being offset by the increase in the no load losses.
Scorecard Metrics	Not proposed. Analysis done in CBA stage

Action 3.2.1: Install low-loss (i.e. higher capacity) low voltage (LV) cables

Description	LV cable sizing increase from 185 mm^2 to 300 mm^2.
Background	From a losses optimisation perspective, the selection of conductor sizes as dictated by the design policy has a greater impact than the equipment standard.
Opportunity	The benefits of low loss design have usually been in the form of higher capacity (larger) conductors[64], taking into account the whole lifetime cost.
Options	The incremental cost of bigger size conductor is compared with the benefits of having bigger capacity, lower resistance conductor, i.e. lower losses, future proofing the extra capacity required to facilitate net zero and improving network performance (i.e. voltage drop, current carrying capacity and earth loop impedance).
Proposal	We have adopted 300 mm^2 aluminium underground cables as a standard cable size for all mains other than tees carrying less than 120 A per phase[65].
Action type	Continue from 2015-23.
Losses impact	High. Losses benefit of 2.3 MWh per kilometre.
Scorecard metrics	For simplicity (and given the similar costs and benefits for both LV and 11 kV higher capacity cables) we have grouped LV and 11 kV higher capacity cables together. On the assumption that we are replacing or installing c4,250 km of HV and LV cable (in total), and 80% of the volume is proposed as (suitable for) 300 mm^2, we propose 3,400 km as a 2023-28 target. *Note: The volume driver is not losses, and therefore the total volume of HV/LV cable is subject to change.*

Action 3.2.2: Install low-loss (i.e. higher capacity) high voltage (HV - 11 kV) cables

Action description	11 kV cable sizing increase from 185 mm^2 to 300 mm^2.
Background	From a losses optimisation perspective, the selection of conductor sizes as dictated by the design policy has a greater impact than the equipment standard.
Opportunity	The benefits of low loss design have usually been in the form of increased sizing of conductors, taking into account the whole lifetime cost.
Options	The incremental cost of bigger size conductor is compared with the benefits of having bigger capacity, lower resistance conductor, i.e. lower losses, future proofing the extra capacity required to facilitate net zero and improving network performance (i.e. voltage drop and current carrying capacity).

[64] The cost benefit analysis (CBA) for sizing increase of conductors is described in our 2015-23 Losses Sttrategy. This policy has also been adopted by other DNOs.
[65] IMP/001/911 – code of practice for the economic development of the LV system

Proposal	The standard HV underground cable size used on distribution feeders at 11 kV is 300 mm^2 aluminium.
Action type	Continue from 2015-23
Losses impact	High. Losses benefit of 2.7 MWh per kilometre.
Scorecard Metrics	For simplicity (and given the similar costs and benefits for both LV and 11 kV higher capacity cables) we have grouped LV and 11 kV higher capacity cables together. On the assumption that we are replacing or installing c4,250 km of HV and LV cable (in total), and 80% of the volume is proposed as (suitable for) 300 mm^2, we propose 3,400 km as a 2023-28 target. *Note: The volume driver is not losses, and therefore the total volume of HV/LV cable is subject to change.*

Action 3.2.3: Install low-loss (i.e. higher capacity) high voltage (HV - 20 kV) cables

Description	20 kV cable sizing increase from 185 mm^2 to 300 mm^2.
Background	From a losses optimisation perspective, the selection of conductor sizes as dictated by the design policy has a greater impact than the equipment standard.
Opportunity	The benefits of low loss design have usually been in the form of sizing increase of conductors, taking into account the whole lifetime cost.
Options	The incremental cost of bigger size conductor is compared with the benefits of having bigger capacity, lower resistance conductor, i.e. lower losses, future proofing the extra capacity required to facilitate net zero and improving network performance (i.e. voltage drop and current carrying capacity).
Proposal	For our 20 kV standard underground cables, the sizing increase option was discounted in 2015-23, hence the size remains at 185 mm^2 for distribution feeders[66]. We will review our position on this in 2023-28, as potentially higher capacity cables might be beneficial on selected, highly loaded and high growth networks.
Action type	New action to consider in 2023-28. To revisit this CBA, based on the up-to-date DFES, with a more targeted approach based on loading.
Losses impact	Low. Based on the 2015-23 CBA, we envisaged that the standard application of higher capacity cables provides limited benefits.
Scorecard metrics	Not proposed. This action is to review our current practice on the sizing of 20 kV cable.

Network Operation

Ref.	Initiative Group	Initiative	Action Name	Action Type	Losses Impact
4.1.1	Network Operation	Static Network Operation	Static HV voltage optimisation	Continue	Medium
4.1.2			Static EHV voltage optimisation	Continue	Low
4.1.3			Multi-objective system optimisation of network operation	Expand	Medium
4.2.1		Dynamic Network Operation	Dynamic voltage optimisation	Expand	High
4.2.2			Soft Open Point (SOP)	Research	Low
4.2.3			Transformer Auto Stop Start (TASS)	Discount	Low
4.2.4			Optimising network configuration using multi-time step approach (e.g. hourly reconfiguration)	Discount	Low

Action 4.1.1: Static HV voltage optimisation

Description	HV voltage optimisation
Background	During 2015-23 we commenced a significant voltage optimisation programme of works to reduce the voltage at our primary substations from 11.3 kV to 11.1 kV (and 20.3 kV to 20.1 kV). Continued application of, and/or more aggressive static voltage optimisation could better facilitate net zero, reduce energy consumption, and potentially reduce network losses.
Opportunity	Through our smart grid enablers programme in 2015-23, we have improved our understanding of voltages and transformer tap positions across the network (action 2.1.2). Combined with our ability to use the enhanced level of network monitoring data, and to undertake more powerful modelling the network (action 2.2.1), alongside the use of modern, smart voltage controllers, AVCs (delivered as part of our 2015-23 smart grid enablers programme) to better control the network in real time, we recognise the opportunity of more aggressive static voltage optimisation, alongside the more comprehensive method of applying dynamic voltage optimisation.

[66] IMP/001/912– code of practice for the economic development of the HV system

Options	The existing approach of a static voltage target at primary substations is unlikely to be suitable in a future with a substantial uptake of LCTs, and therefore we believe there will be an increased need to use smarter, more flexible voltage optimisation techniques. Ahead of the application of dynamic voltage optimisation (Action 4.2.1), we recognise that we should continue and expand the use of static voltage optimisation in the interim, and/or in parallel.
Proposal	We will build on our successful programme of reducing HV voltages (static).
Action type	Expand
Losses impact	High – majority of the benefit are direct energy consumption benefits to customers rather than improved NPg network efficiency.
Scorecard Metrics	Not proposed, losses is not the main driver.

Action 4.1.2: Static EHV voltage optimisation

Description	EHV voltage optimisation
Background	EHV (i.e. 33 kV and 66 kV) voltages have been generally kept at the design voltage (i.e. at 33 kV and 66 kV) for decades. The increased complexity of power flows across our network has challenged the on-going suitability of maintaining this status-quo. For example: the ability of HV voltage optimisation is limited by the tapping range of primary transformers (which can be better supported by adjusting EHV voltages); and the ability to connect more low carbon technologies is limited by voltage considerations.
Opportunity	During 2015-23 we undertook a comprehensive analysis of all EHV networks, and determined that the majority of the network should either be adjusted to a new voltage, or should adopt a more sophisticated voltage target which changes as the network loading changes (i.e. a dynamic voltage). This significantly improves the amount of capacity on our network, whilst also enabling HV voltage optimisation.
Options	Option 1) Not revisit the EHV network analysis. This would limit the potential capacity increase of the EHV Network; Option 2) Keep them under review as the network condition changes.
Proposal	Keep them under review, and review whenever there is a material change (e.g. a new connection to the network, or significant change in load profiles).
Action type	Continue with our 2015-23 strategy of undertaking sophisticated network studies to determine the optimum EHV voltage for each network.
Losses impact	Low – although directly facilitates net zero and HV voltage optimisation
Scorecard Metrics	Not proposed, losses is not the main driver.

Action 4.1.3: Multi-objective system optimisation of network operation

Description	Multi-objective system optimisation of network operation (using DSAT platform), considering various future net zero pathways.
Background	A fully automated multi-objective system optimisation tool would enable a robust analysis of the different decarbonisation pathways, and would consider the various objectives required to ensure whole system optimisation, such as network reliability, thermal and voltage limits and losses optimisation. At present, the tools the industry use are not fully capable of catering for the future, more complex energy system.
Opportunity	Our existing system analysis does not have this multi-objective capability, and our option to optimise network configuration is limited to manual intervention.
Options	Multi-objective function will allow us to apply different weights (depending on our preferences) on the objectives and select the one with the best overall performance.
Proposal	We plan to improve the robustness and regularity to which this activity is undertaken, particularly as the level of automation on our network increased, and the number of configuration options also increases.
Action type	Expand this initiative in 2023-28 from the findings in the Enhanced Understanding of Network Losses project[67], in parallel with the development of DSAT.
Losses impact	Medium. Development of this initiative will optimise network losses on our network, however we do not anticipate that this will produce a significant losses impact during 2023-28.
Scorecard metrics	Not proposed, this action requires DSAT to be fully operational.

Action 4.2.1: Dynamic voltage optimisation

Description	Dynamic Voltage optimisation using smart grid enablers (LDC as a minimum, and application of the method being trailed in our NIA project 'Boston Spa Energy Efficiency Trial' if successful).
Background	The key driver for this is primarily to enable conservation voltage reduction (CVR); improving behind the meter energy efficiency, and therefore saving customers money on their energy bills,

[67] Action 2.2.3, Action 4.1.3 and Action 4.2.5 – Refer to Enhanced Understanding of Network Losses:WP3-5 Report

	and reducing the amount of generation (and therefore carbon emissions) associated with our customers' energy needs.
Opportunity	Given the primary benefit of voltage optimisation is CVR, this aligns with our vision of optimising whole system losses; where behind-the-meter efficiency should be considered in the same way we consider losses, and therefore recognising that our actions can impact customers' energy efficiency; it is a significant opportunity for us to apply whole systems solutions for the benefit of our customers. Note also that voltage optimisation better enables the connection of more load and generation, in addition to reducing energy consumption (whole system optimisation); which in turn can reduce network losses.
Options	The two main options are (a) load drop compensation (which we have trialled successfully), or (b) adoption of the BEET innovation project learnings (which is due for completion by the end of 2023-28).
Proposal	Dynamic Voltage optimisation using smart grid enablers (LDC as a minimum, and Boston Spa Energy Efficiency Trial learnings if successful). This proposal also appears as a Whole Systems Initiative (where funding of £7.5m is located, along with quantification of benefits of tens of £m). Given the significant societal benefits of this proposal, Dynamic Voltage Optimisation is also being proposed as a Customer Value Proposition (CVP). CVPs are initiatives that we are proposing in 2023-28 that go above and beyond what our licence and Ofgem's Business Plan Guidance requires of DNOs. Note: DNOs are obligated to provide voltage compliance (within the ESCQR range), not voltage optimisation.
Action type	Expand
Losses impact	High – on the basis that treating behind the meter inefficiency as a type of whole system losses, where the impact will be significant to the order of 4% of total consumption (i.e. similar order of magnitude to distribution system losses), by applying dynamic voltage optimisation where this adds value. This will make the most use of our smart grid enablers investment, and should better facilitate net zero whilst providing direct benefit to customers (in terms of consumption reduction). The specific dynamic options to be adopted will depend on the learning of the BEET project, whilst also taking into account any changes to the legal (ESQCR) voltage limits that we will seek to take advantage of should they change.
Scorecard Metrics	Yes – build around CVR benefit

Action 4.2.2: Soft open point (SOP)

Description	The application of soft open points (SOP) to optimise network losses, following the findings from Enhanced Understanding of Network Losses project[68].
Background	Soft open points (SOPs) are power electronic devices which are used to interconnect two (or more) feeders in place of normally open points.
Opportunity	SOP has the ability to continuously control active power flow between the interconnected feeders (potentially between different phases), and to inject/absorb reactive power independently at the AC terminal nodes.
Options	These characteristics can significantly influence the optimal operation and planning of modern distribution networks.
Proposal	To further research SOP optimisation to optimise network losses and to investigate learning from Active Response[69], an innovation project from UKPN which trialled SOP.
Action type	Research
Losses impact	There will be losses benefit; quantification will be possible once the model is established.
Scorecard metrics	Not proposed, this action is research-based.

Action 4.2.3: Transformer auto stop start (TASS)

Action description	Transformer auto stop start (TASS) project by SSEN through their innovation project LEAN[70].
Background	The transformer auto stop start method will switch off one in a pair of transformers in selected substations to reduce fixed losses. The Alternative Network Topology method will be deployed alongside the above where appropriate, to further reduce losses and maintain network supply integrity.
Opportunity / issue	These methods could save over 31,000 MWh of electricity over 45 years, worth over £40m to GB customers. This equates to savings of 6,421 tonnes of CO_2. On a per customer basis, this is c£0.03 p.a.

[68] Enhanced Understanding of Network Losses:WP3-5 Report
[69] https://innovation.ukpowernetworks.co.uk/projects/active-response/
[70] Low Energy Automated Networks (LEAN) project can be viewed at https://www.ssen.co.uk/LEAN/

Options	We see this as some valuable learning, albeit a potentially niche application, as we need to consider the interactions of such schemes with network automation, voltage optimisation and ANM schemes.
Proposal	We have reviewed the learning - unlikely to implement when taking into account the potential conflicts with other network management schemes that we have.
Action type	Discount. WPD, in their 2020 DSO Losses Strategy, carried out analysis on the application of this technology for their network. The key findings were that only 1 out of 25 sites identified as suitable, and there were additional concerns about the detriment to security of supply, which would further reduce the overall benefit of this initiative. Although their updated 2021 DSO Losses Strategy does not provide an updated position on this, we take their view in their 2020 Losses Strategy to further strengthen our position not to pursue this technology as we need to consider the interactions of such schemes with network automation, voltage optimisation and active network management (ANM) schemes.
Losses impact	Low. The losses benefits are documented in the TASS project document, but we are discounting this project anyway.
Scorecard Metrics	Losses is the main driver, but we decided to discount.

Action 4.2.4: Optimising network configuration using multi-time step approach

Description	Optimising network configuration using multi-time step approach (e.g. hourly reconfiguration).
Background	Network reconfiguration can be defined as changing the topology of the network by opening and closing switches. The goal of network reconfiguration is to find a radial configuration which minimises a specific objective. A multi-time step analysis means that we optimise the configuration of the network each time step (for example every hour) accounting for the variability of demand to achieve an objective, for example to optimise losses.
Opportunity	Generally, multi-time step (here hourly) reconfiguration provides improved results at the cost of performing multiple switching actions to change between different network configurations throughout a specific period, for example throughout the day.
Options	Network reconfiguration using multi-time step approach, compared to fixed optimal configuration, only provides small additional improvement, which can be considered negligible.
Proposal	We have decided not to pursue this action from the findings of the enhanced understanding of network losses project[71].
Action type	To discount. Action 2.2.3 is sufficient
Losses impact	Losses benefit can be achieved, at the cost of performing multiple switching actions.
Scorecard metrics	Not proposed, this action is discounted.

Non-technical losses

Ref.	Initiative Group	Initiative	Action Name	Action Type	Losses Impact
5.1.1	Non-technical losses	Energy efficient substations	Improve the energy efficiency of our substations	Adopt	High
5.2.1		Theft	Theft - monitoring data	Consider	High
5.2.2			Theft - tamper alerts	Consider	Medium

Action 5.1.1: Energy efficient substations

Description	Energy efficient substations - improving the energy efficiency of our substations with alternative building materials, and improved energy management (including technology such as modern dehumidifiers, improved ventilation, LCTs such as heat pumps or solar PV).
Background	Each year our substations consume c21 GWh of electricity. NPg pays for this electricity, and at a cost of c£2.5m each year; it is clear that improving energy efficiency of our substations could provide significant financial and environmental benefit. Note that these supplies are currently unmetered, and therefore the usage is based on estimation. This unmetered arrangement was agreed with Ofgem over a decade ago on the basis that to retrospectively install metering would ultimately cost consumers more.
Opportunity	Our major substations, in particular, consume a significant amount of electricity; at roughly 13.5 MWh each, this is roughly equivalent to four 'typical' homes. In recent years, the availability and cost of energy efficiency retrofit technology has improved. We recognise that to lead by example, and to be a force for good within our region, that we must also play our part when it comes to energy efficiency. Apart from the significant financial and environmental benefits

[71] Action 2.2.3, Action 4.1.3 and Action 4.2.5 – Refer to Enhanced Understanding of Network Losses:WP3-5 Report

	afforded from energy efficiency, there are also potential benefits of improving the environment in which our critical infrastructure operates. By assessing our substations for energy efficiency measures, we will (a) determine with greater accuracy the electricity consumed by our substation supplies, and (b) be able to determine a rollout strategy for our entire population of major substations that we will then be in a position to implement as required, particularly during 2028-33 (for significant changes), else 2023-28 for those changes that are easy to implement.
Options	Doing nothing is not a suitable option. At the other extreme, installing energy efficiency measures that do not provide a positive net present value are also not suitable. We therefore intend to undertake a measured, and balanced approach to first monitoring and understanding the performance of our substations, and then identify and appraise the different options. In the same way a home-owner would review an EPC and select the most appropriate options; we propose the same approach.
Proposal	Apply BREEAM energy and carbon management standards (which resembles EPC), or equivalent, and implement appropriate recommendations. This initiative shall be carried out at all major (i.e. supply point and primary) sites. This initiative shall be covered as part of BCF considerations; however substation energy use is a subset of 'losses', hence included here. We will incorporate learning from Scottish Power Transmission's 'Substation Transmission Losses Project', which undertook similar analyses, mainly aimed at reducing heating requirements.
Action type	Adopt – undertake assessments, and implement appropriate measures.
Losses impact	High
Scorecard Metrics	Potentially, based on number of sites.

Action 5.2.1: Theft - monitoring data

Description	Utilising smart meter data and LV monitoring to better identify theft, working closely with stakeholders such as ElectraLink.
Background	Energy (i.e. electricity and gas) theft across the UK is estimated to be valued at £400m each year. It is important to stress that this is an estimate based on research from 2016, and in reality, we do not know how much electricity theft takes place on our network. It is however known that electricity theft does occur, and when it does, it can be unsafe, it can be linked to crime, and the stolen electricity is paid for by other bill-paying customers. It is also well-recognised that vulnerable customers are at greater risk of exposure to energy theft, whether it be intentional or not.
Opportunity	The smart meter rollout together with our smart grid enablers programme which is rolling our LV monitoring should enable us to better analyse LV network energy flows, and determine outliers that could be a tell-tale sign of energy theft. The existing theft reduction service is administered by ElectraLink, who have advised that the techniques used are limited, and have a success rate of c5%. We are working closely with ElectraLink on this topic.
Options	Doing nothing is not a suitable option given the significant impact of theft on UK consumers, especially vulnerable customers. Whilst it is not known how successful the use of monitoring data and smart meter data will be, we believe that the time is right to commence further work on this opportunity.
Proposal	Consider the use of LV monitoring data, which together with smart meter data could be a useful method of determining electricity theft. We are pro-actively engaging with stakeholders (particularly ElectraLink and suppliers) to drive this initiative, focussing on vulnerable customers.
Action type	Consider
Losses impact	High
Scorecard Metrics	No – This action is proceeding with heavy involvement from ElectraLink. We believe there is substantial potential for this action but this needs further investigation. This could potentially appear in our future iterations of key actions.

Action 5.2.2: Theft - tamper alerts

Description	Non-technical losses - smart meter tamper alerts
Background	Smart meters have tamper alert capability, unlike the non-smart electromechanical, or early digital meters; which would not identify if the meter had been tampered with.
Opportunity	Because electricity theft has historically been via meter tampering, the capability of smart meters to communicate tampering events could provide invaluable information that could be used to target theft initiatives. Early application of tamper alerts has identified that (a) the alerts are not accurate, and (b) there are likely to be other methods of theft (including bypassing the meter, or simply not electing for a smart meter to be installed). The application could thus be limited by the smart meter rollout not being mandated.
Options	Despite the early signs that tamper alerts may not be the most useful source of information, it is reasonable to keep their use under consideration. The option of not using tamper alerts at all is not

	deemed suitable (given that the use of the alerts is likely to still prove useful), whilst to assume that tamper alerts will be the primary method of determining theft may be over-ambitious.
Proposal	Tamper alerts will continue to be reviewed, alongside other methods of determining theft (specifically, action 5.2.1).
Action type	Consider the use of tamper alerts (together with action 5.2.1 on using monitoring data to determine theft) – subject to on-going pan-industry work to determine the success rate of using tamper alerts.
Losses impact	Medium
Scorecard Metrics	Potentially, based on signals received and acted upon.

Research & Development

Ref.	Initiative Group	Initiative	Action Name	Action Type	Losses Impact
6.1.1	Research & Development	Investigation / Trial	Losses correction factors	Research	Low
6.1.2			Contact Voltage Losses	Research	Low
6.1.3			Low loss EV charging	Consider	Low
6.1.4			Micro-resilience learning	Consider	Low
6.1.5			Alternative transformer technologies	Consider	Medium
6.1.6			Losses price signals driving flexibility	Research	Medium
6.2.1		Horizon scanning	Revolution of assets	Research	Low

Action 6.1.2: Losses correction factors

Description	Correction factors applied to losses calculations (including the impact of losses on wholesale price).
Background	The existing approach to quantifying the impact of losses is to use half-hourly information to determine the annual losses, and then multiply this annual energy by a pre-determined whole-sale price and averaged carbon-intensity.
Opportunity	First, noting that half-hourly measurements will always underestimate losses should there be any variation at sub-half-hourly intervals, we can seek to better understand the level of underestimation at different sections of the network. Further to this underestimation, the majority of our studies assume a perfectly-sinusoidal, balanced system. In reality this is also not the case, hence there are correction factors we could develop and adopt to better account for this. Second, noting that the majority of our (variable) losses occur at peak periods, these losses will generally occur at a time at which the wholesale price is higher than the annual average, and the generation mix is more carbon intensive than the annual average.
Options	We could continue with the existing, status-quo; however this is not suitable given that the network will become increasingly utilised, with more power-electronic (non-linear) loads; together with the underlying wholesale market becoming increasingly volatile (e.g. with very low carbon intensity during the day, and very high at winter peak, coupled with an ever widening spread between lowest wholesale price and highest wholesale price).
Proposal	Consider further research and development, along with other DNOs and market participants (particularly energy trading experts on the wholesale considerations).
Action type	Research
Losses impact	Low – difficult to quantify. This work will enable DNOs to better quantify the impact of losses (so that the assessment is more realistic in the actual financial and environmental impact).
Scorecard Metrics	Not proposed.

Action 6.1.3: Contact voltage losses

Description	Contact voltage losses.
Background	A perfect insulator (or dielectric) does not exist, and therefore there is always a level of discharge that exists on the network. In general, these dielectric 'losses' (or stray currents) are approximately zero, hence are normally neglected. Unfortunately, there are situation where insulation break-down can result in energisation of objects that should not be energised (e.g. street lighting columns). The resulting stray currents can be both dangerous, and result in losses (that are not traditionally captured via modelling).
Opportunity	Energised objects (where there would be a 'contact' voltage) can be identified by use of modern electronics, sensitive down to 1 Volt from several meters away. UKPN have been using a

	commercial offering from a US company, and we have engaged with both UKPN and the US company to agree a potential trial within the NPg network.
Options	To simply reject this initiative would be a lost opportunity for further learning. Instead, undertaking further research and assessment of the technology and to engage with others who have used the technology, together with a potential trial in areas with known issues (e.g. consac cable) would enable us to better understand the capability of the mobile asset assessment vehicle (MAAV) technology.
Proposal	Research further and assess the potential for a trial during 2023-28. This will enable pan-industry dialogue to determine the application of the MAAV. In particular, to better understand and quantify the health and safety case, along with the losses driver. Due to the different network topology and earthing arrangements (compared to LPN), we are unlikely to determine a need for this technology; particularly when considering the significant rollout of LV monitoring. We have thus, not built the use of MAAV into our core 2023-28 planning assumptions (beyond losses).
Action type	Research
Losses impact	Low. Whilst UKPN has determined that contact voltage losses form the majority of addressable losses for DNOs, we note that this remains untested, and unlikely to be true for our network given the different topology, cable technology / earthing arrangements. We will, however, continue to work with UKPN and other DNOs to better understand this area.
Scorecard Metrics	Not proposed.

Action 6.1.4: Low loss EV charging

Description	Consider lower loss EV charging facilities. This will require collaboration with the EV industry.
Background	EV charging facilities will be required on a large scale to cope with the increasing uptake of EVs of all sizes.
Opportunity	WPD is working with local authorities on plans to create low loss EV charging hubs, applying amorphous core transformer technology on a pad-mount. We should also look into this.
Options	EV charging comes in different transformer voltage ratios, different technical specifications and technologies for different power outputs, ranging from less than 100 kW to more than 1 MW capability.
Proposal	We will review the existing and future EV charging technologies to look into the impact on losses, and the opportunity for a low loss, smart EV charging on our network.
Action type	To consider.
Losses impact	Low. There will be losses benefit, but not straightforward to quantify for now.
Scorecard metrics	Not proposed.

Action 6.1.5: Micro-resilience learning

Description	Implementing learning from micro-resilience innovation project, including power factor correction, phase balancing, losses reduction using batteries, etc.
Background	Existing secondary transformer sites (HV/LV) are passive in nature, simply supporting the real and reactive power needs of the customers. We are currently trialling the use of power electronic transformers and batteries that could be used to improve resilience as seen by the customer (i.e. the ability for islanded operation, for an HV fault). This is being undertaken as an NIA innovation project.
Opportunity	In addition to the resilience benefits, power electronic (HV/LV) transformers, together with a battery, could provide both reactive power (i.e. power factor) correction along with real power injection to optimise network loading. This is further boosted when considering this can be provided independently on each phase, to provide phase balancing. The losses benefit is not the primary driver for micro-resilience, but the losses benefit could further support the on-going rollout of such systems.
Options	Option 1) Losses benefits could be left out of consideration from micro-resilience project. Option 2) Incorporating losses considerations into the project is preferred as this could provide valuable learning for losses management in future, together with ensuring synergies such as resilience and losses are taken into account; therefore strengthening value of these innovative solutions.
Proposal	Research losses as part of micro-resilience NIA project during 2015-23, and consider the operation of micro-resilience solutions to improve losses management during 2023-28.
Action type	Consider the application of losses optimisation for micro-resilience offerings during 2023-28.
Losses impact	Low
Scorecard Metrics	Not proposed.

Action 6.1.6: Alternative transformer technologies

Description	Alternative transformer technologies.
Background	The existing transformer technology is very reliable and sturdy. It has inherently high efficiency and has been used since the beginning of the electricity grid, although incremental improvements to improve efficiency have been developed throughout the decades.
Opportunity	Advancement in technologies nowadays allows us to look into alternative technologies that could improve the efficiency and provide flexibility to operate the network.
Options	One technology to consider is solid-state transformers (SST). They have been developed over the past 15 years, especially in the railway industry, and now the application is considered in smart grid applications. SPEN, in their innovation project LV Engine[72], termed this as 'Smart Transformer'. The configuration can either be direct AC/AC like the normal transformer or AC/DC/AC that contains DC link. Alternative core technologies, such as the triangular wound core transformer configuration or ultra-thin silicon steel core technology could also be considered.
Proposal	To look into the potential of SST, currently applied in the LV Engine innovation project as well as considering other technologies.
Action type	To consider the potential for application during and beyond 2023-28, and to implement if viable. Our MicroResilience project will apply the power electronic transformer technology.
Losses impact	Medium. There will be losses benefit that can be quantified once the model is established.
Scorecard metrics	Not proposed.

Action 6.1.7: Losses price signals driving flexibility

Description	Use of flexibility – incorporating losses price signals into the decision-making process within a future DSO scenario.
Background	Whilst the majority of flexibility is expected to be driven by wholesale energy prices, which in turn drive time-of-use tariff price fluctuations, it is acknowledge that DSO flexibility will also be required in order to ensure networks can run within limits (e.g. thermal) and optimally. Operation within limits is the key driver for DSO flexibility, however we also recognise that optimisation could take into account factors such as losses.
Opportunity	The enhanced understanding of network losses project[73] has shown that signalling available network capacity in the form of active losses charging offers a potential mechanism by which the DSO could increase overall system efficiency and maintain integrity within the distribution system. The scenario discussed in the report is the EV charging and discharging actions.
Options	Option 1) Do nothing. This option is not appropriate given the significant role that price signals and associated flexibility will have on the future network. If we do not appropriately incorporate losses as the market develops, the outcomes could result in higher overall costs for customers. Option 2) Take the learning from the CLDS[74] project (and other relevant projects) as and when it arises, and take further action as appropriate.
Proposal	Research losses as part of CLDS is on-going, and we will continue to (and likely to expand) research this area as appropriate, subject to the learning that are derived from CLDS and other projects. This area is primarily research-biased; hence the action type is listed as research.
Action type	Research
Losses impact	Medium
Scorecard Metrics	Not proposed.

Action 6.2.2: Revolution of assets

Description	Revolution of assets (e.g. new materials/technologies).
Background	As a network operator, we need to keep up-to-date with new technologies to support flexible and smart grid development of our network.
Opportunity	This includes looking into new cable technologies (e.g. superconducting or capacitor cables), power electronic applications to support DC operation of the network embedding LCTs, looking into new assets to support the possibility of micro grids on certain parts of our network and improving network congestion through the application of real time thermal ratings (RTTR).
Options	To carry out innovation projects or to apply as business-as-usual (BAU) for those already trialled in 2015-23.
Proposal	To continue, and trial as necessary in collaboration with other DNOs, industry players and academia, and to consider for a trial as technology matures.
Action type	Research.

[72] https://www.spenergynetworks.co.uk/pages/lv_engine.aspx
[73] Enhanced Understanding of Network Losses:WP3-5 Report
[74] Customer-Led Distribution System (NIA_NPG_19): https://www.northernpowergrid.com/innovation/projects/customer-led-distribution-system-nia-npg-19

Losses impact	There will be losses benefit once a model is developed.
Scorecard metrics	Not proposed, this is horizon scanning.

Stakeholder

Ref.	Initiative Group	Initiative	Action Name	Action Type	Losses Impact
7.1.1	Stakeholder	Customer Energy Efficiency	Power factor advice	Expand	Medium
7.1.2			Community energy coaching (advisors)	Adopt	High
7.2.1		Education and engagement	Losses educational material	Continue	Medium
7.2.2			International collaborations	Continue	Low
7.2.3			Collaboration, sharing and adopting best practice	Continue	Medium
7.2.4			ENA Engineering Recommendation on Losses	Adopt	Low
7.3.1		Expert stakeholder collaboration	Internal stakeholder engagement	Continue	High
7.3.2			Collaborations with academia	Continue	Medium

Action 7.1.1: Power factor advice

Description	Power factor advice for non-domestic customers.
Background	Poor power factor can increase system losses, together with reducing spare network capacity and impacting voltage regulation. Industrial and commercial customers are charged for poor power factor, and we have found during 2015-23 that many of these customers have a poor awareness of the topic in general.
Opportunity	Educating customers and arming them with key information can result in customers taking action to remedy poor power factor; saving them money in the process, and reducing system losses. We commenced this activity during 2015-23, producing a power factor guide, and communicating with several hundred customers who could most benefit from taking action. Building on this further could unlock the benefits further.
Options	Option 1) Take no further action. Not considered appropriate given the significant benefit that could be created for customers, with minimal NPg benefit. Option 2) Limited power factor action (as undertaken during 2015-23). Not considered appropriate given that the learning from 2015-23 highlighted the materiality of poor power factor. Option 3) Expand on the 2015-23 power factor advice, by further targeting key customers, and then using this learning to continuously improve our advice.
Proposal	Expand on the 2015-23 power factor advice, by further targeting key customers, and then using this learning to continuously improve our advice.
Action type	Expand
Losses impact	Medium – TBC
Scorecard Metrics	Not proposed.

Action 7.1.2: Community energy coaching

Description	Community energy coaching: 1) community energy savings 2) energy advice for vulnerable customers Incorporating lessons learnt from WSP losses work (behind the meter)[75] and SAVE[76] project by SSEN. Working together with other stakeholders (e.g. Infrastructure North, Green Doctor etc.).
Background	Whilst fixed losses are broadly independent of network-operation and loading conditions, variable losses are anticipated to increase significantly as network utilisation increases. With the exception of utilising low resistance assets and optimising network operation to better balance (share) loading between network assets; the variable losses are primarily controlled by customer power demand. i.e. variable losses (often referred to as I^2R losses) are determined by the 'I' component; which is directly controlled by customer demand.
Opportunity	Recognising the 'I' component has the most significant impact on variable losses, and that this component is determined by customer demand, we recognise that working with customers (to impact demand), could have significant impacts on losses. The key opportunity is related to the direct benefit of customers reducing energy bills and their direct carbon footprint by either:

[75] A study commissioned by Northern Powergrid to WSP: 'Impact of voltage and harmonic variations on domestic losses'. The report can be viewed on our losses webpage: https://www.northernpowergrid.com/asset/1/document/4121.pdf
[76] Solent Achieving Value from Efficiency (SAVE): https://save-project.co.uk/

	a) Reducing energy demand, either through behavioural change or efficiency upgrades (e.g. upgrading to LED lights); or b) Demand shifting to lower demand, greener demand periods (e.g. shifting energy intensive tasks from 9am to lunch time). The secondary benefit is that the two actions above can directly reduce losses.
Options	We could assume that this is not our role, and is one for others (e.g. government) to fulfil. On the other extreme, we could seek to single-handedly provide energy coaching to all of our 3.9m customers. Instead, a more balanced approach is to undertake energy coaching with existing NPg staff, whilst expanding our core coaching staff to provide targeted, regional support. In addition, we believe that other stakeholders that we have worked with during 2015-23 (e.g. green doctor) will complement our Losses Strategy initiatives.
Proposal	'Customer service' and 'vulnerability' led initiatives to educate and inform our customers is proposed as the most effective route to ensuring that (a) the key messaging for customer is focussed on energy savings and the environmental impact of customer actions, and (b) losses is included within this engagement, but not as the leading message. This is in line with our learning from our engagement for the 2023-28 Losses Strategy. As a result, this (cross-cutting) initiative will be led within the customer service section of our business plan. Community Energy Coaching will involve the continuation of (NPg-funded) projects such as: Community Energy Net Zero fund; Community Partnering Fund - which has a primary focus on supporting those in fuel poverty; Decarbonosation Support for Vulnerable Customers – includes advice on energy efficiency and decarbonisation; developing an online service tool with NGED; work with Green Doctor (supporting 20,000 vulnerable customers p.a. in fuel poverty, work with local Citizens Advice Bureaus; Energy Heroes – working with many of the most deprived schools; and the our net zero education programme, Ahead Partnerdhip.
Action type	Adopt
Losses impact	High
Scorecard Metrics	Yes – Cross referenced against Customer Services actions.

Action 7.2.1: Losses educational material

Description	Losses educational material and website.
Background	Educating stakeholders and disseminating our losses learning and progress is key to sharing of best practice between DNOs, and with customers.
Opportunity	High quality educational material, that is tailored for specific stakeholders will drive better outcomes; such as improved collaboration between DNOs, to customers and communities being more aware of their role in net zero. This action is therefore a key enabler for all stakeholder activities.
Options	Option 1: Stop producing high quality losses educational material. Option 2: Continue producing updated losses educational material to better support stakeholder engagement activities.
Proposal	Continue, and update educational material based on stakeholder feedback. This material will be produced for a range of stakeholders in a range of contexts; from other utilities during Energy Networks Innovation Conference ENIC (formerly LCNI) conferences, to presenting losses initiatives at CIRED, down to contacting non-domestic customer about power factor and energy efficiency. Stakeholder engagement and educational material is to be audience specific.
Action type	Continue
Losses impact	Medium (enabler)
Scorecard Metrics	Not proposed – supports energy efficiency education initiative.

Action 7.2.2: International collaborations

Description	International collaboration - decarbonisation and losses.
Background	See section 'International engagements' of this document.
Opportunity	This is an opportunity to share best practice, knowledge and to improve our understanding on a whole system approach to manage losses.
Options	To continue this engagement and to expand our collaborations.
Proposal	We will continue to engage with and seek value in areas of power system operation and management from the BHE group and Lede AS, looking to expand the collaborations with other international industry players and academia.
Action type	To continue from 2015-23
Losses impact	Low
Scorecard metrics	Not proposed. This is an on-going initiative.

Action 7.2.3: Collaboration, sharing and adopting best practice

Description	Collaboration, sharing and adopting best practice.
Background	Collaboration with other network operators has featured highly in our losses work plan, such as sharing our understanding and learning on losses with other DNOs and open networks project.
Opportunity	This has been a key group to facilitate industry knowledge sharing and has fostered candid discussions between the respective losses experts from the different DNOs.
Options	One option is to continue the collaboration, sharing and adopting best practice, which has been successful in 2015-23 through the losses discretionary reward initiative.
Proposal	To continue and improve collaborations, sharing and adopting best practice. This is important as losses will increase and will become more complex in the future.
Action type	To continue from 2015-23.
Losses impact	Medium
Scorecard metrics	Not proposed. This is an on-going initiative.

Action 7.2.4: ENA Engineering Recommendation on Losses

Description	ENA engineering recommendation on losses.
Background	The ENA TLTG proposed the development of an engineering recommendation on losses.
Opportunity	One of the issues within the industry is the inconsistent approach to assess and report on losses on the network.
Options	One option would be to continue this initiative to come up with a scope for a methodology to assess losses and to develop this further, potentially collaborating with experts within the industry and academia.
Proposal	To develop this document for a consistent approach to manage losses within the industry.
Action type	Adopt.
Losses impact	Low – on the basis that although this will drive a consistent approach to manage losses across the industry, we do not envisage that this will impact our Losses Strategy (i.e. our existing management approach is at the more mature end of the spectrum).
Scorecard metrics	Not proposed.

Action 7.3.1: Internal stakeholder engagement

Description	Internal stakeholder engagement to ensure successful implementation of our ambitious Losses Strategy.
Background	Losses is generally a difficult area, that can sometimes be seen as an 'add-on', where we have recognised that from our engagement activity that losses and whole life cost analysis (i.e. CBAs) are not generally a core part of syllabi across colleges and universities. Losses management is integrated into the way in which we operate, and therefore we require the on-going learning and development of our engineers to reflect our latest thinking and capabilities. Further, If we do not effectively engage internally and do not build the losses actions into our business, we will not be successful in delivering our Losses Strategy.
Opportunity	Given the significant changes taking place within our business – ranging from DSO to net zero – we have the opportunity to educate, engage and build actions that ensure we deliver the Losses Strategy alongside these other existing area of change.
Options	We must deliver our Losses Strategy, and to do so requires a significant effort to educate and inform our internal stakeholders, and build clear actions that need to be delivered. To support this, we fully incorporate management of losses into our code of practices (CoP) for designing the network (including a specific losses CoP), into our product specifications and procurement processes. To ensure accountability for overall implementation of the Losses Strategy, we have a specialist team (the smart grid implementation team) that is tasked with developing and implementing the Losses Strategy, alongside other key business improvements related to design policy.
Proposal	Continue to educate and engage the right people from across the business to ensure that (a) our Losses Strategy is understood, (b) clear actions are defined for which delivery can be clearly tracked, and (c) those delivering against the actions receive the required training and tools to deliver their actions.
Action type	Continue
Losses impact	High – as without ensuring our engineers are working to the most up-to-date process, we cannot implement our Losses Strategy.
Scorecard Metrics	Not proposed.

Action 7.3.2: Collaborations with academia

Description	Collaborations with Bradford University IAB / Newcastle University / University of Manchester/ University of Leeds and other academic institutions.
Background	We have been collaborating with academia to solve engineering problems and as part of innovation projects, including with Newcastle University, on enhanced understanding of network losses.
Opportunity	Collaboration to share knowledge and experience is beneficial to both us and academia.
Options	Collaborations on big innovation projects, smaller scale projects or actions in Losses Strategy. Getting students involved (as part of their dissertation work), keynote talks to students, course syllabi that include subjects on losses.
Proposal	To use the existing platform (e.g. IAB) or to approach them, or to consider their research proposals.
Action type	To continue from 2015-23
Losses impact	Medium - difficult to quantify, however our collaboration with academia is the bedrock of our R&D programme, and ensures new insights and ideas can be further developed.
Scorecard metrics	Not proposed. This is an on-going initiative.

Whole system

Ref.	Initiative Group	Initiative	Action Name	Action Type	Losses Impact
8.1.1	Whole System	Flexibility optimisation	Embed losses costs in optimising flexibility assessments	Expand	High
8.2.1		Whole system collaboration	Collaborations within the industry for a whole system approach	Expand	Low
8.3.1		Whole life-cycle sustainability	Whole life-cycle sustainability	Research	Low

Action 8.1.1: Losses costs in optimising flexibility assessment

Description	Developing a consistent and transparent approach to assess losses in the common evaluation methodology (CEM) to optimise flexibility assessment.
Background	To facilitate flexibility, decarbonisation and DSO, whilst taking losses into account to determine the optimum solution, all DNOs under the ENA open networks platform have developed a common evaluation methodology (CEM) to make investment decisions when comparing flexibility products to traditional network interventions. However, DNOs currently do not have a consistent approach to assess losses. Flexibility will be assessed on a level playing field against traditional network solutions to resolve network constraints. We expect that as network utilisation increases, driven primarily by uptake of LCTs (e.g. EVs, HPs, PVs), that losses will generally increase. We therefore need to ensure that losses are properly taken into account as part of the cost benefit analyses.
Opportunity	We have the opportunity now to ensure that the right data and capabilities are in place to ensure that losses are properly accounted for in the CBA. The availability of high quality data, high quality tools for analyses and the right training can ensure we fully incorporate losses into optimising flexibility assessments to account for losses.
Options	Option 1) Continue with the existing approach where DNOs input the value of losses, with no transparency on the methodology (as defined in the latest open networks CEM WS1A CBA). This option is a rudimentary attempt at ensuring losses are fully quantified, and therefore is a good start, but is not fit for the future as the complexity of losses assessment increases further. Option 2) Collaborate with industry (particularly via other DNOs) to ensure that the latest techniques are applied to the flexibility CBA model, and that any learning results in continuous improvement of the CBA model, together with the underpinning assumptions.
Proposal	We propose option 2 for a consistent and transparent approach to take losses into consideration in the CEM for flexibility options.
Action type	Expand (the open networks CEM work).
Losses impact	High – on the basis that flexibility will play an increasingly important role on our system.
Scorecard Metrics	Not proposed.

Action 8.2.1: Collaborations within the industry for a whole system approach

Description	Working with other stakeholders for whole systems optimisation.

Background	Both DNOs and NGET/NGESO collaborate to ensure the development and operation of an economic, efficient and coordinated network. This primarily focuses on ensuring on-going security of supply, and to enable connection of load and generation.
Opportunity	As the interaction between DNOs and the transmission network become more complex as we transition to net zero; the need to improve collaboration strengthens. Building on projects such as UKPN's power potential, there is a need to review whole system losses, whereby there may be overall whole system benefit in DSOs undertaking actions that increase distribution losses for the benefit of the system as a whole. Without collaboration, these interactions will not be optimised. As part of our wider strategy on whole systems thinking – which extends beyond electricity, and spans other sectors and vectors – it is critical that losses is appropriately considered.
Options	Option 1) Continue as existing, yielding some of the benefits. Option 2) Expand existing levels of collaboration by continuing with DNOs, and expanding the audience to include NGET (in addition to NGESO); and ensure losses is considered as part of new work-streams (e.g. pathFinder projects).
Proposal	Expand existing levels of coordination to ensure losses considerations are fully incorporated in whole systems solutions.
Action type	Expand.
Losses impact	Low
Scorecard metrics	Not proposed. This is an on-going initiative.

Action 8.3.1: Whole life-cycle sustainability

Description	Investigate whole life-cycle sustainability considerations, such as; embodied carbon, water use, recyclability and circular economy alignment, etc.
Background	A whole life-cycle assessment includes not just the future environmental impact (e.g. losses), but also assesses the sustainability impact of producing and installing an asset, along with the end-of life sustainability impact. This cradle-to-grave approach would be better.
Opportunity	We recognise that whole life-cycle sustainability goes beyond just assessing losses, and that we should assess aspects such as embodied carbon, wider ecological considerations (e.g. water and land use), together with end of life considerations, such as re-cyclability. Norwegian utilities are currently undertaking work in this area, and we could learn from these utilities, together with embedding our own sustainability strategy more firmly into our asset management considerations.
Options	Option 1) continue with existing approach of undertaking minimal whole-life-cycle assessments (e.g. no embodied carbon nor ecological considerations made). Option 2) Research international best practice regarding whole-life-cycle sustainability, collaborating where appropriate (e.g. with Lede AS) to share best practice. Embed learnings as appropriate.
Proposal	Undertake research on whole-life-cycle assessment that we will then review to determine how to improve our asset management activities; adopting recommendations from this review where appropriate.
Action type	Research
Losses impact	Low
Scorecard metrics	Not proposed, this action is research-based.

Cost Benefit Analyses (CBAs) to support optimal investment decisions

In this section, we further expand on how we determined the 'optimal' solution. Our whole lifecycle approach to asset management is inclusive of losses; whereby we seek to proceed with options that provide the lowest annualised whole life cost to our customers. In essence, this means that we do not look at simply selecting the cheapest (capital cost) option, but instead consider a wide range of costs and benefits, which includes the societal cost of losses. The way in which we do this is by undertaking a CBA, which simply monetises each cost and each benefit. The key aspects of this approach are:

- We start by using the Ofgem approved CBA template, and we determine the costs and benefits (including societal benefits, such as reduction in losses);
- Specifically for losses, we calculate the losses for each option for each year (incorporating variables such as load growth);
- The losses societal benefit accounts for both:
  - the financial impact of losses (i.e. the cost of the energy that was generated and not delivered to customers) for each option, and
  - the monetised cost of carbon associated with the CO_2 emissions linked to the losses (noting that the CBA takes into account the reducing carbon intensity of generation, thus a reduction in the eventual CO_2 emissions associated with each unit of losses).
- All costs and all benefits then take into account the 'time value of money', which is a widely-used concept that £1 today is worth more to society than £1 in a future year. This consideration of the time value of money is considered in the CBA by the application of discount rates; i.e. future values of money are discounted;
- By modelling the sum of the discounted costs and benefits over the lifetime of the asset, we determine a net present value (NPV); that is the total value (i.e. benefits minus costs) of each option in today's money. The option with the highest (most positive) NPV is the option which will have the lowest annualised whole life cost, and therefore represents the best value option for customers (when incorporating losses).

We highlight within this document that the use of CBAs for our 2023-28 strategy supports the on-going action of installing 300 mm^2 cables on our LV and 11 kV networks instead of a slightly lower cost 185 mm^2 cable, as the NPV of the 300 mm^2 cable is better than that of the lower cost cable when incorporating the societal cost of losses. Similarly, we also undertook trials and subsequent CBAs for amorphous core distribution transformers, this analysis underpinned our proposed strategy of installing amorphous core (secondary) transformers during 2023-28. However, the funding necessary for this was not granted. These funding constraints have restricted our planned actions regarding amorphous core transformers. The output for our CBAs (unitised; per km for cable, else per transformer) are summarised in the table below, while samples of the full supporting CBAs for our actions (including the excluded proposed action regarding amorphous core transformers) are also listed in Appendix 4.

CBA	Options considered	NPV £ (whole life)	ED2 benefit - vs. baseline (MWh/yr)	Decision
CBA-23-LV Cable sizing	0) 0.4 kV 300mm2 AL XLPE / -- (No Tapering)	0	0.0	Propose
	1) 0.4 kV 185mm2 Al XLPE / -- (No Tapering)	-8,377	-2.3	Reject
CBA-24-11 kV Cable sizing	0) 11 kV 300mm2 Triplex XLPE / -- (No Tapering)	0	0.0	Propose
	1) 11 kV 185mm2 Triplex XLPE / -- (No Tapering)	-11,023	-3.7	Reject
	2) 11 kV 300mm2 Triplex XLPE / 185mm2 Triplex XLPE -- (Tapering from first leg)	-7,614	-2.7	Reject
CBA-25-100 kVA 1ph PMT - Amorphous	0) 11 kV PM 100 kVA 1 ph CRGO new	0	0.0	Reject
	1) 11 kV PM 100 kVA 1 ph CRGO old	-600	-0.3	Reject

CBA	Options considered	NPV £ (whole life)	ED2 benefit - vs. baseline (MWh/yr)	Decision
	2) 11 kV PM 100 kVA 1 ph Amorphous	488	0.5	Proposed but not funded
	3) 11 kV PM 50 kVA 1 ph CRGO new	-4,201	-0.8	Reject
	4) 11 kV PM 50 kVA 1 ph CRGO old	-3,147	-0.8	Reject
	5) 11 kV PM 50 kVA 1 ph Amorphous	-4,140	-0.6	Reject
CBA-26-315 kVA 3ph PMT - Amorphous	0) 11 kV PM 315 kVA 3 ph CRGO Tier 2	0	0.0	Reject
	1) 11 kV PM 315 kVA 3 ph CRGO Tier 1	-1,032	-0.6	Reject
	2) 11 kV PM 315 kVA 3 ph Amorphous Tier 2	1,628	1.4	Proposed but not funded
	3) 11 kV PM 200 kVA 3 ph CRGO Tier 2	-340	0.3	Reject
	4) 11 kV PM 200 kVA 3 ph CRGO Tier 1	-1,916	-0.4	Reject
	5) 11 kV PM 200 kVA 3 ph Amorphous Tier 2	670	1.3	Reject
CBA-27-315 kVA 3ph GMT - Amorphous	0) 11 kV GM 315 kVA 3 ph CRGO Tier 2	0	0.0	Reject
	1) 11 kV GM 315 kVA 3 ph CRGO Tier 1	-2,708	-1.0	Reject
	2) 11 kV GM 315 kVA 3 ph Amorphous Tier 2	1,349	1.4	Reject
	3) 11 kV GM 500 kVA 3 ph CRGO Tier 2	231	-0.3	Reject
	4) 11 kV GM 500 kVA 3 ph Amorphous Tier 2	2,350	1.7	Proposed but not funded
CBA-28-800 kVA 3ph GMT - Amorphous	0) 11 kV GM 800 kVA 3 ph CRGO Tier 2	0	0.0	Reject
	1) 11 kV GM 800 kVA 3 ph CRGO Tier 1	-4,106	-1.7	Reject
	2) 11 kV GM 800 kVA 3 ph Amorphous Tier 2	2,768	2.6	Proposed but not funded
	3) 11 kV GM 500 kVA 3 ph CRGO Tier 1	-11,297	-3.0	Reject
	4) 11 kV GM 500 kVA 3 ph CRGO Tier 2	-3,921	-0.7	Reject
	5) 11 kV GM 500 kVA 3 ph Amorphous Tier 2	-1,802	1.3	Reject
	6) 11 kV GM 1000 kVA 3 ph CRGO Tier 2	-5,713	-0.4	Reject
	7) 11 kV GM 1000 kVA 3 ph Amorphous Tier 2	-2,983	2.3	Reject
CBA-47-500 kVA 3ph GMT – Pre-1958	0) 11 kV GM 500 kVA 3 ph BS171: 1936	0	0.0	Reject
	1) 11 kV GM 500 kVA 3 ph CRGO Tier 1	19,005	17.6	Reject
	2) 11 kV GM 500 kVA 3 ph CRGO Tier 2	22,843	19.0	Reject
	3) 11 kV GM 500 kVA 3 ph Amorphous Tier 2	24,962	21.0	Reject
	4) 11 kV GM 315 kVA 3 ph Amorphous Tier 2	19,160	19.6	Reject
	5) 11 kV GM 800 kVA 3 ph CRGO Tier 1	21,291	17.7	Reject
	6) 11 kV GM 800 kVA 3 ph CRGO Tier 2	23,324	18.9	Reject
	7) 11 kV GM 800 kVA 3 ph Amorphous Tier 2	26,092	21.5	Proposed but not funded

Table 9: Summary of CBAs output of investment options for 2023-28 period.

Note 1: Each CBA is based on a single unit installed in 2025/26 (to represent the typical 'unit').
Note 2: The whole life NPV year begins at the start of ED2 (2023/24). This means that the whole life NPV of 2082/83 in the CBA corresponds to each asset being in service for a full 57 years.
Note 3: On-going dialogue with transformer manufacturers has identified that the excessive weight of 315 kVA pole mounted amorphous core transformers may preclude their use.
Note 4: Although transformer replacement with amorphous core transformers was proposed, the unit cost in Ofgem's final determination was not sufficient to continue with the proposal. Replacement of these transformers will still be done, but with CRGO Ties 2 transformers.

We have carried out sensitivity analyses on different input parameters, such as loading and cost premium in our CBAs. For distribution transformers, we only include a sample of key CBAs for the sake of simplicity. This is because we have carried out over 350 CBAs that cover four quartiles of existing loading, alongside sensitivities on load growth assumptions and the cost premium on each of our standard size pole-mounted and ground-mounted units.

Quantification of losses savings for activities in 2023-28

Category of activity	Type of activity	Action	2023-28 total volumes	Annual losses savings (MWh)	2023-28 cumulative losses savings (GWh)
Opportunistic	Non-load related	Install low-loss (i.e. higher capacity) 11 kV cables	867	473	7.1
Opportunistic	Non-load related	Install low-loss (i.e. higher capacity) LV cables	215	100	1.5
Not driven by losses	Load related intervention (LV reinforcement)	LV network intervention (split or overlay circuit) without increased sizing of the new cables installed	2,898	8,698	130.5
Opportunistic	Load related intervention (LV reinforcement)	LV network intervention (split or overlay circuit), with incremental benefit of installing new higher capacity cables	2,318	5,336	80
Proactive	Non-load related	Pre-1958 ground-mounted transformer replacements with CRGO tier 2 transformers	350	1,210	18.1
~~Proactive~~	~~Non-load related~~	~~Pre-1958 ground-mounted transformers, with incremental benefit of replacing with amorphous core transformers~~	~~350~~	~~156~~	~~2.3~~
Not driven by losses	Non-load related	Distribution transformer replacements with CRGO tier 2 transformers	13,551	2,761	41.4
~~Opportunistic~~	~~Non-load related~~	~~Distribution transformers, with incremental benefit of replacing with amorphous core transformers~~	~~11,518~~	~~1,443~~	~~21.6~~
Not driven by losses	Load related intervention (HV/LV reinforcement)	Distribution transformer replacements with CRGO tier 2 transformers	1,728	849	12.7
~~Opportunistic~~	~~Load related intervention (HV/LV reinforcement)~~	~~Distribution transformers, with incremental benefit of replacing with amorphous core transformers~~	~~765~~	~~345~~	~~5.2~~
		Total	**34,560**	**21,371**	**320.6**
		New Total (without amorphous core transformers)	**34,560**	**19,427**	**291.4**

Table 10: Quantification of Losses savings for activities to be carried out in 2023-28.

Note 1: Cables are unitised per km, and transformers are unitised per transformer.
Note 2: Cumulative losses savings are based on delivery profiles of each activity, where the annual losses savings beyond 2023-28 are roughly 107 GWh.
Note 3: The volumes driving the quantified losses benefits are based on the NPg Planning Scenario.

Note 4: Activities highlighted in red and struck-through are no longer paet of our Losses Strategy as a result of Ofgem under-funding the unit cost for secondary transformers, but remain within the table to provide clarity on the impact of no longer proceeding with AMTs. These transformers will be replaced with CRGO Tier 2 transformers resulting in a lower Losses savings.

Table 10 above lists our planned actions, that have been funded, within their relevant category and type of activities over the course of 2023-28 that have the potential to contribute to a revised total cumulative losses savings of 291.4 GWh. It can be seen that the biggest savings come from activities that are not driven by losses (but primarily decarbonisation investment), a total of 184.6 GWh. This is followed by opportunistic actions, a total of 88.6 GWh and proactive action, with a total of 18.1 GWh. This potential losses savings align with our strategy of not bringing forward work programmes solely to target losses reduction, where we justify improvements in losses as part of investment with other primary driver, that is network reinforcement.

This quantification mainly focuses on the LV network and sought to capture only the significant programme level benefits, and not specific schemes, nor programmes which deliver only a minor losses benefit (e.g. HV reinforcement). This is due to significant investment to be carried out to reinforce this network as they take centre stage towards our journey to decarbonisation in facilitating the increasing uptake of LCTs, such as EVs and heat pumps. This will result in a network with bigger capacity, which will have the added benefit of improved losses.

An example of a specific scheme is our proposal to replace poor condition transformers at Hebburn 66/6 kV and Wardley 66/6 kV substations with new 15/30 MVA, 66/11 kV system transformers, and to also upgrade the existing HV network from 6 kV to 11 kV. We estimate a reduction in losses on this section of network of approximately 73 per cent; reducing the annual losses of 1,248 MWh down to 337 MWh[77]. This saving is not included in the quantification of losses saving activities, above, along with other site-specific schemes which will also provide losses benefit.

[77] Engineering Justification Paper 11.22: Decarbonisation (voltage rationalisation – Hebburn & Wardley)

Future considerations: 2023-28 and beyond

In this section, we focus on horizon-scanning of learning, ideas and opportunities for 2023-28 and beyond that will have impact on losses, how we manage and optimise losses and how these will potentially shape our future Losses Strategy. We will update this section accordingly in future iterations of this document to ensure that we are always up-to-date with the development of technologies and policies around us. It is worthwhile to recognise that some of the considerations discussed in this section will experience regulatory challenges. However, we believe that that should not be a barrier for us to be innovative in moving forward.

We have considered five key areas that could add significant value in the long term:

Continuous improvement – network losses and sustainability

As a network operator, we are an important enabler of the clean energy transition to net zero, and it is thus important to focus on the climate and environmental footprint of our daily operations, purchases, network design choices and the electricity network itself. This also includes how we manage network losses and our holistic approach to it.

Towards the end of 2023-28, we will be embedding lifecycle assessment (LCA) in our procurement and investment decisions as part of our BCF commitments, to keep track of the impact of the everyday running of our activities and supply chains on our carbon footprint. Although losses is not the primary driver behind LCA, this assessment would encourage having more efficient assets installed on our network, which will have added benefits of optimising losses.

Collaboration is key to synchronise our effort within the industry in achieving carbon neutrality by 2050. In Norway, a proposal was made on a collaborative research project between some of the distribution system operators, (DSOs), Energy Norway (Norway's energy networks association), and NORSUS (a research institute focusing on sustainability and LCA methodology), focusing on the climate and environmental footprint of the electricity network. The project has several elements, which include LCA-methodology, network infrastructure, material and energy usage, network losses considerations, climate footprint, land use, the use of spatial data sets and biodiversity. It focuses on assessment methodologies, environmental indicators, and a framework for different types of assessments and on how the results can be applied to business-as-usual activities.

We believe that collaborations like this between DNOs, ENA and research organisations would be an ideal platform to help meet the targets set by the UK government net zero and the sixth (and subsequent) carbon budget(s) through having a holistic approach to sustainability, where losses optimisation will also be embedded.

Power electronics technology

We and other network operators have been trialling power electronics technology under several innovation projects since the Low Carbon Networks Fund (LCNF) period and throughout 2015-23[78]. While we acknowledged the challenges and opportunities presented by this technology, we expect that it will become more visible in our network throughout 2023-28 as part of innovation projects under specific funding mechanisms. We believe that this technology will become an essential component of our network as it becomes widely accepted within the industry beyond 2023-28, particularly as we transition to a DSO role where we will heavily rely on ANM using real-time data for fast and precise network intervention. The capability of this technology to independently control active and reactive power on the network would generally mean that we can better manage our power flow, and thus optimise losses. In addition, power electronics transformers configuration does not contribute to 'iron losses' as opposed to the existing transformer technology however, power electronic technology does incur significant losses in the form of switching losses, which will need to be considered, along with the impact of these devices on power quality (and therefore losses) across the wider network. The development of power electronics is the building block of the next generation of not just our network, but the whole energy system overall.

[78] An overview of power electronics technology is described in the *report 'Power Electronics in Electricity Networks: Applications, Opportunities and Challenges'* by Compound Semiconductor Applications (CSA) Catapult, PowerelectronicsUK and SP Energy Networks (SPEN)

Future grid architecture: DSO, microgrids and DC network operation

DSO: Our network is currently experiencing a transition from a passive network operation within a traditional hierarchical grid architecture to a more active and intelligent DSO operation while we are dealing with the increased penetration of LCTs, development of technologies (including power electronics and communication technologies), infrastructure revolution (for instance microgrids) and advancement in services provision (for instance the flexibility market). We will change the way we manage and operate the network to ensure that we can enhance the way we observe and control it while having new forms of interaction with market and operation actors which does not exist yet within the current industry structure. We anticipate that the future DSO network can achieve an increased system efficiency with real time control and management, which would ultimately optimise network losses.

Microgrid: A microgrid consists of energy generation and energy storage that can power a building or community when not connected to the electricity grid, for example in the event of a disaster. A microgrid can be self-sufficient, and can offer improved resilience of the network in the event of either planned or unplanned outages. It can also be proactive in a sense that they can 'de-couple' themselves to relieve network congestion on the wider network that they interconnect to. We anticipate that increased utilisation within microgrid due to the operation of year-round renewable generation and connection of LCTs would increase losses. However, we also think that the reduced energy costs and greenhouse gases (GHGs) emissions would eventually result in what we call 'green losses', where the financial and environmental impact would be minimal.

DC network operation: The development of power electronics, the future DSO architecture and the emergence of microgrids would eventually make it possible to have a direct current (DC) network as the configuration, or part of the configuration of the future. There are many advantages of having DC network[79], particularly in terms of improved efficiency by eliminating losses due to multiple conversions of DC and AC when connecting LCTs onto our existing network, bearing in mind that many LCTs, for example solar, wind, heat pumps and EVs either generate or require DC power anyway. Despite many challenges that this configuration might present, for instance the issue of network fault and protection and whether it is possible to interconnect this with the existing network, we see the potential that this can offer.

A whole systems approach to optimise losses – green hydrogen

We believe that aiming to deliver a net zero energy system will require a more joined up multi-vector approach across the industry to deliver safe and secure energy to customers. Major changes to the demand for electricity or the scaling up of use of hydrogen might not be seen until towards the end of the 2023-28 period or after it. Although there are very likely to be significant pockets of electrification of transport and heat that will heavily impact on our networks, especially in the second half of the decade, we should also be open to all future possibilities, including working with the hydrogen industry.

For example, the application of hydrogen network as an alternative energy storage technology for a co-ordinated power and hydrogen flexible network operation will be a promising solution to manage the aggravated imbalance between electricity supply and demand as a result of increasing integration of intermittent embedded generation such as wind. Without storage, excess generation would not only result in network congestion, but will increase network losses. The power-to-hydrogen (P2H) solution converts excess generated power into hydrogen via electrolysis and stored for later use. The gas-to-power (G2P) facility in the form of gas turbine will then convert this energy to electricity and feeds back to the power grid. Hydrogen and electricity network infrastructure can be developed side-by-side for optimised and efficient whole energy network that may improve overall network losses, which includes both the electricity losses and gas losses (shrinkage).

Our whole systems initiatives include further exploration of future inter-seasonal storage requirements and technologies. Hydrogen could potentially play a role in long term storage of harvested energy. It is, however, important to note that the general application and use of hydrogen is significantly less efficient than the equivalent electrical equivalent. For example, Climate Change Committee analysis[80] highlights a typical fuel-to-wheel efficiency of 86 per cent

[79] *'Is the dawn of the DC town nearer than we think?'* – An article by WSP on their website.
[80] https://www.theccc.org.uk/wp-content/uploads/2018/11/Hydrogen-in-a-low-carbon-economy.pdf, Figure 2.2: Relative efficiency of battery electric vehicles vs. electrolytic hydrogen fuel cell vehicles

for electric vehicles against 41 per cent for hydrogen vehicles when incorporating electrolysis (74 per cent efficiency), compression (91 per cent efficient) and then finally conversion using fuel cells (61 per cent efficient). Distribution electrical losses of several percent are therefore considerably lower than the inefficiency of hydrogen technologies.

Voltage rationalisation: operating at higher voltage

Technical losses on our network could be reduced by implementing newer or more efficient assets, for example amorphous transformers, or by operating higher voltages in our network, among other possible approaches that we have outlined in this document. Earlier in this document we have described how the losses on the Darlington/Rise Carr 6 kV, as well as Hebburn and Wardley 6 kV networks are reduced by about three quarters when operating at the rationalised voltage of 11 kV. Potentially, increasing our 11 kV network to 20 kV would reduce the network losses by about a quarter of the losses at 11 kV, and even significantly lower at 33 kV and 66 kV. The higher voltage in distribution network might be the reason for relatively low losses in countries where this type of operation is common[81]. This is an interesting and wider reaching strategy that may need to be explored. Upgrading the network to operate at higher voltage requires significant network investment, and in the short term, losses benefit alone does not justify this initiative.

[81] 2nd CEER Report on Power Losses.

Summary

Our Losses Strategy for 2023-28 has taken into account a wide range of stakeholder engagement, and has evolved to reflect the significant challenges and opportunities presented by decarbonisation, DSO, and the new data and technology improvements available through programmes such as our 2015-23 smart grid enablers programme and the national smart meter rollout. Our vision to **optimise whole system losses whilst facilitating net zero** embodies this evolution.

For our 2023-28 Losses Strategy, we have identified a number of 'main' actions to optimise both technical and non-technical losses, along with improving our understanding of losses to further contribute to the evidence base of what we can influence or control. These main actions are summarised in Table 11 below, and are split across eight initiative groups. These main actions are a shortlist of 28 actions out of the total of 46 actions that we consider within this Losses Strategy. These main actions are those that we estimate as having either a 'medium' or 'high' impact on losses on our network in 2023-28. We have also categorised these actions into different action types (continue, consider, expand or adopt), to reflect that some of the actions are already embedded into the business, whilst others are not and may need further development.

Ref.	Initiative Group	Initiative	Action Name	Action Type	Losses Impact
1.1.1	Accelerated asset replacement	Accelerated asset replacement	Pre-1958 ground-mounted transformer replacement	Continue	Medium
1.1.3			Upgrade unbalanced networks	Adopt	Medium
1.1.4			Upgrade small-section LV overhead conductors	Adopt	Medium
1.1.5			Replace pre-1987 PCB-contaminated pole-mounted transformers	Adopt	High
2.1.1	Data & Analytics	Data	Enhanced monitoring	Expand	Medium
2.1.2			Data improvement	Adopt	High
2.2.1		Analytics	Modelling improvement	Adopt	High
2.2.3			Optimising network configuration for a specific loading condition (single time step)	Expand	Medium
3.1.2	Design Policy	Specification	Lower loss HV overhead line (OHL) conductors (i.e. AL3 to AL5)	Continue	Medium
3.1.3			**<u>Install Ecodesign Tier 2 transformers</u>**	**<u>Adopt</u>**	**<u>High</u>**
3.1.4			Service connection review	Consider	Medium
3.2.1		Optimal asset sizing	**<u>Install low-loss (i.e. higher capacity) low voltage (LV) cables</u>**	**<u>Continue</u>**	**<u>High</u>**
3.2.2			**<u>Install low-loss (i.e. higher capacity) high voltage (HV - 11 kV) cables</u>**	**<u>Continue</u>**	**<u>High</u>**
4.1.1	Network Operation	Static Network Operation	Static HV voltage optimisation	Continue	Medium
4.1.3			Multi-objective system optimisation of network operation	Expand	Medium
4.2.1		Dynamic Network Operation	**<u>Dynamic voltage optimisation</u>**	**<u>Expand</u>**	**<u>High</u>**
5.1.1	Non-technical losses	Energy efficient substations	**<u>Improve the energy efficiency of our substations</u>**	**<u>Adopt</u>**	**<u>High</u>**
5.2.1		Theft	Theft - monitoring data	Consider	High
5.2.2			Theft - tamper alerts	Consider	Medium
6.1.5	Research & Development	Investigation / Trial	Alternative transformer technologies	Consider	Medium
6.1.6			Losses price signals driving flexibility	Research	Medium
7.1.1	Stakeholder	Customer Energy Efficiency	Power factor advice	Expand	Medium
7.1.2			**<u>Community energy coaching (advisors)</u>**	**<u>Adopt</u>**	**<u>High</u>**
7.2.1		Education and engagement	Losses educational material	Continue	Medium
7.2.3			Collaboration, sharing and adopting best practice	Continue	Medium
7.3.1		Expert stakeholder collaboration	Internal stakeholder engagement	Continue	High
7.3.2			Collaborations with academia	Continue	Medium
8.1.1	Whole System	Flexibility optimisation	Embed losses costs in optimising flexibility assessments	Expand	High

Table 11: 28 main actions for our 2023-28 Losses Strategy

Note 1: The 'key actions' are shown in bold-underlined text. The 18 actions that are not covered as part of the key actions will be reported on as part of the higher level appraisal of our Losses Strategy implementation.
Note 2: Action 3.1.3 was originally to install super low-loss amorphous core transformers. We undertook a robust analysis using the Ofgem cost benefit analysis template and this analysis supported the use of amorphous technology in 80% of cases. Because the use of lower loss (amorphous) transformers would provide a net benefit to our customers in that the 29 GWh reduction in losses over RIIO-ED2 2023-28, and the compound loss benefits thereafter, offsets the higher cost, we proposed an ambitious adoption of this technology as part of our 2023-28 business plan submission. We, therefore, increased the unit cost of our secondary transformer replacement to cover the incremental unit cost of amorphous core technology when compared with Ecodesign Tier 2 transformers.

Although our Losses Strategy was 'approved' by Ofgem, the increased unit cost was not funded in Ofgem's final determination. Without the appropriate funding to enable the use of amorphous core transformers, it has been necessary for us to revert to installing Ecodesign Tier 2 transformers during 2023-28. Replacement with Tier 2 transformers will still provide an incredible 72 GWh benefit over this price control period (2023-28) and we will continue to investigate the use and benefits of amorphous core transformers in ED2 and consider submitting this as a request in a future price control.

Table 12 below list the four 'key' actions that will reported on alongside our wider environmental action plan reporting, with two of the actions being reported elsewhere in our business plan. For simplicity the LV and HV cable actions have been merged into a single reportable action. The fifth action (regarding community energy advice) is being delivered and reported on as part of our customer service business plan section[82], and is therefore cross referenced to this section of our plan. The sixth action (dynamic voltage optimisation) is being delivered and reported as part of our 'enabling whole systems solutions' plan section (and within the consumer value propositions business plan section), and is therefore cross referenced to these sections of our plan.

Action	Measure (output)	ED1 2015-23 complete	ED2 2023-28 target
EP2.1) Develop and report on our Losses Strategy annually	*Updates issued*	*4*	*5*
EP2.2) Install super low-loss amorphous core transformers (funding for this not provided in 2023-28)	*Units*	*5*	*Action closed (see Note 3)*
EP2.3) Install low-loss (i.e. higher capacity) LV and HV cables	*Circuit km*	*2,909*	*3,400*
EP2.4) Improve the energy efficiency of our substations	*% major substations assessed*	*n/a*	*100%*
Community energy advisors **(see CO3 in the 2023-28 business plan, consumers and network – customer service section)**			
Dynamic voltage optimisation for domestic energy efficiency **(see 'whole systems: dynamic voltage optimisation for domestic energy efficiency' CVP (annex A1.5 detail on our CVPs) and decarbonisation – enabling whole system solutions section of our 2023-28 business plan)**			

Table 3: Key actions and associated performance measures.

Note 1: The Action IDs are those used in our environmental action plan (EAP), and are listed above to enable cross-referencing.
Note 2: The targets with respect to installation volumes of transformers and cables are not driven by losses, and therefore there could be variation against this target during 2023-28. This should not be seen as failure to manage losses, where our commitment is to install the asset that has the lowest whole life cost when including losses.
Note 3: The ED2 2023-28 target for the installation of amorphous core transformers has been reduced to zero due to the funds essential for this work not being granted for the ED2 2023-28 price control. We still plan to replace c15,000 existing transformers (mainly PCB contaminated designs) with Ecodesign Tier 2 transformers.

We are now proposing a total cumulative losses savings of 291.4 GWh over the course of 2023-28 from our activities that we will undertake over the course of 2023-28, as summarised in Table 13 below. These savings are grouped into three main category of activities: activities that are not driven by losses (for instance network reinforcement or health related asset replacement), activities that are opportunistic (where our CBAs justify installing higher capacity assets on works that are not driven by losses) and activities that we carry out proactively to manage losses (where losses is a driver or one of the drivers). The benefit from these activities beyond the 2023-28 period will be an estimated 105 GWh per annum.

[82] Specifically, deliverables 'CO3.1' and 'CO3.2' as detailed in the Customer Service section of our business plan.

Category of activity	2023-28 cumulative losses savings (GWh)
Not driven by losses	184.6
Opportunistic	88.6
Proactive	18.1
Total	**291.4**

Table 13: Summary of losses savings for activities to be carried out in 2023-28.

Update process

Our Smart Grid Implementation team is responsible for updating this Losses Strategy as necessary driven by changes to the inputs to our strategy. However events that would be expected to trigger changes going forwards would include the following scenarios:

- The strategy will be reviewed following the annual revision of our investment plans. Any change to the investment plan may require a revision to our actions to implement the Losses Strategy and also our overall view of losses movements.

- The strategy will be revised following major changes to the contracts through which investment with losses impacts are delivered. Input price changes will affect the degree to which we should be pursuing losses management investment.

- The strategy will be reviewed should the pathway through which the net zero target could be achieved becomes more certain and requires re-prioritisation of initiatives and activities, for example if the presence of hydrogen technology in the energy system is beginning to take precedence.

- The strategy will be reviewed in light of learning from other DNOs, the DNOs' respective Losses Strategy updates and their innovation projects. Any relevant recommendations are then recorded in this document as appendices.

As a result of these scenarios, a review of the Losses Strategy would be expected annually.

The review would take the form of an internal expert review and engagement with stakeholders to confirm direction and actions remain appropriate.

Revision of the strategy would be undertaken following this review incorporating changes as appropriate, but in the event of no changes being required then as a minimum a statement that the previous strategy remains valid should be expected.

Appendix 1– Full list of Losses Strategy actions (including those discounted)

Ref.	Initiative Group	Initiative	Action Name	Action Type	Losses Impact
1.1.1	Accelerated asset replacement	Accelerated asset replacement	Pre-1958 ground-mounted transformer replacement	Continue	Medium
1.1.2			Voltage rationalisation	Expand	Low
1.1.3			Upgrade unbalanced networks	Adopt	Medium
1.1.4			Upgrade small-section LV overhead conductors	Adopt	Medium
1.1.5			Replace pre-1987 PCB-contaminated pole-mounted transformers	Adopt	High
2.1.1	Data and analytics	Data	Enhanced monitoring	Expand	Medium
2.1.2			Data improvement	Adopt	High
2.2.1		Analytics	Modelling improvement	Adopt	High
2.2.2			ANM optimisation	Consider	Low
2.2.3			Optimising network configuration for a specific loading condition (single time step)	Expand	Medium
3.1.1	Design policy	Specification	Maximum economic loading guide for distribution transformers	Continue	Low
3.1.2			Lower loss HV OHL conductors (i.e. AL3 to AL5)	Continue	Medium
3.1.3			**Install Ecodesign Tier 2 transformers**	**Adopt**	**High**
3.1.4			Service connection review	Consider	Medium
3.1.5			Increased distribution transformer size	Adopt	Low
3.2.1		Optimal asset sizing	**Install low-loss (i.e. higher capacity) low voltage (LV) cables**	**Continue**	**High**
3.2.2			**Install low-loss (i.e. higher capacity) high voltage (HV - 11 kV) cables**	**Continue**	**High**
3.2.3			Install low-loss (i.e. higher capacity) high voltage (HV - 20 kV) cables	Consider	Low
4.1.1	Network operation	Static network operation	Static HV voltage optimisation	Continue	Medium
4.1.2			Static EHV voltage optimisation	Continue	Low
4.1.3			Multi-objective system optimisation of network operation	Expand	Medium
4.2.1		Dynamic network operation	**Dynamic voltage optimisation**	**Expand**	**High**
4.2.2			Soft open point (SOP)	Research	Low
4.2.3			Transformer auto stop start (TASS)	Discount	Low
4.2.4			Optimising network configuration using multi-time step approach (e.g. hourly reconfiguration)	Discount	Low
5.1.1	Non-technical losses	Energy efficient substations	**Improve the energy efficiency of our substations**	**Adopt**	**High**
5.2.1		Theft	Theft - monitoring data	Consider	High
5.2.2			Theft - tamper alerts	Consider	Medium
6.1.1	Research and development	Investigation / Trial	Losses correction factors	Research	Low
6.1.2			Contact voltage losses	Research	Low
6.1.3			Low loss EV charging	Consider	Low
6.1.4			Micro-resilience learning	Consider	Low
6.1.5			Alternative transformer technologies	Consider	Medium
6.1.6			Losses price signals driving flexibility	Research	Medium
6.2.1		Horizon scanning	Revolution of assets	Research	Low
7.1.1	Stakeholder	Customer energy efficiency	Power factor advice	Expand	Medium
7.1.2			**Community energy coaching (advisors)**	**Adopt**	**High**
7.2.1		Education and engagement	Losses educational material	Continue	Medium
7.2.2			International collaborations	Continue	Low
7.2.3			Collaboration, sharing and adopting best practice	Continue	Medium
7.2.4			ENA engineering recommendation on Losses	Adopt	Low
7.3.1		Expert stakeholder collaboration	Internal stakeholder engagement	Continue	High
7.3.2			Collaborations with academia	Continue	Medium
8.1.1	Whole system	Flexibility optimisation	Embed losses costs in optimising flexibility assessments	Expand	High
8.2.1		Whole system collaboration	Collaborations within the industry for a whole system approach	Expand	Low
8.3.1		Whole life-cycle sustainability	Whole life-cycle sustainability	Research	Low

Table 1: Losses Strategy actions

Appendix 2– Additional information

Stakeholders	Stakeholders engagement activities	Measures to continue the activities
ENA TLTG (ENA working group, now disbanded)	• Teach-in session with Ofgem on losses. • Commissioned WSP to study the Impact of LCT on losses. • Commissioned WSP to develop a losses incentive mechanism for 2023-28. • Presented at LCNI 2017 and 2019. • Shared best practice, identified areas for collaborations: BAU, trials results, develop common policies. • Produced group initiatives tracker for Losses Strategy and LDR.	• Continue to work on the Engineering Recommendation document. • Regular meetings – sharing best practice, preparing for 2023-28. • Active engagement with Ofgem for 2023-28 • ENA webpage update. • Amorphous transformer (AMT): NPg to share outcome of ground-mounted trial as a case study – informing future specifications, operational aspects of installation, environmental noise impact and power quality factors.
Other ENA Working Groups	• ENA LCT Working Group • ENA Open Networks • ENA Transformer Assessment Panel (TAP)	• Continue to engage with different ENA working Groups to generate ideas, share information and knowledge
UKPN (DNO)	• Reviewed contact voltage losses (CVL) from Princeton Report, built up the work from this report to investigate pole leakage CVL. • Joint meeting with UKPN and Power Survey on CVL and Mobile Asset Assessment Vehicle (MAAV) trial. • AMT trial.	• We are planning to trial MAAV, which is to be provided by UKPN. • We will discuss our pole leakage CVL with other DNOs.
Wilson Power Solutions (AMT manufacturer)	• AMT trial. • Joint news updates on AMT trial via social and trade media platforms.	• To share outcome of trial as a case study – informing future specifications, operational aspects of installation, environmental noise impact and power quality factors
Freedom (service provider)	• AMT trial – operational aspects. • Joint news updates on AMT trial via social and trade media platforms.	• To share outcome of trial as a case study – informing future specifications, operational aspects of installation
Non-domestic customers	• Customer var advice	• Continue working with customers • Track progress and feedback in the ICE initiative
Social responsibility partners and local communities	• Energy efficiency initiatives • Infrastructure North; Citizens Advice; Green Doctor; Ahead partnership; Energy Heroes	• Continue working with our partners to discharge our social responsibility which has a positive impact of reducing losses
Yorkshire Water (YW)and Northern Gas Networks(NGN) (other utilities)	• Sharing best practice to manage losses	• Regular meetings to follow up with discussions or any potential collaborations
Lede AS (international DSO)	• Sharing best practice to manage losses	• Regular meetings to follow up with discussions or any potential collaborations
Academic partners	• Sheffield University: Smart data project • Newcastle University: Enhanced Losses • University of Bradford: Industrial Advisory Board (IAB) • Presentation in 25th International Conference and Exhibition on Electricity Distribution (CIRED) 2019	• Continue direct involvement in losses-related projects • Continue to learn about any losses impacts from other projects with academia • Continue to involve academic partners in research on losses • IAB – Explore opportunity for syllabus on network losses
Consultancies	• WSP, TNEI, Element Energy, EA Technology	• Continue working with consultancies on losses work and any projects that have impact on losses
Delegates for Stakeholder summit	• Stakeholder engagement to inform and educate stakeholders on network losses	• To continue to inform and educate stakeholders on network losses and its importance in net zero targets
Energy suppliers	• Smart meter temper alerts • Non-technical losses and electricity theft	• Continue collaboration, review position from temper alerts data analysis as penetration of smart meter grows
YW, NW (Northumbria Water) and NGN	• Infrastructure North	• To continue collaborations in this platform to promote energy efficiency and waste reduction

Table 1: Summary of engagement activities with our stakeholders

Transformer Type	No load loss £/kW	Load Loss £/kW
System transformers (CER & CMR)	£12,217	Calculated on a bespoke basis
Distribution transformers (Ground-mounted)	£12,217	£1,471
Distribution transformers (Pole-mounted)	£12,217	£737

Table 2: No load loss £/kW and load loss £/kW

The no load losses on a per kW basis are the same for all transformer types as they are incurred as a result of an asset being energised and are largely independent of network loading. The difference in load losses values are attributed to differing loss load factors (LLFs) and utilisation factors. The distribution transformers have been split with separate copper loss values for ground-mounted and pole- mounted. The capitalised copper loss values for system transformers are calculated on a bespoke basis. This allows Northern Powergrid to better target its expenditure on reducing losses on assets which are more highly utilised.

Appendix 3 – Mapping to Ofgem's baseline requirements

Ofgem baseline standard	Key actions	Reporting mechanism	Meets/ Exceeds	Outcome Ref.
Business Carbon Footprint (BCF)				
Adopt a science-based target[83] for the company to reduce its scope 1 and 2 BCF by 20xx[84], without relying on international GHG offsetting, that is in line with Net Zero.	- Our Science Based Target requires us to reduce emissions by 4.2% annually. Our forecasts align to this reduction excluding losses. - Losses, which are included in scope 2, are dependent on the rate at which the grid decarbonises; we will support the reduction in carbon intensity through accommodating low carbon generation to the network.	**EAP, LO** – Reduce emissions by 4.2 per cent annually	Meets	EP1
Identify metrics, and associated targets, for 2023-28 to track the impact of implementing actions and the overall progress towards the science-based target and Net Zero.	- We will reduce scope 1 and 2 emissions (excluding losses) by 4.2 per cent each year in line with our SBTs.	**EAP, LO** - Scope 1 and 2 emissions (excluding losses) at 8,920 tCO_2e by 2028	Meets	
Commit to reporting on BCF reduction and progress towards science-based target and Net Zero using a common BCF methodology. Reporting should include progress in reducing scope 3 emissions[85].	- As part of our AER we will report on our BCF emissions, including SBTs for scope 1 and 2 emissions. - We will also report on progress on scope 3 emissions.	**EAP; LO, ODI-R** - Scope 1 and 2 emissions at 374,130 tCO_2e by 2028. - Report on scope 3 BCF annually	Meets	
Losses				
Develop and commit to implementing a strategy to efficiently manage both technical and non-technical losses on the DNO's network over the long term. This should include specific actions and performance measures to track the impact of actions in 2023-28.	- We will develop and report on our Losses Strategy annually - As part of our transformer and cable replacement programme we will install low loss solutions to enable synergies - We will complete substation energy efficiency assessments to implement measures to reduce substation energy emissions	**EAP, LO** - We will report on our Losses Strategy annually	Meets	EP2
Commit to reporting on the progress of implementing the Losses Strategy and associated performance measures.	- Publish an annual environmental report for our stakeholders covering the delivery of our EAP commitment	**EAP; LO, ODI-R** - Annual reporting	Meets	
Contribute to the evidence base on the proportion of losses that network companies can influence/control.	- We will collaborate with the wider industry to develop our understanding of losses and contribute to the DNO evidence base	**EAP, LO** - We will report on our Losses Strategy annually	Meets	

Table 1: Mapping to Ofgem's baseline requirements

[83] This should be verified by the science-based target initiative (SBTi): https://sciencebasedtargets.org/

[84] 20XX denotes that companies will need to specify a long term date to achieve the specified target. We would then expect companies to specify the associated RIIO-ED2 milestone.

[85] Scope 3 emissions are a consequence of actions which occur at sources which the DNO does not own or control and which are not classed as Scope 2 emissions. Although a DNO's science-based target does not include scope 3 emissions, DNO's reporting should include progress against reducing scope 3 emissions.

Appendix 4 – List of Cost Benefit Analysis accompanying the Losses Strategy

CBA Name
CBA-23-LV Cable sizing
CBA-24-11 kV Cable sizing
CBA-25-100 kVA 1ph PMT - Amorphous
CBA-26-315 kVA 3ph PMT - Amorphous
CBA-27-315 kVA 3ph GMT - Amorphous
CBA-28-800 kVA 3ph GMT - Amorphous
CBA-47-500 kVA 3ph GMT – Pre-1958

Table 1: List of CBAs.

List of Changes

1. The key change to the Losses Strategy relates to adjusting the initiative that previously proposed the use amoprohous technology, to using Ecodeisgn Tier 2 units (instead). We undertook a robust analysis using the Ofgem cost benefit analysis template and this analysis supported the use of amorphous technology in 80% of cases. Because the use of lower loss (amorphous) transformers would provide a net benefit to our customer (c29 GWh reduction in losses over RIIO-ED2 2023-28, which then compounds thereafter for the life of the asset, likely far in excess of 40 years), whereby the benefit outwieghts the higher unit cost, we proposed an ambitious adoption of this technology as part of our 2023-28 business plan. We, therefore, increased the unit cost of our secondary transformer replacement to cover the incremental unit cost of amorphous core technology when compared with Ecodesign Tier 2 transformers. Although our Losses Strategy was 'approved' by Ofgem, the increased unit cost was not funded in Ofgem's final determination. Without the appropriate funding to enable the use of amorphous core transformers, it has been necessary for us to revert to installing Ecodesign Tier 2 transformers during 2023-28. Replacement with Tier 2 transformers will still provide an estimated 72 GWh benefit over this price control period (2023-28) and we will continue to investigate the use and benefits of amorphous core transformers in ED2 and consider submitting this as a request in a future price control. Throughout the document, (and specifically for Action 3.1.3) we have adjusted our proposal from 'Install super low-loss amorphous core transformers' to 'Install Ecodesign Tier 2 transformers'.
2. Numbers referring to quantities/volumes of activities achieved in 2022-23 have been updated throughout.
3. The whole document has been updated so that reference to ED1 2015-23 is in the past tense.
4. Page 1: The carbon emissions as a percent of our total carbon footprint for Scopes 1, 2 and 3 has been corrected (70% to 94%).
5. Page 2: Number of actions corrected to 46 (not 48).
6. Page 4, Table 3: Due to this Action EP2.2 not being funded it has been listed as 'Closed'; and Note 3 has been added to explain this.
7. Page 4, Table 3: Numbers have been updated for 2022-23 and those forecast for RIIO-ED2.
8. Page 5: Section entitled 'Summary of losses savings quantification for activities in 2023-28'. Values have been added to give the calculated figures for installing Tier 2 transformers rather than amorphous core transformers.
9. Page 5, Table 4 updated to contain losses savings without using amorphous core transformers.
10. Page 8: The wholesale electricity price has been updated to a figure that more closely represents today's £/MWh and this has been used in the calculations of expected financial savings.
11. Page 8: The electricity demand and carbon savings have been updated.
12. Page 13: Within the text the move from amorphous core transformers to Ecodesign Tier 2 is discussed.
13. Page 18: The ENA Technical Losses Task Group has been disbanded and therefore removed from this document.
14. Page 27: The expected energy bill savings for the BEET project have been updated to £35 (from £20) due to the increase in wholesale energy prices.
15. Page 55 and 56: More detail has been added to the Proposal section of the table for Action 7.1.2 Community Energy Coaching.
16. Pages 60 and 61: The outcome of the cost benefit analyses for the installation of amorphous core transformers has been changed in the table to 'Proposed but not funded' and the text has been amended.
17. Page 62, Table 10 updated to display the actions that were not funded, and a row added to display the recalculated losses.
18. Page 67-69: The summary gives the updated tables and text described throughout the document.