Energy Networks Association

ENA WORKING GROUP PROJECT
Impact of Low Carbon Transition - Technical Losses
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EXECUTIVE SUMMARY

PROJECT AIM

WSP, on behalf of the Energy Networks Association Technical Losses Task Group, have undertaken a study to understand the impact of the low carbon and smart grid transition on technical network losses. The objective was to improve technical understanding of future technical losses in order to inform Distribution Network Operator (DNO) loss strategies and the regulatory approach to losses.

This report presents the results of system analyses which have assessed losses in typical networks expected in 2030 when Low Carbon Technologies (LCTs) are connected and accommodated through either traditional reinforcement or the application of smart solutions.

METHODOLOGY

Losses have been evaluated through simulations of the Urban and Rural network models developed for the DS2030 project. Both models are considered representative of their type and provide confidence in the arising results by being based on real data for existing GB distribution networks.

Connections of Heat Pumps, Electric Vehicles, LV PV generation and larger generators connected at HV and 33kV were simulated based upon the DS2030 Central uptake levels for 2030 that have been shown to correlate well with National Grid’s Future Energy Scenarios. Regional variations between the uptakes in the Urban and Rural networks were reflected in the distribution of LCTs through consideration of the numbers of customers, types of properties and socioeconomic conditions.

The following smart solutions have been considered as alternatives to traditional reinforcement;

- Demand Side Response (DSR)
- Network Energy Storage
- Active Network Management (in the form of flexible generator connections)
- Alternative Customer Profiles

Losses have been determined for each network voltage level from whole year simulations undertaken at half hour granularity. Existing system losses have been taken as the baseline for the comparison of losses in future networks incorporating LCTs, whilst the losses in networks with smart solutions applied have been compared against the losses occurring in a traditionally reinforced network.

The results presented in this report have been interpreted within the context of the networks analysed, the underlying assumptions and the methodologies adopted. Different uptakes of LCTs, other network topologies and alternative forms of smart solutions will alter the losses. These study results should be considered as an indication rather than an accurate prediction on the impact on losses of the complex reality that is likely to exist in the future when different smart solutions are applied in different areas of the network and used together to provide layered benefits.

KEY FINDINGS

The uptake of low carbon technologies will significantly impact losses.
Future connections of LCTs will increase losses depending upon the uptake level, the connection location and the balance between demand and generation. Generation may reduce losses when it does not result in significant net export, but at maximum levels of penetration it can increase losses to 350% of existing levels.

How networks accommodate low carbon technologies will impact losses.
Methods of network reinforcement and how the network is used have been shown to affect losses. Future percentage losses have been shown to be unchanged with the perpetuation of traditional reinforcement. Whilst, smart solutions which increase the utilisation of existing network assets increase losses.

Losses are complex, difficult to measure and vary based on regional topology.
Losses have been shown to be complex and vary significantly across the different voltage levels and with network topology, LCT uptake, and the amount of connected distributed generation.
IMPLICATIONS

The following implications stem from the analysis of the study results and related conclusions;

Understanding of Losses

- Absolute future losses (kWh values) will increase if the amount of energy supplied to customers increases; therefore it is most appropriate to consider future optimisation of losses rather than their reduction.
- Losses have been shown to be sensitive to inherently uncertain parameters and so predicting future losses is problematic.
- Connection of renewable generation is necessary to meet environmental targets and hence any associated increase in losses could be in society’s and customers’ interest.
- Although smart solutions have been shown to increase losses, the whole life costs of smart solutions may be lower than the corresponding values for traditional reinforcement which would maintain losses at approximately the existing level.
- The increased losses due to the use of smart solutions correspond to an ongoing cost which must be adequately considered when comparing alternative reinforcement options because customers ultimately pay for both operational and capital costs.

Treatment of Losses

- A general approach to losses may be unfair to some customers, specifically those customers without site specific loss adjustment factors, because losses differ between localities and depend upon network topology, demand and generation capacity.
- HV and LV generators may be credited for reducing losses through the use of generic line loss factors and customers unfairly affected as a consequence because distributed generation can increase losses when there is an overall export or due to the connection location.

Evaluation of Losses

- Difficulties in measuring losses may mean that alternative methods of evaluating losses may need to be considered. Adoption of a simulation approach would require representation of an extensive network in detail to ensure inclusion of the variations and sensitivities of losses observed in this study.
- Apparent losses specifically the losses evaluated based on the measurement of energy, will be affected by future changes to the mix of large and small generators since they employ different metering accuracies.
- Introduction of Smart meters will affect the losses evaluated based on the measurement of energy as they may consume more energy than existing current whole energy metering, they may be of different measurement accuracy and will provide annual data meaning that annual losses can be evaluated with fewer approximations than necessary when using whole energy meter data.

Regulatory Approach to Losses

- Regulatory approaches to losses should recognise that an economic balance between the costs of losses and the network adoptions to reduce losses must be struck because both are ultimately paid for by customers.
- Future regulatory approaches to losses need to reflect the ability of the DNO to manage losses and the impacts on losses outside of DNO control as losses have been shown to depend upon customer choices to install LCTs and participate in smart solutions such as DSR.
- LCT connections have been shown in these studies to increase losses and so a regulatory approach that penalises increased losses could potentially conflict with low carbon incentives which are necessary to meet environmental targets and protect our planet.
# INTRODUCTION

WSP were commissioned by the Energy Networks Association (ENA) Technical Losses Task Group to undertake a study to understand the impact of the low carbon and smart grid transition on technical network losses.

Reporting to the ENA Electricity Networks and Future Group, the ENA Technical Losses Task Group, comprising representatives of all Distribution Network Operators (DNOs) along with National Grid and chaired by SP Energy Networks, was convened in March 2016 with objectives to:

- improve understanding of technical losses,
- develop best practices for loss strategies, and
- inform the development of a fair and effective losses incentive mechanism for the next regulatory review period.

## 1.1 PROJECT AIM

The aim of the project was to provide understanding of:

- The impact on losses due to connection of Low Carbon Technologies (LCTs),
- How and when smart alternatives to traditional reinforcements affect losses,
- The influence on losses due to customer usage patterns.

It is intended that the information gathered in this project can inform interested parties including DNOs, Ofgem and government. To achieve the project aim, it was divided into 4 tasks as shown in Figure 1.

![Figure 1 – Losses Study Tasks](image)

## 1.2 BACKGROUND

Losses are an inherent consequence of the operation of electrical networks. The majority of electrical losses do not result from network defects; so they cannot be totally eliminated. They depend upon the innate characteristics of network equipment and power flows.

Losses arise as power flows through equipment such as cables, overhead lines and transformers due to their resistance and these “ohmic“ losses are related to the square of the current. Other losses, such as hysteresis losses in transformer cores, occur at all times that the equipment is energised and do not depend on how much power is flowing.

Losses are expected to be impacted by the predicted increase in electrical demands as Great Britain (GB) adopts LCTs for heat and transport such as heat pumps (HPs), electric vehicles (EVs) and photo voltaic solar...
generation (PVs). Increases in demand are associated with increased losses, however, absolute losses could be reduced if larger conductors or additional circuits are added and network utilisation is reduced. Distributed generation connected in close proximity to demand reduces losses when the generation offsets power flowing through the wider network to supply the demands, however, distributed generation can increase losses when the generation is sufficiently in excess of the demand.

Smart innovative technologies such as energy storage and active network management, have the capability to defer or mitigate traditional reinforcement, often resulting in greater average utilisation of assets. This increase in utilisation may however increase losses as a result, but the cost of increased losses with smart solutions is likely to be outweighed by the cost saving of alternative traditional reinforcement investment deferral. Overall, installation of smart solutions can be advantageous to customers’ despite increased losses.

1.3 REPORT STRUCTURE

This report presents the results of the studies undertaken to examine the impact on losses of the low carbon transition and the subsequent conclusions and implications arising from those results. It comprises the following sections:

Section 1  this introduction
Section 2  summarises the key findings of the studies
Section 3  outlines the study approach including brief descriptions of the study networks and smart solution models. Detailed information about the study parameters are provided in the interim report\(^1\) which complements this report.
Section 4  presents the results relating to the impact of the connection of LCTs
Section 5  presents the results relating to the impact of the use of smart solutions
Section 6  draws out conclusions and the implications of the study results; and
Section 7  lists a number of recommendations for dissemination of the study findings and further work.

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\(^1\) ENA Working Group Project - Impact of Low Carbon Transition - Technical Losses – Interim Report September 2017
The key findings of the project are summarised in Figure 2 below.

The uptake of low carbon technologies will significantly impact losses.

• Studies of networks including future LCT connections have shown increased losses expressed as a percentage of energy supplied. The effect on losses depends on the uptake level, the connection location and the balance between demand and generation. Although generation can reduce losses when it does not result in significant net export and when it is connected close to the demand, it can also increase losses significantly. Overall network losses as a proportion of demand were shown to be up to 350% of baseline levels when simulating a network with the increased levels of managed 33kV generation connections; a scenario that already exist in parts of GB. These large increases in losses highlight the sensitivity of losses and the impact of accommodating generation, however, it is recognised that the connection of renewable generation is necessary to meet environmental targets and hence the effect on losses could be in society’s and customers’ interest.

How networks accommodate low carbon technologies will impact losses.

• Methods of network reinforcement and how the network is used have been shown to affect losses. Future percentage losses can be unchanged with the perpetuation of traditional reinforcement. Whilst, smart solutions which increase the utilisation of existing network assets increase losses. Since these increased losses correspond to an operational cost, choices between alternative reinforcement and connection options should consider lifetime costs adequately. Increasing losses to accommodate the transition to a low carbon future can be justified by the massive cost savings smart solutions provide compared to traditional reinforcement.

Losses are complex, difficult to measure and vary based on regional topology.

• Losses have been shown to be complex due to multiple dependencies and vary significantly across the different voltage levels and with network topology, LCT uptake, and the amount of connected distributed generation. Difficulties in measuring losses may mean that alternative methods of evaluating losses may be considered. Adoption of a simulation approach would require representation of an extensive network in detail to ensure inclusion of the variations and sensitivities of losses observed in this study.
3 STUDY APPROACH

The results presented in this report have been interpreted within the context of the networks analysed, the underlying assumptions and the methodologies adopted. Significant aspects of the modelling are summarised in this section to enable the results to be interpreted with appropriate understanding. Further detail on the modelling can be read in the preceding interim report.

3.1 STUDY METHODOLOGY

The effect of the transition to low carbon on network losses was investigated by simulating two representative networks (Urban and Rural) using a methodology defined by the following points:

- Whole year simulations at half hour granularity in DlgSILENT PowerFactory,
- Losses recorded for each voltage level,
- DS2030 original network losses studied as a baseline,
- Only intact networks studied as they persist for the majority of the time,
- Considered traditional reinforcement and smart solutions;
- Network loading comprising the base load plus additional LCTs (EVs, HPs and PV) corresponding to predicted 2030 uptake levels.

All loss results included in this report are presented as percentages of the energy supplied because distribution losses are commonly considered as such as they are in Line Loss Factors and also so that results can be compared between scenarios with different loading conditions. Line Loss Factors are multipliers which are used to scale energy consumed by a customer to reflect the network losses incurred in the delivery of that energy.

3.2 STUDY MODELS

The Urban and Rural base network models developed for the Distribution System 2030 (DS2030) project were used to study losses on the basis that they provided a number of benefits, including:

- real 132kV, 33kV, 11(6.6)kV and LV voltage networks including customer services with actual parameters,
- measured (real) half hour loading profiles for existing circuits,
- include predictions for LCT uptake (HPs, EVs and PV technologies) at all voltage levels based upon details of the local population,
- ability to simulate annual profiles at half hour granularity, and
- availability of scripts developed for DS2030 to provide built in flexibility to study various scenarios.

The Urban base network is based upon the system downstream of Northern Power Grid’s Norton Grid Supply Point which comprises 4 x 240MVA 275/132kV transformers with a maximum demand of approximately 440MW and supplying 9 x 132kV substations and approximately 234,000 customers.

The Rural base network is based upon the system downstream of Electricity North West’s Padiham Grid Supply Point which comprises 2 x 240MVA 400/132kV transformers with a maximum demand of approximately 240MW and supplying 4 x 132/33kV substations and approximately 120,000 customers.

All networks were modelled with balanced loadings.

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3.3 **LCT UPTAKE**

Studies of future network losses have been undertaken based upon the DS2030 Central LCT uptake level for HPs, EVs, LV PV and other generation in 2030. A comparison of these uptake levels with National Grid’s Future Energy Scenario has shown good correlations. These national uptake levels have been allocated to the Urban and Rural base networks used in these studies leading to the numbers of HPs and EVs, and generation capacities summarised in Table 1.

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<td><strong>LCT</strong></td>
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<td><strong>Urban</strong></td>
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<tr>
<td>EV (number of units)</td>
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<tr>
<td>(52% of customers)</td>
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<tr>
<td>HP (number of units)</td>
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<tr>
<td>(27% of customers)</td>
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<tr>
<td>LV PV (MW)</td>
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<td>(21% of customers assuming 3kW capacity per installation)</td>
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<tr>
<td>Large 33kV, 11kV &amp; 6kV Generators (MW)</td>
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<td>(52% of maximum demand)</td>
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LV PV export profiles and EV and HP demand profiles developed for the DS2030 project have been used in these losses studies. Constant export was assumed for large generators connected to the Urban base network analogous to energy from waste and CHP. Large generators connected to the Rural network were assumed to have a PV export profile as this is expected to dominate rural connections.

Large generator uptake has been modelled with direct connections at 33/11kV substations without dedicated circuits so that losses in these circuits were not included in the study results. It was not appropriate to model dedicated circuits because the present settlement approach attributes losses specific to 33kV generators to the individual generator through site specific Line Loss Factors. This means that they are not applied to all customers through the use of generic Line Loss Factors.

The modelled LCT network loading scenario, although considered to relate to the year 2030 could occur before 2030 if the uptake rate is greater than expected or later than 2030 if the uptake rate is lower. Observed changes in losses are indicative of the effect of the specific modelled load conditions which could occur in a year other than 2030.

Variations in loss results can be expected for different loading conditions. Uncertainty regarding future loading means that the impact on losses is also uncertain, so the changes in losses should be considered indicative of the impact in 2030. Loss results will be affected by clustering of LCT connections beyond the regional variation considered by studying the Urban and Rural base networks.

3.4 **SMART SOLUTION MODELLING**

As well as studying the impact of the connection of LCTs on network losses, studies have also addressed the effect of how these LCTs are accommodated within the network. Traditional reinforcement has been considered including upgrading equipment ratings and adding new circuits and transformers.

The following smart solutions have been considered as alternatives to traditional reinforcement as described in subsequent subsections:

- Demand Side Response (DSR)
- Energy Storage
- Active Network Management (flexible generator connections)
- Alternative Customer Profiles
DEMAND SIDE RESPONSE
DSR was simulated by considering the future loading conditions in an unreinforced network which was checked to operate within equipment ratings for the intact network only. It was assumed that DSR provides an alternative to traditional reinforcement by reducing power flows so that the network operates within equipment ratings and limits during an outage.

NETWORK ENERGY STORAGE
HV Network Energy Storage was modelled connected to the Urban and Rural network models to resolve circuit overloads due to the future loading condition which is just one of the ways that Energy Storage could be operated. The Energy Storage was assumed to be connected close to overloaded circuits and operate at times of peak power flow to reduce the circuit power flows to 95% of their rating. A round trip efficiency of 90% was assumed and the Energy Storage was assumed to charge immediately after the circuit power flow had dropped below the 95% limit as shown in Figure 3. Current arrangements prohibit distribution network operators from owning and operating Energy Storage, but flexibility services could be purchased from Energy Storage owners to manage network power flows as an alternative to network reinforcement.

![Figure 3 – Example of circuit loading with and without Network Energy Storage](image)

ACTIVE NETWORK MANAGEMENT (FLEXIBLE GENERATOR CONNECTIONS)
Active Network Management (ANM) has been considered as a form of generator export control (flexible generator connections). The studies have simulated the situation that network power flows are maintained within limits by a generator accepting export constraints rather than paying reinforcement costs. Such managed connections already exist and it is becoming increasingly common that the intact network is saturated with generation.

Additional 33kV generation was added to the two network models so that the power flowing in all 33kV circuits was the maximum allowable export at all times. More generation was accommodated at times of greater demand and less generation added at times of lower demand to keep the net export at the steady state circuit rating at all times.

ALTERNATIVE CUSTOMER PROFILES
Two alternative customer profiles have been examined to assess the effect on losses of changing the time that energy is delivered to customers.

Peak Lopping Customer Profile
The study has considered a “Peak Lopped” effect which could transpire if suppliers implement time of use tariffs or due to DNO driven actions to relieve network constraints including application of DSR, time of use tariffs or controlled EV charging.
Peak lopping was simulated by scaling the customer demand in any half hourly such that the energy supplied to the network was capped at a limit defined as a percentage of the daily Grid Supply Point peak demand. Energy which was lopped in this manner was shifted to a time immediately after the demand fell below the limit. 90% and 80% limits were considered as illustrated in Figure 4.

![Figure 4 - GSP profile with and without peak lopping (90% and 80% limits) for an example day](image)

**Domestic Energy Storage Customer Profile**

The second alternative customer profile approximated the change in the timing of a customer drawing power from the network that might come about if they installed Distributed Energy Storage (DES) alongside their LV PV. All energy generated during the day by the LV PV was assumed to be stored and then discharged during the evening thus displacing energy normally drawn through the distribution network. Daytime demands are increased and evening demands decreased for customers with LV PV and DES, compared to those with LV PV only.

The effect was simulated by modifying the generation profile of all LV PV generation included in the models such that no power was exported during daylight hours, but instead 90% (assumed roundtrip efficiency) of the daily energy was exported at times of peak demand between 17:30 - 21:00 as shown in Figure 5.

![Figure 5 – DES export profile](image)
IMPACT OF LCT UPTAKE STUDY RESULTS

Loss results were taken directly from simulations which were performed to provide understanding of the individual and combined impact on losses of LCT connections and alternative reinforcement options. Loss results are presented in this section for the following scenarios:

- Baseline – network without future LCTs,
- Incremental future LCTs,
- Additional large distributed generation connected at HV and 33kV, and
- Traditional reinforcement

All results relate to the main sources of technical losses included in the model, specifically resistive losses and transformer iron losses. Other technical sources of losses including corona losses and losses in joints were not taken into consideration as they are relatively small compared to the modelled resistive and transformer losses. Non-technical losses, including theft in conveyance, unmetered supplies, meter errors, meter tampering and unregistered meters, were not included in the assessment as they are not directly affected by the uptake of LCTs and how the network is reinforced. There are no significant consequences of omitting these losses because the impact of the low carbon transition is established by taking the difference between results to identify the impact on losses of specific changes.

Undertaking studies at half hour granularity provides a balance between the number of studies and the accuracy of the loss results. When there are numerous customers involved, diversity between individual connections means that power flows averaged over a half hour are good approximations of the power flows during the half hour. Power flows in the network models considered in this study are affected by numerous customers, except for some parts of the LV network, for example customer services or the end of the main LV circuit. In practice the consumption of individual customers is sporadic and consequently actual losses in the parts of the network without diversity can be greater than modelled based upon half hour studies. However, for this wide-ranging study of total network losses, half hour studies are most appropriate due to the extent of the networks involved and because the erratic nature of individual demands is not practical to model or study. The potential effect of half hour studies on a component of the LV network losses results should be noted and is considered in the analysis of the results.

Percentage (relative) losses were calculated by dividing the absolute values of lost energy by the energy supplied to all customers at that voltage level and below; for example 11kV percentage losses were calculated by dividing the absolute value of losses observed over the year in the 11kV network by the sum of the energy delivered to customers at 11kV and downstream LV customers. It should be noted that the sum of the annual energy delivered to customers is not the same as the energy delivered at the voltage network interface(s); the energy delivered from the 11kV network to the LV network will be less than the total energy consumed by LV customers due to LV generation.

The results presented in this section relate to specific networks, baseline loading and assumed future loads. Although considered indicative of Urban and Rural networks, these networks have specific topologies and loading profiles and as such the absolute annual losses are specific to them; however percentage losses are comparable with other distribution systems in GB. For this reason the absolute losses values arising from these studies are considered less important than the changes in relative losses arising due to variations in the network operation. Examination of how the level of losses changed from the baseline level has enabled the impacts of different network connections and alternative forms of system reinforcement to be inferred. The focus of the analysis of the study results has been to understand if network changes had a significant impact on losses, where in the network the impact occurred, the magnitude of the impact, whether it was positive or negative and the sensitiveness of the impact.
4.1 BASELINE LOSSES

A baseline for losses was established by calculating the losses in the network for the start of the DS2030 studies, specifically the starting network arrangement, starting loading conditions and no future connections. Total Urban and Rural network losses were found to be 4.0% and 3.5% respectively, broken-down between the different voltage networks as shown in Figure 6.

For the Urban network model, losses in the HV circuits and HV/LV transformers are particularly significant. This is explained by the high utilisation of HV circuits which is common in urban areas where the load and circuit density is high. Within the Urban HV system circuits can be highly utilised because some circuits are interconnected with 2 or more others, forming circuit groups. When designed appropriately, a group of circuits provides support for each other when one of the group of circuits is out of service. This is unlike when there are only two circuits supporting each other; they cannot be more than 50% loaded in accordance with security criteria to ensure sufficient spare capacity to pick up the load of the one circuit if it is out of service.

For the Rural network model, losses in the 33kV circuits and 11kV/LV transformers are particularly significant. This is explained by the high utilisation of the 11kV/LV Transformers and long 33kV circuits between remote load centres.

Comparisons of these baseline results and loss values with other studies may yield differences which are likely due to dissimilarities in the network topologies, equipment parameters and loading and generation profiles. Confidence in the accuracy of these loss results is assured by basing studies on real networks and measured annual load profiles. It is not a concern that the losses in the Urban and Rural network models do not precisely match the percentage loss values from other studies because losses can vary significantly between segments of the network across GB. By looking at changes in losses, conclusions arising from this study are less sensitive to the absolute values of baseline losses.

At 4.0% and 3.5% the simulated losses are slightly smaller than the commonly accepted 6% total losses reflected in typical Line Loss Factors. These discrepancies, explained by the omission of non-technical losses and approximations in the simulations, are not an issue because the conclusions of this study are based on the differences between results rather than the absolute values. The simulated baseline losses will be reflective of the actual regional variations because they were determined using existing networks modelled with real parameters. This also means that the variation in losses due to changes in the network operation will be valid.

These baseline losses are the basis of comparison of losses for all subsequent results in this section.
4.2 LOSSES IN A SYSTEM WITH INCREMENTAL FUTURE LCTs

The impact on losses of LCT connections has been explored by considering the sequential connection of future HPs and EVs, LV PV and large distributed generation to observe how losses change due of these individual modifications. The results are useful for demonstrating the variances that could occur across the wide range of GB networks. In practice LCT connections may be clustered beyond the regional variations that are represented in the study models. Numbers of customers, types of properties and socioeconomic conditions have been taken into consideration when determining the distribution of LCT uptake across the modelled networks. However, it is possible that the actual situation is different, for example, there may be areas where HPs and EVs connect, but the expected level of LV PV is not realised.

All loss results in this section correspond to a network without reinforcement, meaning that the networks are not guaranteed to provide the security of supply provided by today’s network designs. Although parts of the network may have sufficient margin to accommodate the new LCTs, changes in power flows due to new connections in other parts of the network may be such that circuits could be overloaded when a single circuit is out of service.

Figure 7 shows the total losses for the Urban and Rural network models with incremental LCT connections and no reinforcement. Results corresponding to each incremental scenario are discussed in this subsection (4.2) and subsection 4.3.

![Figure 7 – Base network losses with sequential addition of LCTs](image)
FUTURE HP AND EV CONNECTIONS

The second columns of the graphs in Figure 7 show that the connection of the HPs and EVs expected in 2030 increases losses in the Urban and Rural networks, specifically:

- **Urban network** – losses increase from 4.0% (baseline) to 5.6%, corresponding to a factor of 1.40
- **Rural network** – losses increase from 3.5% (baseline) to 4.0%, corresponding to a factor of 1.12

The impact on losses in the Urban network is more pronounced than in the Rural network partly because the combined EV and HP uptake expressed as a percentage of the existing demand is lesser for the Rural network.

The overall scaling factors of 1.40 and 1.12 correspond to the increase in the average losses as the losses in the component voltage networks are not all affected by the same scaling factor. Total losses for the network with HPs and EVs are broken-down between the different voltage networks as shown in Figure 8. When compared to the split of the baseline losses, the most dramatic increase is in Urban network LV losses which are 240% of their corresponding baseline value. The extent of the impact on different parts of the network depends on not only the magnitude of the increase in power flows, but also the timing of the increases. The topology of the network also has an effect as the increase in the power flow on individual circuits will be less if there are more circuits in that network to share the power flowing to the new connections.

Transformer losses expressed as a percentage of the energy consumed by customers are seen to be least affected by the HP and EV connections. This is because the absolute value of transformer iron losses does not change; they are fixed and do not depend on transformer loading, consequently iron losses correspond to a lower value when expressed as a percentage of the greater energy supplied to customers. This reduction can somewhat compensate for the increase in transformer resistive losses which do depend on transformer loading.

**Figure 8** – Comparison of the split of baseline losses and those in the network with future HPs and EVs
PLUS FUTURE LV PV CONNECTIONS

Losses in the Urban and Rural networks with 2030 HPs, EVs and LV PV are shown in the third columns of the graphs comprising Figure 7 and their comparison to the baseline losses is summarised as follows;

- **Urban network** – losses increase from 4.0% (baseline) to 5.3%, corresponding to a factor of **1.32**
- **Rural network** – losses increase from 3.5% (baseline) to 3.9%, corresponding to a factor of **1.10**

Losses with connection of the projected 2030 LV PV in addition to the HPs and EVs are still greater than those in the baseline system; however, they are slightly less than with just the HPs and EVs because at the modelled uptake level the LV PV on average reduces power flows due to it being connected close to the LV demands. Compared to the case with just HPs and EVs connected, Urban losses are 5% less (5.3% \(/ 5.6\)) with connection of the LV PV which provides approximately 3.6% of the annual energy consumption, whilst for the Rural network the losses are 2% (3.9% \(/ 4.0\)) lower than with the addition of HPs and EVs alone when the LV PV provides 1.3% of the annual energy consumption. Such reduction corresponds to the specific level of LV PV which is less than the demand on average during daylight hours. Greater penetrations of LV PV can cause net export from parts of the network and losses could consequently increase locally or overall if such conditions were repeated across the network.

The break-down of the losses with HPs and EVs, plus LV PV between the different voltage networks shown in Figure 9 illustrates the reduction in all line losses; the reduction in the LV and HV line losses is most visible because the reduction in 33kV and 132kV line losses is less than rounding precision.

![Comparison of split of losses in Urban network with EVs and HPs, plus LV PV](image1)

![Comparison of split of losses in Rural network with EVs and HPs, plus LV PV](image2)

**Figure 9** – Comparison of the split of baseline losses and those in the network with future HPs and EVs, plus LV PV

PLUS FUTURE LARGE GENERATION CONNECTIONS

Losses in systems with future large generators connected at 11kV and 33kV in addition to the 2030 HPs, EVs and LV PV are shown in the fourth columns of the graphs comprising Figure 7 and their comparison to the baseline losses is summarised as follows;

- **Urban network** – losses increase from 4.0% (baseline) to 4.4%, corresponding to a factor of **1.11**
- **Rural network** – losses increase from 3.5% (baseline) to 3.7%, corresponding to a factor of **1.06**
Figure 10 – Comparison of the split of baseline losses and those in the network with future HPs, EVs and LV PV, plus 2030 large generators

This specific generation scenario sees generation connected such that there is insignificant net export. It supplies downstream demands and reduces power flows in the 132kV and 33kV networks and consequently reduces 132kV and 33kV network losses as shown in Figure 10. HV and LV network losses are unaffected because the large generators are considered to connect at 33kV and at the HV busbars of 33/HV substations.

4.3 LOSSES IN A SYSTEM WITH ADDITIONAL LARGE GENERATION CONNECTIONS

Section 4.2 presented study results for the 2030 scenario in which the projected large generation was averaged across the GB network. DNO experience has shown that generator connections can be clustered and parts of the network are already saturated with generation such that further generator connections could not be accommodated without network reinforcement. Export from some generators is already being dynamically controlled to maximise power generation whilst also ensuring that network reverse power limits are not exceeded. This form of flexible connection is enabling generators to connect without the expensive network reinforcement that could otherwise render their plant uneconomic. For example, rather than contribute towards the cost of network reinforcements, a generator may operate with a controller that reduces their export when the local demand is low so that the reverse power flow remains within network limits.

There are already parts of the GB network where the level of generation, including managed generation connections, is such that there is a net export of power observed for part of the year. This scenario has been modelled by applying additional time varying 33kV generation to the Urban and Rural models such that the reverse power flows through each 33kV network were at the permitted maximum at all times. The simulated time varying export from the generators mimics the effect of dynamic generator control. In the Urban case, the study results indicated that the total export from the distributed generation was 107% of the annual energy consumed by customers, whilst the corresponding value for the Rural network was 143%.

Losses in the networks with 2030 HPs, EVs, LV PV and the additional large generators are illustrated in Figure 11 and their comparison to the baseline losses is summarised as follows;

- **Urban network** – losses increase from 4.0% (baseline) to 8.2%, corresponding to a factor of 2.1
- **Rural network** – losses increase from 3.5% (baseline) to 12.3%, corresponding to a factor of 3.5

The greatest impact of the additional generation is evident in the 33kV and 132kV losses as shown in Figure 12. 33kV losses increase significantly compared to the baseline; 33kV circuit losses in the Urban network increase by a factor of approximately 10 (from 0.4% baseline to 4.1%), whilst 33kV circuit losses in the Rural network increase by a factor of approximately 12 (from 0.8% baseline to 9.6%). These large increases in losses highlight the sensitivity of losses and the impact of accommodating generation, however, it is
recognised that the connection of renewable generation is necessary to meet environmental targets and hence the effect on losses could be in society’s and customers’ interest.

**Figure 11 – Network losses with additional 33kV generation**

**Urban**

<table>
<thead>
<tr>
<th>Loss Type</th>
<th>Percent of Energy Supplied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Base Network</td>
<td>4.0%</td>
</tr>
<tr>
<td>Additional Generation</td>
<td>8.2% (maximum 33kV reverse power at all times)</td>
</tr>
</tbody>
</table>

**Rural**

<table>
<thead>
<tr>
<th>Loss Type</th>
<th>Percent of Energy Supplied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Base Network</td>
<td>3.5%</td>
</tr>
<tr>
<td>Additional Generation</td>
<td>12.3% (maximum 33kV reverse power at all times)</td>
</tr>
</tbody>
</table>

**Figure 12 – Comparison of the split of baseline losses and those in the network with future HPs, EVs and LV PV, plus additional 33kV generation**

**Comparison of split of losses in Urban network with EVs, HPs and LV PV plus additional generation**

- 132kV Line Losses: 0.3%
- 132/33kV Transformer Losses: 0.3%
- 33kV Line Losses: 0.4%
- 33kV/HV Transformer Losses: 0.6%
- HV Line Losses: 0.8%
- HV/LV Transformer Losses: 1.6%
- LV Losses: 4.1%

**Comparison of split of losses in Rural network with EVs, HPs and LV PV plus additional generation**

- 132kV Line Losses: 0.05%
- 132/33kV Transformer Losses: 0.58%
- 33kV Line Losses: 0.25%
- 33kV/HV Transformer Losses: 0.17%
- HV Line Losses: 1.28%
- HV/LV Transformer Losses: 0.44%
4.4 LOSSES IN A SYSTEM WITH TRADITIONAL REINFORCEMENT

Figure 13 shows the results of studies undertaken to investigate the impact on losses of traditional reinforcement comprising typical conventional DNO approaches to reinforcement including reconfiguration of networks, new circuits, larger conductors and higher rated transformers.

Study results show that losses are broadly maintained at the baseline levels with the perpetuation of traditional reinforcement approaches. Although traditional reinforcement can be more expensive than smart solutions, upsizing equipment is seen to offer the benefit of slightly reducing losses.

The slight reductions in losses in the networks with traditional reinforcement are attributed to the granular nature of traditional reinforcement. Specifically, when a network reaches its limits, the traditional approach is to add equipment with standard ratings which reduces the network utilisation and losses in that part of the network. This reduction in the losses in the reinforced parts of the network opposes the increase in losses in the unreinforced parts of the network where power flows and utilisation are increased due to new LCT connections. Whether the overall impact is a slight reduction or slight increase in losses depends on the balance of these reductions and increases.
5 IMPACT ON LOSSES OF SMART SOLUTIONS

Loss results have been calculated based on outputs from the simulation of the Urban and Rural networks with the application of the following smart solutions modelled as outlined in section 3.4:

- Demand Side Response
- Network Energy Storage
- Active Network Management (flexible generator connections)
- Alternative Customer Profiles

Losses in networks with smart solutions applied are compared to losses in the traditionally reinforced network as presented in section 4.2.

Smart solutions have been modelled using the approaches described in Section 3.4. However, it should be borne in mind that the actual realisation of a smart solution may be different. For example, time of use tariffs may not incentivise reduction of power consumption at the time of the established peak demand as simulated in the “Peak Lopped” alternative customer profile studied as part of this work. Time of use tariffs may reflect the availability of generation and incentivise use during the daylight hours when PV exports are greatest, or offer a less predictable incentive to use power when it is very windy and wind generation export is greatest. The reported studies have considered the same smart solution applied to all parts of the Urban and Rural networks, but in practice different smart solutions may be applied in different areas or used together to provide layered benefits. Consequently, these study results should be considered indicative of the more complex reality that it likely to exist in the future, rather than an accurate prediction.

5.1 LOSSES IN A SYSTEM WITH THE APPLICATION OF DEMAND SIDE RESPONSE

Figure 14 illustrates the losses in the Urban and Rural networks with the application of DSR as an alternative to traditional reinforcement and their comparison to the losses in the traditionally reinforced networks is summarised as follows:

- **Urban network** – losses increase from 3.9% (traditionally reinforced) to 4.4%, corresponding to a factor of 1.1
- **Rural network** – losses increase from 3.3% (traditionally reinforced) to 3.7%, corresponding to a factor of 1.1

Use of DSR was noted not to affect LV network losses. DSR used as an alternative to traditional reinforcement permits better utilisation of circuits on which spare capacity must be retained to allow for the backfeed of other circuits in the event that they are out of service. A consequence of this is that DSR does not affect the loading and associated losses of radial LV circuits which are not interconnected and are not designed with backfeed capabilities.

The major increase in losses in networks using DSR compared to those in a traditionally reinforced network was noted to be focused in the parts of the network that would require traditional reinforcement, specifically the HV circuits in the Urban network and the 33kV circuits in the Rural network. This is explained by the utilisation of circuits in the intact configuration of the reinforced network being less than in the network using DSR.
5.2 LOSSES IN A SYSTEM WITH THE APPLICATION OF NETWORK ENERGY STORAGE

Figure 15 illustrates the losses in the Urban and Rural networks with the application of Network Energy Storage as an alternative to traditional reinforcement and their comparison to the losses in the traditionally reinforced networks is summarised as follows;

Urban network – losses increase from 3.9% (traditionally reinforced) to 4.6%, corresponding to a factor of 1.2

Rural network – losses increase from 3.3% (traditionally reinforced) to 3.9%, corresponding to a factor of 1.2

Application of Network Energy Storage to relieve network overloads was seen to increase losses due to increased utilisation of circuits. In the Urban network, the overall increase in losses was dominated by the increase in the losses in the HV network where the Energy Storage was considered to be connected. With Network Energy Storage, losses in the Urban HV network were nearly doubled compared with the traditionally reinforced network, yet the increase in losses in other parts of the network were small or zero. Losses in the battery associated with the battery’s assumed round trip efficiency of 90% were found to be small compared to network losses. It is recognised that battery losses are likely to be the responsibility of the battery operator and therefore not shared amongst customers in the same way as network losses.

The simulated infrequent Network Energy Storage operation means that their effect on annual losses is averaged over the year and consequently diluted. Network Energy Storage used to relieve network overloads only operates and affects losses for part of the day on the days of the year that the loading is above the network limits, i.e. between approximately 16:00 and 21:00 on winter days in the Urban network.

Network Energy Storage could provide services other than relieving overloads, for example balancing services including frequency response and short term operating reserve. It is likely to operate more frequently than for relieving overloads alone, meaning that the effect on losses is likely to be more frequent than simulated in the yearlong study. Network losses on a single typical day when Energy Storage is in use have been examined to get a better understanding of the potential impact on losses of the operation of Energy storage if it was to be used for any of a variety of purposes. A single day was studied because the unpredictable nature of the use of Energy Storage means that it is difficult to model a whole year considering multiple functions. The results for
the typical day, as shown in Figure 16, illustrate that overall losses in a network employing Network Energy Storage can be more than 40% greater than those in the traditionally reinforced Urban network. Results for this single day could be extrapolated to a year to reflect frequent use of the Network Energy Storage.

Figure 15 – Network losses with 2030 LCTs plus Network Energy Storage

Figure 16 – Single Day losses when network energy storage is operating to relieve HV network overloads
5.3 LOSSES IN A SYSTEM WITH ACTIVE NETWORK MANAGEMENT

Application of ANM in which generator exports are maximised whilst the reverse power flow remains within steady state circuit ratings at all times produces the same network conditions and losses as the network with additional large generators as discussed in section 4.3.

On this basis, Figure 11 illustrates the losses in the Urban and Rural networks with the application of ANM as an alternative to traditional reinforcement and their comparison to the losses in the traditionally reinforced networks is summarised as follows;

- **Urban network** – losses increase from 3.9% (traditionally reinforced) to 8.2%, corresponding to a factor of 2.1
- **Rural network** – losses increase from 3.3% (traditionally reinforced) to 12.3%, corresponding to a factor of 3.8

5.4 LOSSES IN A SYSTEM WITH ALTERNATIVE CUSTOMER PROFILES

Losses have been evaluated for two alternative customer profiles which modify when customers consume energy, specifically “Peak Lopped” and “Domestic Energy Storage” customer profiles.

5.4.1. “Peak Lopped” Customer Profile

Figure 17 illustrates the losses in the Urban and Rural networks when customers modify their behaviour according to the “Peak Lopped” profile as an alternative to traditional reinforcement and comparison of these losses to the losses in the traditionally reinforced networks is summarised as follows;

- **Urban network** – losses increase from 3.9% (traditionally reinforced) to 4.4%, corresponding to a factor of 1.1
- **Rural network** – losses increase from 3.3% (traditionally reinforced) to 3.7%, corresponding to a factor of 1.1

Modifying customer profiles to reduce peak power flows as an alternative to traditional reinforcement increases losses in a similar way that DSR increases losses. The increases in losses were mainly concentrated in the HV part of the Urban network and 33kV part of the Rural network. This indicates that the increases are related to the avoided reinforcement rather than the modification of when energy was consumed with the “Peak Lopped” customer profile.

Losses corresponding to the 90% and 80% “Peak Lopped” customer profiles are very similar losses for all voltage networks. This indicates that losses were not very sensitive to the two different “Peak Lopped” customer profiles.
Figure 17 – Network losses with “peak lopped” customer profile
5.4.2. “Domestic Energy Storage” Customer Profile

Figure 18 illustrates the losses in the Urban and Rural networks when customers modify their behaviour according to the “Domestic Energy Storage” profile as an alternative to traditional reinforcement and comparison of these losses to the losses in the traditionally reinforced networks is summarised as follows:

- **Urban network** – losses increase from 3.9% (traditionally reinforced) to 4.4%, corresponding to a factor of 1.1
- **Rural network** – losses increase from 3.3% (traditionally reinforced) to 3.6%, corresponding to a factor of 1.1

Losses with the “Domestic Energy Storage” customer profile were greater than the traditional reinforced network and very similar to the losses with DSR and the “Peak Lopped” customer profile. Again, it is deduced that the increase in losses is related to the avoided reinforcement rather than the modification of when energy was consumed with the “Domestic Energy Storage” customer profile.

![Figure 18 – Network losses with “domestic energy storage” customer profile](image-url)
6 CONCLUSIONS & IMPLICATIONS

This study has provided an improved understanding of the impact of low carbon transition on technical losses which can inform future approaches to losses and how losses are considered in network development and operation.

The loss results relate to the assumed 2030 network loading, meaning that losses will not be the same for different future loadings.

6.1 IMPACT ON LOSSES OF LOW CARBON TECHNOLOGIES

LCT Demand Uptake

The uptake of low carbon technologies has been shown to appreciably impact losses.

Increased customer demand, through the uptake of HPs and EVs, increases the utilisation of the network and hence increases losses. Absolute losses will always increase as the amount of energy supplied increases but the variation of relative losses, i.e. losses as a percentage of energy supplied, will depend upon the network characteristics.

Based on the modelled 2030 projection for HP and EV uptake, overall percentage losses were seen to increase to 140% and 112% of existing levels in the Urban and Rural networks respectively.

LV PV

At the modelled level, the connection of LV PV has been seen to reduce relative losses. At this level the LV generation is noted to offset local LV demand and reduce power flows through upstream higher voltage networks with an associated reduction in LV and upstream network losses providing a potential carbon benefit.

Large Generators

Larger generation connections have a significant impact on losses, particularly at those voltage levels at which they connect and higher. At the average projected levels, connection of larger generators reduce losses, but losses increase when more generation is connected. When the maximum generation capacity is connected to a network, the overall losses were shown to be increased significantly at 210% and 350% of existing levels in the Urban and Rural networks respectively.

Regional Variations

Losses and the impact of LCT uptake have been shown to vary between regions. Differences in percentage losses for the urban and rural networks are attributed to the network topologies and their operation. Lesser percentage losses for rural circuits have been identified despite rural circuits being longer on average. This is explained by lower utilisation of the modelled rural circuits perhaps due to the low demand density in rural areas and voltage limitations on long circuits.

Losses in rural networks were noted to be less affected by the connection of LCTs than the comparable urban network losses. This is explained by the lower customer concentration in rural areas and due to the regional variation in LCT uptake, such as fewer EVs in rural areas because they are currently less appropriate for driving longer distances and there is likely to be less charging infrastructure. A different LCT uptake would change the results which currently reflect a defined LCT uptake and relate to the specific network and existing conditions.

The impact on losses of the connection of larger generation has been shown to also vary between rural and urban networks. Generation capacity and generator load factor were both noted to have a significant influence on how losses were affected.

6.2 IMPACT ON LOSSES OF DISTRIBUTION NETWORK DEVELOPMENT

Studies of networks with the same loading and different methods of reinforcement to satisfy today’s security of supply requirements have shown that losses are affected by how networks accommodate LCT connections.

Traditional Reinforcement

Future percentage losses have been shown to be largely unchanged with the perpetuation of traditional reinforcement. Installation of new circuits and transformers to accommodate future LCTs means that average network utilisation and losses remain similar.
Smart Solutions

Studies of the application of smart solutions have shown losses up to 30% greater than the network with traditional reinforcement.

With the application of Demand Side Response, losses were found to be between 13% and 16% greater than in the traditionally reinforced network. Losses are greater because circuit utilisation of the intact network is inherently more as Demand Side Response is used to constrain customers when a circuit is out of service.

With the application of Network Energy Storage used to alleviate HV network overloads, annual losses were found to be up to 18% greater than in the traditionally reinforced network. With Network Energy Storage, daily losses were shown to be up to 30% more and this is considered to be reflective of the impact on losses of Network Energy Storage used for different applications such as balancing services.

Losses in a network with modified customer demand profiles were shown to be up to 14% greater than losses in a traditionally reinforced network. The results were similar for the two different customer demand profiles studied; specifically the profile assumed to correspond to the application of domestic energy storage and the profile corresponding to the use of tariffs that incentivise reduction of consumption at times of today’s peak demand.

Losses in networks with any of the studied smart solutions were found to be greater than those corresponding to traditional reinforcement. Ongoing operational costs of greater losses when smart solutions are used are balanced by the potentially greater cost of traditional reinforcement. Consequently choices between alternative reinforcement and connection options should consider capital and operational costs adequately. Smart solutions with increased losses may be found to be the least overall cost and therefore in the customers’ interest. Increasing losses to accommodate the transition to a low carbon future can be justified by the potential cost benefits that smart solutions can provide compared to traditional reinforcement.

Some smart solutions may require smart meters at customer’s properties so that information can be shared between the customer and the smart system. Application of such smart solutions could therefore be affected by the delay\(^3\) in the rollout of the latest version of smart meters (SMETS2) which provide the necessary functionality for smart solutions.

Although the studied smart solutions have been shown to increase losses, other smart solutions may be considerate losses. An example is active network management used to control normal open points to manage losses, although it is recognised that other parameters such as the number of customers and minimisation of customer interruptions may also be part of the control algorithm.

6.3 COMPLEXITY OF LOSSES

The complexity of losses has been demonstrated by the studies which have highlighted how losses vary with network topology and how the impact on losses of LCT uptake varies between the different voltage networks. Studies have shown how losses are very sensitive to the balance between demand and generation and their annual and daily profiles. Greater regional variations in future losses can be inferred from the results as LCT uptake and the application of smart solutions varies across the networks.

It has been necessary to undertake numerous studies to accurately assess losses. Each year corresponds to a minimum of 17,520 individual load flow studies based on a half hour granularity, but many more have been required to simulate smart solutions and controls.

Adoption of a simulation approach for the evaluation of losses should balance the accuracy achieved by considering an extensive network in detail and the time required and cost involved with undertaking the studies.

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\(^3\) https://utilityweek.co.uk/beis-extends-installation-deadline-smets1/
6.4 UNCERTAINTY OF FUTURE LOSSES

Future losses cannot be accurately predicted because they depend upon expected network changes that are yet unknown.

Losses have been shown to be sensitive to inherently uncertain parameters. Losses depend upon the magnitude and timing of network power flows which are changing as new LCTs connect as part of the transition to low carbon energy. The significant numbers of distributed generators that have already connected to the distribution network have shown influences of political incentives and market trends which are difficult to predict. Future EV, HP and more distributed generation uptake will be sensitive to similar influences which cannot be accurately forecast, meaning that predicting future losses is problematic.

Although variations in actual losses will occur due to the nature of network characteristics and operation, apparent losses will also change as the accuracy of the measurement of the components used in the evaluation of losses changes. Distribution losses are normally calculated as the difference between the energy into the network and the energy out of the network. The accuracy of the measurement of energy into the network will change as the mix of transmission network connected, large and small distribution network generation changes since they employ different metering accuracies. Modification to the overall accuracy that energy into the network is measured could be reflected in a change in the apparent losses. Just how much the apparent losses will be altered by changes in the measurement accuracy and the timing are uncertain as the transformation of the generation mix cannot be predicted.

6.5 REGULATORY APPROACH TO LOSSES

Regulatory approaches to losses can be informed by the study results which have highlighted the variance of future losses and their dependency on factors that are likely to vary during the next regulatory price review period.

A previous regulatory loss approach which paid incentives and applied penalties when DNOs exceeded or missed loss targets respectively was withdrawn in 2012 meaning that it was not effective through distribution price review period DPCR5 (from 1st April 2010 to 31st March 2015). It was recognised that the data used in the evaluation of losses was not of adequate quality and that the financial impact could be inappropriate as a consequence.

The revised losses reporting approach now operating in RIIO ED1 requires DNOs to define in their business plan their strategy for reducing losses and to annually report on their loss reduction activities. Typical actions taken by DNOs to manage technical losses include:

- Consideration of losses in Cost Benefit Analysis using Ofgem guidance for their value,
- Consideration of losses in network design including optimised voltage, locating substations near load, and optimisation of normal open points,
- Use of suitable cable sizes
- Installation of low loss equipment, including proactive replacement of high loss equipment in some cases
- Adoption of EU Eco design transformer specifications

Consideration of losses in regulatory approaches reflects their importance due to their impact on carbon and their cost to customers. However, an economic balance must be found because the cost of traditional network adaptations to reduce losses is also ultimately paid for by customers. This balance must be reflected in the approaches driven by regulation and taken by DNOs to manage losses. Future regulatory approaches to losses need to reflect the ability of the DNO to manage losses and the impacts on losses outside of DNO control.

DNOs are only expected to be able to optimise future losses since reducing losses will not be possible when the amount of supplied energy is predicted to increase. Absolute losses have been shown in the studies to increase when the energy delivered to customers increases.

Customers’ use of energy is not within the direct control of the DNO and consequently this significant dependency of losses cannot be totally managed by the DNOs. The results of this study indicate how losses are significantly affected by how much, when and where customers use electrical energy. These customers’
actions are outside DNO control and are largely driven by societal development including environmental issues which are also affected by governmental decisions.

Any future regulatory approach to losses must be cognisant of contradicting LCT connection incentives. LCT connections have been shown in these studies to increase losses and so a regulatory approach that penalises increased losses could potentially conflict with low carbon incentives which are necessary to meet environmental targets and protect our planet. Examination of the value assigned to losses associated with low carbon connections may be appropriate.

The complexity and dependencies of losses highlighted by these studies may point in the direction of considering the impact of LCTs and distributed renewable generation in a different way and there may be a need to consider the sources of losses. Particular factors for consideration of the development of future regulatory approach to losses include;

- Good quality data used to set targets and for reporting
- Consistency of data for target setting and reporting
- Based on factors materially within DNO control and capped / collared accordingly
- Calibrated for factors out-with DNO control to avoid windfall gains / losses

### 6.6 IMPACT ON LOSSES OF THE APPLICATION OF SMART METERS

Studies have shown the sensitivity of losses to the uptake of LCTs and LV generation. These connections will alter network power flows and the consequential actual losses, but apparent losses determined as the difference between energy into and out of the network will also change if the measurement accuracy and evaluation of energy out of the network is affected by the roll out of smart meters.

Approximations are required when evaluating annual apparent losses due to the present use of whole energy meters which are only read periodically. It is necessary to estimate the amount of energy actually delivered during the year because not all whole energy meters are read at the start and end of the year. The availability of smart meters which record electric energy consumption at regular intervals and frequently communicate that information, will eventually reduce the need for approximations in the evaluation of energy out of the network, but not completely until all meters have been replaced. Some assumptions may be necessary if all customers do not have smart meters and because there is likely to be uncertainty about which phase a customer is connected to.

There will be a variable impact on the apparent losses calculated during the transition to smart meters depending upon the deployment rate. Smart meter benefits for the evaluation of losses will depend upon the penetration of smart meters, with the maximum benefit only coming from total or high levels of penetration. Although the Department for Business, Energy and Industrial Strategy have said that smart meter installations are aligned with expectations⁴, it is noted that there are presently very few SMETS2 meters installed beyond trial sites⁵.

Although smart meters will change the nature of LV demand measurements and provide greater visibility of network power flows, understanding of where losses are occurring could be limited by the aggregation of smart meter data that will be necessary because the Data Protection Act (1998) prevents seeing individual customer information.

Smart meters may also change actual losses if they consume energy which is not recorded by the meter and affect calculated apparent losses if they are of a different accuracy than the whole energy meters they replace.

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Smart meters could facilitate time of use tariffs which could influence customer behaviour. Such changes to customer profiles will affect losses, potentially as described in Section 5.3.

Further understanding of the impact of smart meters on the evaluation of losses will only become available after larger numbers have been installed for a considerable time. Experience will also inform the effect on losses of alternative tariff structures facilitated by smart meters, including the time of use tariffs.
7 RECOMMENDATIONS

7.1 DISSEMINATION OF KEY FINDINGS

Key findings of these studies should be disseminated to ensure that future consideration of losses is informed by the arising detailed understanding.

- Key findings should be disseminated to DNOs in order that they can inform best practice for their loss strategies.

- The highlighted sensitivities of losses and expectations that they will be subject to future changes should be communicated and understood by DNOs in order that decision making includes adequate consideration of losses. The increased losses due to the use of smart solutions correspond to an ongoing operational cost and this must be adequately considered in the cost benefit analysis when comparing alternative reinforcement options.

- Ensure that understanding of the impact of low carbon technologies on losses, within the context of the whole story, are communicated to the appropriate national bodies making regulatory and political decisions. In particular, the findings can inform a fair and effective losses incentive mechanism in the next regulatory period RIIO ED2.

- Understanding of the impact on losses of the low carbon transition could inform future losses settlement processes. In particular, the relevant learning includes knowledge that all distributed generation can increase losses when there is an overall export and that there are regional variations in losses.

- Information related to how smart solutions increase losses should be shared with developers so that adequate attention to losses can be given, e.g. incorporation of loss optimisation control algorithms.

7.2 QUESTIONS ARISING

Studies using a time step of less than half an hour may be necessary to determine LV losses, in particular in the sections of the network with fewer customers where there is less diversity. However, for the best results highly detailed consumption profiles for HPs and EVs should be simulated.

The impact on losses of conductor operating temperature should be explored especially as circuit utilisation, associated operating temperature and resistance increases. Conductor resistances have been modelled based on operation at a constant 20 degrees for all studies despite the actual operating temperature varying with ambient temperature and loading. The effect of this approximation will be less significant for traditionally reinforced networks because these circuits operate at lower temperatures because they are typically no more than 50% loaded in order to satisfy security of supply requirements.

However, networks employing smart solutions are likely to be more heavily utilised and operate at greater temperatures, meaning that the approximation due to modelling conductors at a constant 20 degrees will be more inaccurate for this scenario. Similarly, cables with flat power flow profiles will operate at higher temperatures because the cyclic nature of loads presently allows cables to effectively cool down when the current flow is lower.

7.3 FURTHER CONSIDERATIONS

Regulatory approach

Feasible and practicable mechanisms for maintaining the appropriate focus on losses should be considered for application in future regulatory approaches. Due consideration should be given to the sensitivities of losses and their dependencies on uncertain parameters highlighted by the studies.

Smart meters
The impact of the roll out of smart meters on calculated losses should be considered, particularly in terms of the implementation of a loss incentive based on the application of measurements. Previously it was possible to compare annual losses with confidence because they were evaluated in the same way and the components of the calculation were measured using the same standard of metering. Installing more smart meters will mean that the form of metering and the evaluation of losses will change from year to year giving rise to differences between annual loss results. Such differences may distort a regulatory loss incentive because the difference between annual loss values can no longer be totally attributed to changes in network operation alone.

Impact of LCTs

Consideration should be given to the sources of losses, in particular because the connection of LCTs has been shown to increase losses. It may be appropriate to classify and recompense losses associated with LCTs differently. It is most important to address the cost of the lost energy because it will likely be the main future impact as the carbon impact of losses reduces as we move towards lower carbon generation.

Settlement processes

The treatment of losses in the settlement processes should be considered in respect to the impact of the low carbon transition on losses. Suitability of seasonal time of day generic line loss factors needs to be addressed. Study results have highlighted how losses vary between regions and the possibility of applying regional variations in how losses are dealt with in the settlement process should be considered.

The fairness of the treatment of HV and LV generator losses in settlement processes should be considered in the light of the study results. 33kV generation customers are subject to site specific Line Loss Factors which may correspond to either a reduction or increase in network losses, but HV and LV generators are assumed to reduce network losses and they receive related credit as part of settlement. However, these studies have shown that HV and LV generation connections can increase network losses. When generators which actually increase losses are incorrectly credited with reducing losses, all other demand customers have to unfairly pay more to compensate for the over payment to the generator.

Evaluation of Losses

Advantages of alternative ways of evaluating losses should be considered since losses are likely to increase, become more significant and therefore subject to more scrutiny.

Presently metering is assumed to be perfectly accurate and losses calculated using metered values are accurate as a consequence. It is assumed that the population of domestic metering is so large that the numbers of meters with positive tolerances are balanced with those with negative tolerances meaning that the overall measurement is completely accurate. However, in practice domestic meter accuracies may not even out completely and may vary with any consequential inaccuracy being reflected in a significant tolerance in losses. Alternative approaches for the evaluation of losses could be to simulate losses or use different monitoring to avoid the inaccuracies of settlement metering.