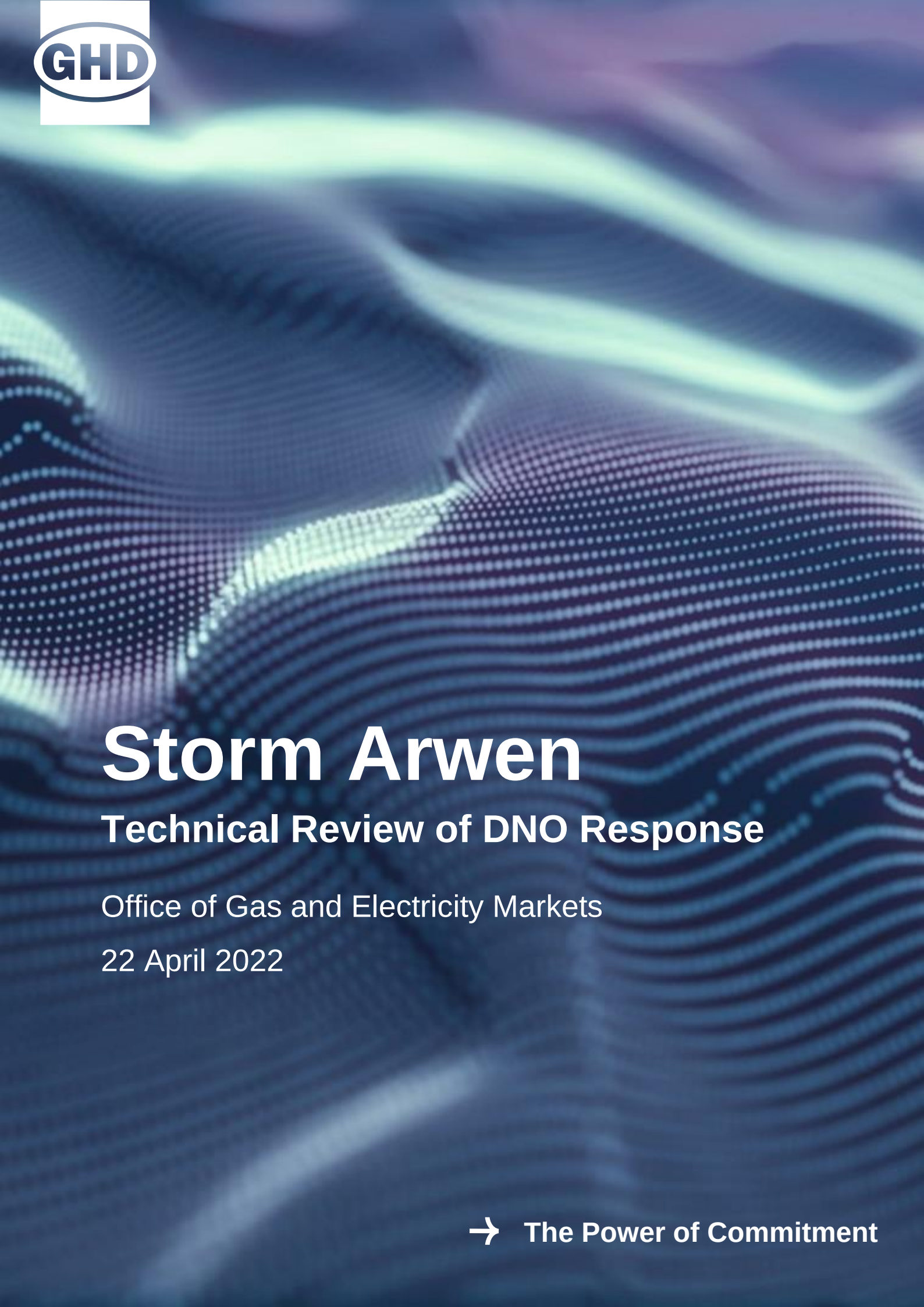

Storm Arwen

Technical Review of DNO Response

Office of Gas and Electricity Markets

22 April 2022

The Power of Commitment

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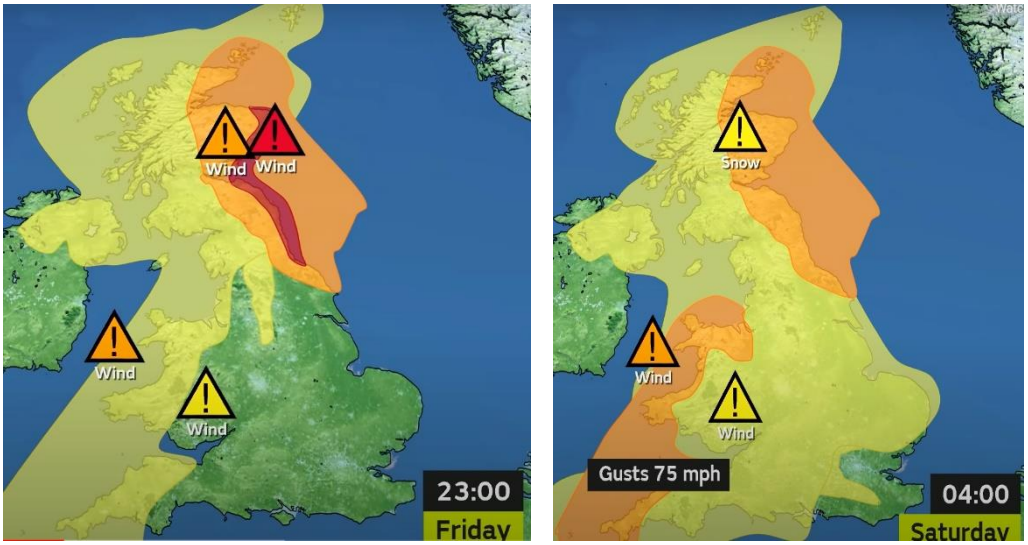
Executive summary

On Thursday 25-November-2021, the Met Office named Storm Arwen and announced an amber wind warning for Northeast Scotland and England for Friday 26-November. Wider yellow warnings were announced for Saturday 26-November for Scotland, Northern Ireland and the west of England and Wales.

Storm forecast

Storm Arwen progressed more severely on Thursday 25-November than forecast, although closely followed the forecast Friday 26-November. On the morning of Friday 26-November, high windspeeds were seen across the north of Scotland, moving down the country as the day progressed. As can be seen in Figure 1. Wind speeds began reaching the high 90 mph in areas of eastern Scotland.

Figure 1: Weekend weather alerts



Source: Met office

By the afternoon of Friday 26-November, windspeed gusts reaching 109 mph were recorded in the northern parts of Scotland. Later, in the evening of Friday 26-November these gusts reduced, however gusts continued through to Saturday 27-November.

In terms of wind speed, the UK has experienced similar storms with winds exceeding 70 mph, for example on 09 February-2020 Storm Ciara recorded winds over 70 mph.

Thousands of trees were felled across the north of the UK, including large mature trees leading to major disruption.[1] One theory[2] is that the wind direction was an unusual northerly as opposed to the more common westerly and this may have been a contributing factor to the loss of trees, as trees show adaptive growth in response to wind movement to counteract the increasing vulnerability to wind.

Customers affected by Storm Arwen

Just under one million homes experienced power loss[3] and over 100,000 homes suffered several days without power. Storm Arwen had the greatest affect in the northern parts of the UK. Four distribution companies (six licence areas) were severely impacted by the storm.

A summary of the number of customers affected is given below.

[1] https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2021/2021_07_storm_arwen.pdf
[2] https://academic.oup.com/treephys/article/16/11-12/891/1663686?login=true
[3] https://www.gov.uk/government/publications/storm-arwen-electricity-distribution-disruption-review/storm-arwen-electricity-distribution-disruption-review-terms-of-reference

Scottish Power Electricity Networks recorded 189,133 interrupted customers across their two licenced areas (Scottish Power Distribution – Scotland, and Scottish Power Manweb – west of England / north Wales). They had restored 87.4 % of the interrupted customers in 24 hours and 99.99% of customers[4] by 29-November. All customers were back on supply by 02-December.

Scottish Power deployed 407 Field Services Engineers from the 26-November rising to a peak of 892 by 01-December. They recorded 1,331 incidents during Storm Arwen. In addition, they deployed up to 311 mobile generators providing temporary supplies in advance of repairs.

This represented a good response both through the first 24 hours and then through the repair phases on subsequent days.

Scottish & Southern Electricity Networks recorded 143,749 customers interruption, with the bulk of the interrupted customers residing in northern Scotland (Scottish Hydro Electricity Power Distribution licence) They had restored all but 54 customers by 03-December, with the final customer restored on 06-December.

Scottish & Southern Electricity Networks deployed 360 Field Services Engineers on the 26-November rising to a peak of 625 by 01-December. They recorded 2,273 incidents across their network and deployed up to 72 mobile generators to provide supplies in advance of repairs.

Given the high number of incidents this was a good response in reducing the customer numbers quickly.

Northern Powergrid had 280,867 customers interrupted across their two licenced areas (Northern Powergrid – Northern and Northern Powergrid – Yorkshire). Northern Powergrid restored 98%[5] of interrupted customers by 30-November, reducing to 39 customers by 06-December and the final customer restored on 08-December.

Northern Powergrid deployed 410 Field Services Engineers on 27-November[6] rising to a peak of 664 by 03-December. This includes an additional 101 NEWSAC resources deployed from the 29-November rising to 196 by 05-December. They recorded 1,246 incidents across the two licenced areas.

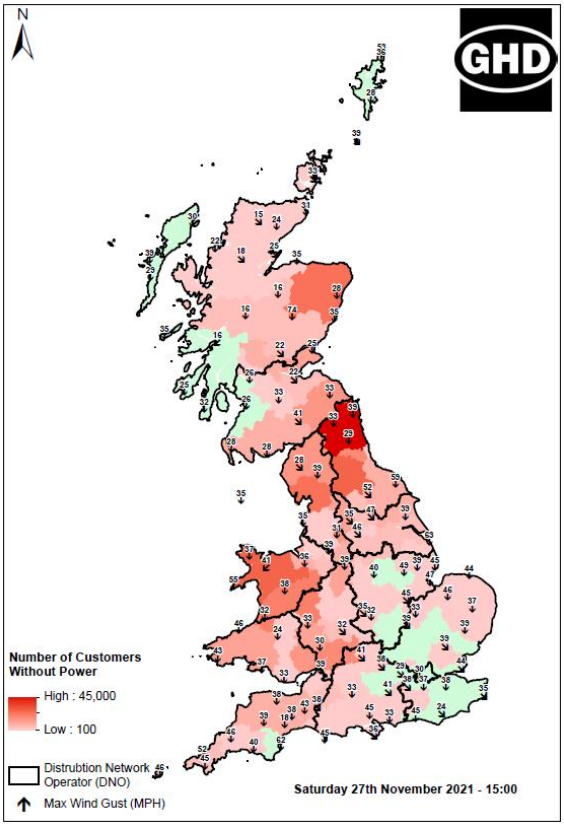
Electricity North West Ltd reported 74,983 interrupted customers for the duration of Storm Arwen dropping to 443 customers off supply by 01-December. All customers were back on supply by 04-December.

Electricity North West had 290 Field Services Engineers deployed by 28-November[7] rising to a peak of 341 by 02-December. This included additional support via NEWSAC, with an additional 122 Field Services Engineers deployed across their licenced area. In total Electricity North West reported 364 incidents across their network and deployed 141 generators to provide supplies in advance of repairs.

Figure 2 shows the number of interrupted customers and their approximate location at the peak of the Storm on Saturday 27-November.

[4] 1,114 customers remained interrupted past 29-November.
[5] 5,717 customers remained interrupted past 30-November.
[6] Northern Powergrid deployed 54 Field Services on Friday 26-November. Storm Arwen affected the north of Scotland early on Friday 26-November and moved south over the day, affecting the north of England on Saturday 27-November. Northern Powergrid did not need to deploy staff large numbers of staff on the Friday
[7] Electricity North West deployed 55 Field Services on Friday 26-November and 149 Field Services on Saturday 27-November. As mentioned earlier Storm Arwen affected the north of Scotland early on Friday 26-November and moved south over the day, affecting the north of England on Saturday 27-November and moving east to west over the day. Electricity North West Ltd did not need to deploy staff large numbers of staff on the Friday and Saturday, but were deploying staff from Saturday 27-November with full deployment on Sunday 28-November.

Figure 2: Saturday 27-November morning wind speed outturn



Source: GHD; Met Office; Ofgem information request presentation 13/01/2022

Two companies were not as severely affected by the storm, UK Power Networks and Western Power Distribution. A summary is below for each of these distribution companies on how Storm Arwen affect their customers.

UK Power Networks were, in the most, unaffected with a total of 19,552 customers interrupted across the three licenced areas. All but 22 customers were reconnected in less than 24 hours, with the final 22 customers resupplied the next day.

Due to the low number of interruptions, UK Power Networks considers the Storm Arwen weekend more akin to a busy day for faults, but not an exceptional event. Over the weekend, UK Power Networks deployed 2 mobile generators, which represents the lower impact the storm had on their network.

Once the severity of Storm Arwen was established, UK Power Networks provided additional Field Services Engineers to the four worst affected distribution network operators.

WPD had the second largest number of customers interrupted due to Storm Arwen of 243,930 customers in total. The damage to the network was not a severe as seen in the north of the UK, and they restored 96.6% of customers within 24 hours. All but one customer was restored by the end of day 3.

Western Power Distribution recorded 1,642 incidents and they were able to resolved these incidents relatively quickly. WPD deployed 65 mobile generators at the peak to restore customers.

After restoring most of their customers, and confidence that Storm Arwen would not cause further damage, Western Power Distribution provided additional Field Services Engineers to the worst affected distribution network business through the NEWSAC arrangement.

Network asset condition

All of network operators, construct, and maintain their overhead line networks to international standards (typically BS EN standards) and industry best practice (Energy Networks Association standards) in force at the time.

Age and condition of poles

All network operators test monitors the condition of their assets via periodic inspections. For this review, we particularly refer to poles.

The condition of wood poles is assessed predominantly for signs of rot at the base and structural damage along its length such as splitting or signs of impact, which obviously reduces the strength of the pole. There is currently no standard site test to ascertain the residual mechanical strength of a pole during its operational lifetime.

Once the test is carried out, the pole is graded on a scale of 1 (new condition) to 5 (deteriorated condition and needs replacing), generally referred to as its Health Index. Poles which are given a health index score of 4 or 5, would typically, but not exclusively, be added to the replacement list.

Condition of the poles affected by Storm Arwen

The distribution companies provided the most recent condition assessment (Health Index scores) of the poles which were damaged during Storm Arwen. The proportion of damaged poles rated at HI4 or HI5, varies between companies with a range of 13 - 38%. There does not appear to be a direct correlation between damaged poles and poles with a HI4 or HI5 condition rating.

Age of the poles affected by Storm Arwen

We also collected data on the absolute age of the damaged poles. We did see that a significant number of damaged poles that were over 40 years old. The percentage of damaged poles varied between companies from 50 - 80%.

The conclusion drawn is that poles aged over 40 years old may be more susceptible to failure in abnormal weather conditions than is currently understood. We do recognise that this is a tenuous link as the network in the areas that were affected would have been constructed around the same time, therefore any failure would have been of a pole of greater than 40 years old.

There is equipment available that can test the residual strength of a pole, which have been trialled under the innovation program, however the use of this equipment is not common or widespread across the UK DNOs.

We do recommend that there is a need to investigate and understand if older poles are more susceptible to failure, and if so, develop the necessary polices to test for these weakened poles.

Fallen trees on to overhead lines

Tree damage to overhead lines is usually where a tree has been uprooted and fallen on to the overhead line. This can cause either a short circuit and the circuit trips, or physical damage where the weight of the tree causes the overhead line conductors to snap or pull the poles / towers down.

With regards to reducing damage due to trees, none of the distribution companies operate a sole cut back policy only that would prevent any tree from touching a line if it were to come down. This would be considered as part of understanding the resilience of the network.

Rather the companies maintain ***Safety Clearances*** as set out in statutory compliance with ESQCR of between 3 – 3.6 m between live conductors and trees. With a typical mature tree height in the UK of between 10 – 20 m, safety clearance requirements do not contribute network resilience during an abnormal weather event.

The ENA produced a voluntary guideline, known as ENA ETR 132, on how to improve network performance under abnormal weather conditions, by adopting a risk-based methodology to identify the most effective locations to carry out additional resilience related activities. It focuses on vegetation management as the first and most important step in improving overhead line resilience and considers the combined effect of high winds and extreme rainfall.

All DNO’s have acknowledged that they embrace resilience philosophy, the overwhelming amount of tree cutting expenditure undertaken by DNO’s is to maintain safety clearances and ensure their statutory compliance with ESQCR, not to ensure that trees are cut back far enough to ensure that they would not touch the line should the tree come down.

A conclusion drawn is that there is a need to explore measures to reduce the impact of interference from trees which would increase ***Network Resilience*** of overhead lines. Options to consider could be greater tree clearance, stronger construction standards, undergrounding and increased automation.

Preparedness and response to Storm Arwen

All companies have emergency plans which are activated for major incidents and commonly for storms. These plans have been developed over many years and includes mechanisms for communications between the companies as the storm progresses.

Preparedness for the storm

All the companies initiated their emergency plans of Storm Arwen landing in the UK. Each distribution company monitors major weather fronts and has access to additional weather information procured from a third party. As reflected in the Met Office notifications of Storm Arwen, knowledge of the storm and its route was forecast.

As part of the emergency plan activation, non-essential work and maintenance is suspended and Field Services teams go into a standby mode. For some distribution companies, who use contractors, these contractors are also placed on standby.

From our review, this occurred in a timely manner and the distribution companies were ready and prepared, as much as is possible for Storm Arwen.

Following activation of an emergency plan, all the companies review their response and look for ways to improve their emergency planning and response. Following Storm Arwen, it was apparent that there were different approaches to responding to the event. This review of all companies gives a national perspective comparing approaches and impacts which should form an integral part of the company reviews and improvement plans.

Response to Storm Arwen

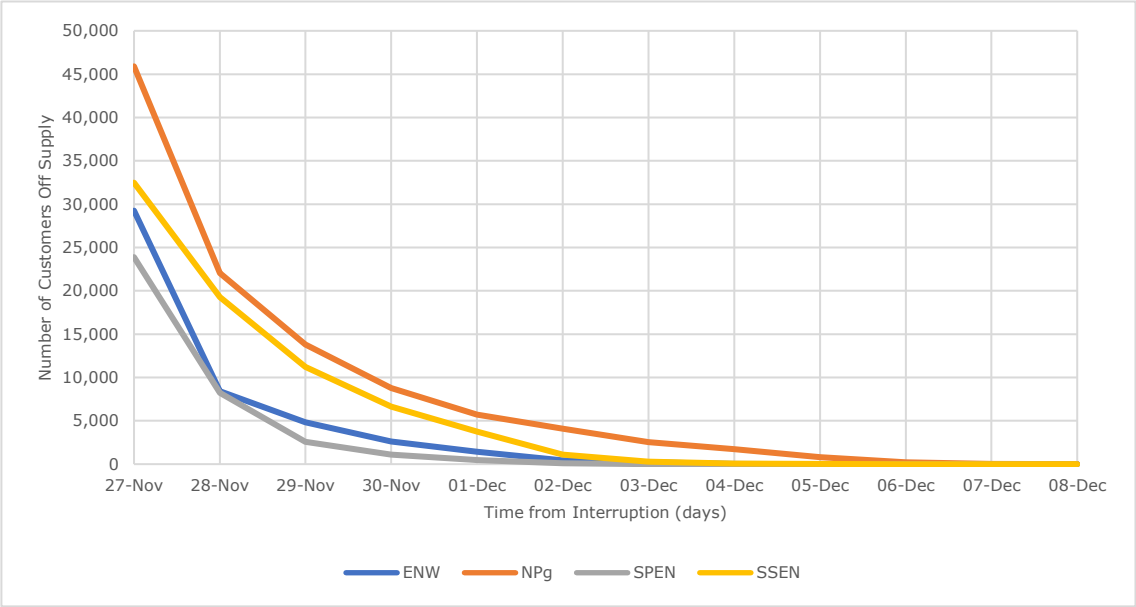
The response to the storm can be assessed through the impact of number of incidents and customers affected and the time to restore both initially and how long till the last customers were restored.

The total number of customers affected was over 950,000 with Northern Powergrid and Western Power Distribution having approximately 55% of the customers interrupted at 280,867 and 243,930 respectively.

In relation to long term interruptions, Northern Powergrid had the 2,537 customers off supply after 7 days and restored the last customer on day 12. Scottish and Southern, who had 143,749 customers off supply, had 299 customers off supply at day 7, and restored the final customers by day 11.

Figure 3 below shows the number of customers off supply for the four most affected distribution companies.

Figure 3 The restoration phase from 27th November after the first 24 hours



Source: Ofgem information request presentation 13/01/2022

It is worth recognising that restoration of customers will be affected by a multitude of factors, including the extent of the damage, the ability for the distribution companies to affect repairs in the form of accessing the damage, prioritization of faults.

However, with that in mind, the data clearly shows that Northern Powergrid suffered the greatest impact in terms of interruptions and also took the longest to resupply all customers.

Mobile generators

One option to reduce the effect of an interruption on a customer is to connect a mobile generator. WPD showed a rapid rise in generator connections to 85 by 28-November, reducing rapidly with all customers restored. ENWL utilised 141 and Scottish and Southern utilised 72 and Northern Powergrid utilised 208.

The DNOs all utilised mobile generation across their networks.

Reported damage caused by Storm Arwen

The primary cause of faults was wind and gales (excluding windborne material) responsible for 68% of all customer interruptions across all the distribution companies. 9% was due to falling trees, 6% snow sleet and blizzard, and 1% classed as windborne material e.g. tree branches[8].

The initial reports suggested that falling trees and windborne material were a significant contributor to the major faults, however this is not borne out in the damage reports supplied by the distribution companies. At this stage we recognise that all the data has not been processed, but all the distribution companies confirmed that they did not expect that primary cause of faults to change significantly.

The initial reports also indicated that ice build-up (ice accretion) on the overhead line conductors was a major factor in customer interruptions, however, again this has not reflected in the damage reports.

The significance of the classification is that if the fault was due to trees and windborne material, then it infers tree clearances is a principal area to address to improve reliability. However, if the damage was due to wind alone on the overhead lines, then it would suggest the design standard could be a factor.

Notwithstanding that, there is evidence of some damage being caused by trees falling, but a substantial number of poles that did fail, were in open areas unaffected by trees and vegetation.

[8] The remaining 14% related to over 10 different fault causes, which were not necessarily attributable to Storm Arwen. That is on any given day, the distribution companies will be managing several faults as part of their normal process.

Our conclusion circles around again that the failure of poles was a contributing factor to the interruptions and understanding the failure mode and the root cause of failure of these poles would lead to improved monitoring or testing.

Mutual aid via NEWSAC

The NEWSAC mechanism was implemented by the four affected distribution business, those party to the mechanism provided staff and the general view from all parties is that it worked well and it was instrumental in supplying additional resource and reducing interruption times to customers.

Overall, NEWSAC performed well and provided additional operational skills in a timely fashion.

Communications

The network operators reported that there were issues with communications between their field services teams and control, especially with the use of mobile phones. Mobile phone service were limited in some areas, the network operators have other modes of communication which they utilised. This ranged from telecoms systems installed in the substations to radio systems. Overall, the lack of mobile phone coverage was limited to certain areas and there were alternatives available.

The loss of communications from mobile phone masts affected customers communicating with the company more than within the companies themselves. This meant that customers were not able to report loss of power, which is a mechanism used by the network operators to identify faults. So, some customer outages may be longer if they are not able to notify the network operator.

The resilience of the operation of the masts is an issue that will require further investigation to determine how that resilience can be provide either by supply security improvement from the distributor or having back up supplies on site provided by the mobile phone companies. Either approach will involve costs which will need to be built into the current funding mechanisms. We understand this will become a bigger issue when BT switches off the entire PSTN network as planned in 2025.

Summary of recommendations

A Summary of the findings of this review are given below.

– We collected data on the absolute age of the damaged poles, and we did see that between 50% and 80% of damaged poles that were over 40 years old. The conclusion drawn is that poles aged over 40 years old may be more susceptible to failure than is currently understood. We do recommend that there is a need to investigate and understand if older poles are more susceptible to failure, and if so, develop the necessary polices to test for these weakened poles.
– The data indicates that NPg and SSEN licences have the lowest level of spend per pole in clearance activity. Although there are significant differences, this may reflect that expenditure in this category has not been correctly assigned, thus leading to apparent overspend. We would recommend that this area is reviewed in more detail to clarify how the expenditure is being allocated.
– NPg had 1,246 incidents and restored 83.7% within 24 hours. The slower restoration over subsequent days with 4,094 customers remaining off supply after 6 days at which point all other companies combined had 1,651 off supply indicates a much slower response in restoring supplies and would represent the period where the effective application of the resources phase of the emergency plan was influencing progress. It would suggest that in the post event review the focus in NPg should be on that area to identify improvement plans.
– The loss of communications from mobile phone masts affected customers communicating with the company more than within the companies themselves. This meant that customers were not able to report loss of power, which is a mechanism used by the network operators to identify faults. We would recommend that this is reviewed in a larger context to determine how that resilience can be provide either by supply security improvement from the distributor or having back up supplies on site provided by the mobile phone companies. We understand this will become a bigger issue when BT switches off the entire PSTN network as planned in 2025

Contents

1. Introduction

This section provides background to this report and outlines the scope and limitations.

1.1 Purpose of this report

This report sets out an independent assessment of the preparedness of the electricity distribution network operators and their response to restoring customers following Storm Arwen which affected the UK from Friday 26-November-2021 until Monday 29-November-2021.

This report has been commissioned by Ofgem and was undertaken in January-2022.

1.2 Background to this study

This study has been commissioned by Ofgem following Storm Arwen and investigates how the electricity distribution network operators prepared for the storm and their restoration performance in areas that experienced significant disruption. This study examines two areas, namely:

Examining factors largely within the network operated control such as

– Asset condition;
– Maintenance practices;
– Tree cutting procedures;
– Network investment;
– Personnel resourcing and mutual aid;
– Storm preparedness plans;
– Temporary generation plans and usage;
– Damage assessment procedures;
– Deployment of resources to effect repairs; and
– Implementation of lessons learned from previous major storms.

Factors out with the network operators' control, such as;

– The weather with respect to the forecasts of Storm Arwen; and
– Resilience of communications systems with regards to restoration efforts and providing information.

Our approach is to review these factors in a logical sequence, starting with the areas which are long term strategies or procedures. They will be in place in advance of any major event or storm, they influence the outcome of the storm. For example, asset condition and tree cutting procedures.

Following this review of the long-term practices, we have reviewed the actions just prior, during and immediately after the storm. We know that all the network operators have major incident plans, this review will examine how those plans and procedures were put into place. This aspect also includes mutual aid amongst the network operators.

1.3 Parallel studies and investigations

In parallel with this study, two additional reviews have been conducted.

1.3.1 BEIS investigation into preparedness of utilities to Storm Arwen

Shortly following Storm Arwen, the Department for Business, Energy and Industrial Strategy (BEIS) and Ofgem placed a request to the network operators for information regarding performance of the businesses during the storm. The data request covered a variety of areas, and an abridged list is provided below.

- Information on the condition of the assets, mainly wood poles, that were affected by the storm.
- Data regarding customers who were off supply including number and duration.
- Operational data relating to number of staff active during the storm including those brought in from other businesses.
- Usage of temporary generation

GHD was provided access to this data, as mentioned in Section 0. Whilst GHD has concentrated on the technical aspects of the electricity distribution network operator's preparedness and activities during Storm Arwen, BEIS has conducted a wider reaching investigation into overall preparedness of utility businesses.

1.3.2 Ofgem Interim report on the review into the networks' response to Storm Arwen

Ofgem has undertaken a wider investigation into the preparedness and actions of the electricity distribution network operators and provide a factual account of Storm Arwen's impact on the electricity network and its customers, and how all the electricity distribution network companies responded to the event. Data was obtained from information through site visits, meetings with each company, information requests, correspondence from affected customers and MPs who wrote on their behalf.

Based on this review Ofgem wanted to explore some issues further. These are:

Companies' investment in network resilience – the data showed that companies are on track to have spent their ED1 allowances, Ofgem wish to explore further how that spend has been targeted.

Customer call abandonment rates – Ofgem want to investigate the availability of phonelines and whether customer enquiries were dealt with in a prompt and efficient manner in accordance with DNOs' licence conditions.

Deployment of generators – DNOs differed in their approaches to deploying generators to temporarily restore customers' power supply. Ofgem want to explore best practice in the use of generators during storm events.

Tree cutting practices – Data showed that DNOs' spending on maintaining vegetation near overhead lines is in line with ED1 allowances, and Ofgem intend to explore further how that spend has been targeted.

Accuracy of estimates time of restoration – Customers' experience of receiving accurate estimates of restoration varied. Ofgem will explore further the extent to which customers received an accurate restoration time and how they were updated when the circumstances changed.

Communication with priority service register customers - DNOs said that they were proactive in contacting Priority Services Register (PSR) customers before and during the incident to provide information and advice. Ofgem will look more closely at the provision of this information in relation to DNOs' licence obligations.

Speed of compensation payments – All DNOs made good progress with paying compensation to customers for whom they had records (most were paid in December). However, it took considerably longer to identify and make payments to customers for whom DNOs do not hold records. Ofgem wish to explore causes of this and any improvements that should be made.

Review of the compensation cap –Ofgem will be examining the compensation cap arrangements and whether they need to be amended for the future potential storm events.

1.4 Scope and limitations

This report: has been prepared by GHD for Office of Gas and Electricity Markets and may only be used and relied on by Office of Gas and Electricity Markets for the purpose agreed between GHD and Office of Gas and Electricity Markets as set out in this report.

GHD otherwise disclaims responsibility to any person other than Office of Gas and Electricity Markets arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

1.5 Approach and methodology

As the timelines for the review were limited, we took a straightforward approach to this review as described below.

In the first stage we reviewed the data provided to BEIS by the Network Operators in December-2021. BEIS placed an information request early in December, where the network operators responded in late December and early January. This was a comprehensive dataset.

To supplement the BEIS data, GHD prepared a questionnaire that focussed on specific areas of interest. The questionnaire is intended to supplement the BEIS data, not duplicate. This means where the network operators had already provided similar data, they were able to point to that data rather than reproduce a similar set. We also focussed on the assets which were affected by Storm Arwen rather than the whole asset portfolio.

GHD's question set focussed on the technical aspects of the preparedness of the network operators and how they performed. The questions focused on:

Asset condition: what was the age and condition of the assets that were affected by Storm Arwen.

Maintenance practices: Were the assets affected by Storm Arwen, up to date with their maintenance practices and routines. Were there any assets that we behind or due maintenance?

Tree cutting procedures: What is the standard tree cutting procedure and were the routes that were affected up to date with tree cutting procedure?

Network investment: Was the business up to date with the expected network investments (i.e. replacement) for those assets affected by the storm?

Personnel resourcing and mutual aid: How many authorised staff were working over the storm period? What request did the business make to other network operators for field services support?

Storm preparedness plans: Were the business major incident plans up to date? When did the business enact (if at all) the major incident event ahead of the storm? What information did the business have access to, prior to the storm?

Temporary generation plans and usage: How many mobile generators were deployed over the storm.

Damage assessment procedures: How did the network operator gather data of the damage that had been caused around their network to inform the business on where to deploy staff and resources?

Deployment of resources to effect repairs: how did the network operator deploy its resources to make repairs, based on the information known at the time?

Implementation of lessons learned from previous major storms: What 'lessons learnt' from prior storms, were in place for this storm?

This report has a corresponding appendix which summarises the data and the findings. This main report provides an overview across the affected network operators.

1.6 Assumptions

This report is based on two data sets: -

– Data set one was supplied by the Department of Business, Energy and Industrial Strategy based on a set of questions sent to the Distribution Network Operators in December-2021 and the response received in late December 2021 and early January 2022.

– Data set two was additional questions raised by GHD and sent to the Distribution Network Operators the week commencing 10-January-2022 with responses received by 21-January-2022.

GHD requested data from the six distribution network operators of England, Wales, and Scotland. We are aware that out of the six network operators, four were severely affected – Northern Powergrid, Electricity North West Ltd, Scottish and Southern (Scotland licenced area); Scottish Power (Scotland and England licence). This report focusses on these four network operators.

We did gather data from UK Power Networks and Western Power Distribution, as mentioned above, these two network operators were not so significantly affected to the extent that UK Power Networks reconnected virtually all customers within 24 hours and Western Power Distribution within 72 hours. Where it is appropriate, we do make mention of the actions of these two network operators.

2. Background to the Industry

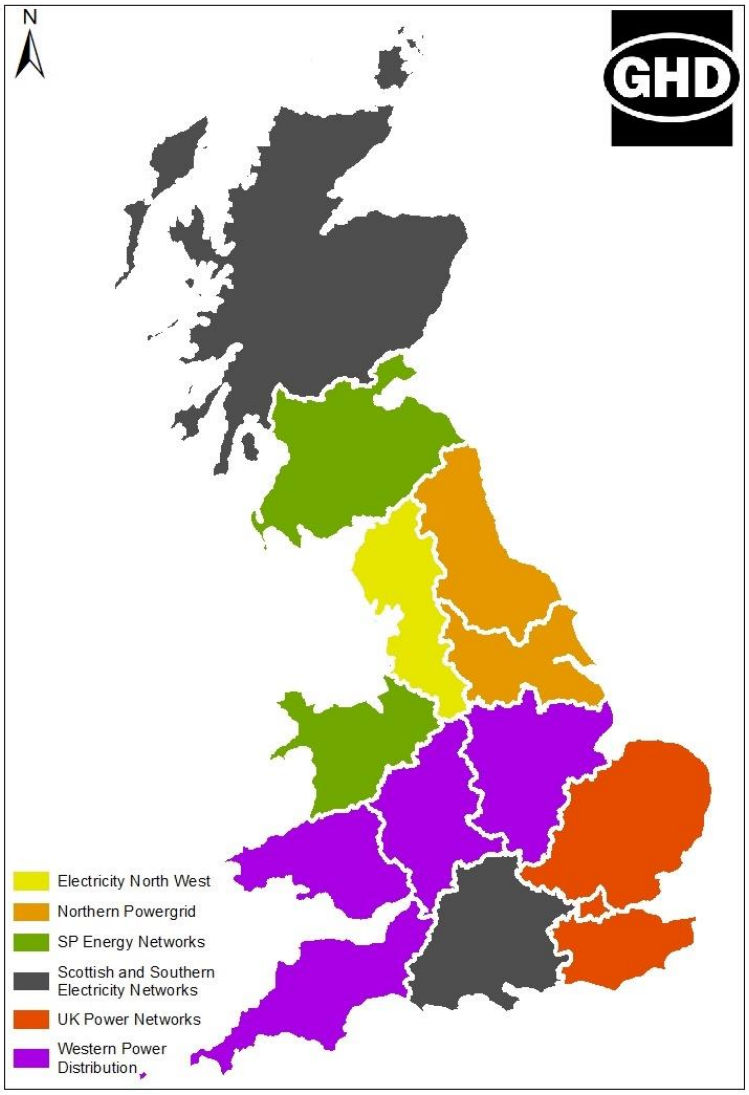
This section provides background on how the electricity distribution networks in the UK are managed an operated.

2.1 Industry structure

The 132kV network and below, in England and Wales and 33kV and below, in Scotland[9] is owned and operated by Distribution Network Operators (DNOs). For completeness, in Scotland the 132kV network is the responsibility of the transmission network operator.

For England, Wales and Scotland, there are 14 licensed areas owned by six companies as shown in Figure 4.

Figure 4: DNOs in England, Wales and Scotland



Source: GHD

Ofgem also licences smaller distribution network operators, known as Independent Distribution Network Operators (IDNOs), who are licensed to develop, operate, and maintain smaller electricity distribution networks. Usually, these networks are directly connected to one of the fourteen DNO networks. IDNOs are regulated in the same way as DNOs, though there are differences in their licence conditions.

[9] For clarity, the UK distribution network operators also include Northern Ireland Electricity Distribution (NIE), however they were not affected by Storm Arwen and are not part of this review. For clarity, NIE are regulated by the Utility Regulator of Northern Ireland, not Ofgem.

2.2 Responsibilities of the Network Operators

The DNO responsibilities stem primarily from The Electricity Act 1989, which sets out the framework for the whole electricity industry. For the purposes of this report, The Electricity Act states that any person involved with the distribution of electricity must be licenced.

Underneath The Electricity Act, any Distributor of electricity is obligated to abide by The *Electricity Supply and Quality and Continuity Regulations*[10] (ESQCR). The ESQCR requires that the Distributor must maintain their network in a safe and reliable manner and take reasonable steps to avoid interruptions to customers supplies.

In reference to Storm Arwen overhead lines were majorly affected, ESQCR has two clauses of relevance:

> *18(5) No overhead line shall, so far as is reasonably practicable, come so close to any building, tree or structure as to cause danger.*

and

> *20(A) A generator or distributor shall, so far as is reasonably practicable, ensure that there is no interference with, or interruption of supply caused by an insufficient clearance between any of his overhead lines and a tree or other vegetation*

The ESQCR is predominantly focussed on ensuring that the Distributors ensure that their assets are operated and managed is a safe manner with regards to the public, not to ensure that they provide resilient network.

For any company to distribute electricity in GB, they must be licensed. In the case of the UK, the licences set out additional requirements more focussed on the business aspects of operating a distribution network. For example, how revenue will be calculated and how the business must conduct itself when it has access to privileged information.

A key part of the Licence is the *Standard Licence Conditions*[11] which places the holder of the Distribution Licence, in this case the DNOs a financial obligation to deliver a network that is efficient and economical to all Users of that network. This includes the requirement to offer a connection to any person who requests a connection.

Part of the Licence is a requirement for the network operator to set out how it will manage new connections, how they will operate the network, what information will be available to other Users of the network, and this is captured in the *Distribution Code*[12] that is owned and written by all the DNOs. The Distribution Code sets out all technical aspects relating to connections, operation and use of the Distribution System. This also sets out how the DNO will operate its electrical plant and apparatus.

To summarise, the DNO is obligated to ensure that their network is managed and operated in a safe manner when members of the public are concerned. In addition, they are further required to build, design, and operate an efficient, reliable, and resilient network now and in the future for all Users of the network.

2.2.1 The Energy Networks Association

Not surprisingly, there are a multitude of standards and specifications relating to specific equipment that the DNO installs on to its network. Many of the standards for distribution networks are managed in a collective forum via the Energy Networks Association (ENA). The ENA has a wider remit than electricity distribution and standards and guidelines, but for the purposes of this report, we have focussed on these two areas.

The ENA provides a collective function for creating and managing standards for a wide-ranging number of functions that the DNO undertakes. As an example, this includes technical specifications for switchgear, or operational standards for establishing tree cutting distances. These standards and specifications consider British design standards and international standards. The context is to provide a consistent approach across the UK network operators that is also in line with international standards.

[10] Electricity Safety, Quality and Continuity Regulations 2002
[11] Electricity Act 1989 Standard conditions of the Electricity Distribution Licence
[12] The Distribution Code of Licenced Distribution Network Operators of Great Britain

In the case of major disruptive events, like storms, the ENA has worked with members, the government and Ofgem, facilitating cooperation between the network operators to ensure resilience of the energy networks is maintained and, where necessary, improved.

This has been achieved through various programmes, which two are mentioned below.

Emergency planning member groups: The ENA facilitates two major forums for its members. The Emergency Planning Managers' Forum and the Resilience and Emergency Coordination Group. Where network resilience and emergency planning initiatives are discussed and shared amongst its members. This has led to the development of guidelines, for example, ETR 132 - Improving resilience of overhead networks under abnormal weather conditions using a risk-based methodology[13]. Which is a voluntary guideline pertinent to this report.

NEWSAC: The Northern, Eastern Western and Southern Area Consortium (NEWSAC) agreement details the application and co-ordination of mutual aid between network operators in the United Kingdom, Ireland, and the Isle of Man during and after network electricity supply emergencies, for example major storms.

Mutual aid includes the transfer of field resources and supplies between network operators in the United Kingdom, Ireland, and the Isle of Man (including National Grid).

The ENA facilitates the review of this agreement with regular six-monthly meetings and consider any learning points from winter events and the autumn meeting is an opportunity to prepare for the winter ahead.

2.3 Responsibilities of Ofgem

The Office of Gas and Electricity Markets (Ofgem) is the independent energy regulator for Great Britain. They operate in a statutory framework set by Parliament and are governed by Gas and Electricity Markets Authority (GEMA).

Ofgem's primary role is to protect energy consumers, especially vulnerable people, by ensuring that they are treated fairly. This includes setting price caps for energy supplies, and in relation to distribution network operators the amount of revenue that the DNO can collect. This is done on a longer cyclic basis known as Price Control with the current Price Control being RIIO-ED1[14] commenced in 01-April-2015 and concludes on 31-March-2023.

The allowed revenue enables the DNOs to provide, plan, build, reinforce and maintain their electricity distribution network that meets acceptable:

– levels of reliability and security;
– safety and technical standards; and
– is efficient and sustainable over the longer term.

Ofgem monitor the DNOs performance against several network reliability targets designed to benefit the customer. Guaranteed standards of performance (GSOP) require DNOs, under certain circumstances, to make a payment to individual customers if their supply is interrupted.

In this context the incentive to the DNOs in the event of severe weather conditions is to have the capability to restore supplies quickly and efficiently.

[13] Engineering Technical Report 132; Improving resilience of overhead networks under abnormal weather conditions using a risk based methodology; Issue 2; August 2016.
[14] Further details can be found about RIIO-ED1 at www.ofgem.gov.uk/network-regulation-–-riio-model/riio-ed1-price-control

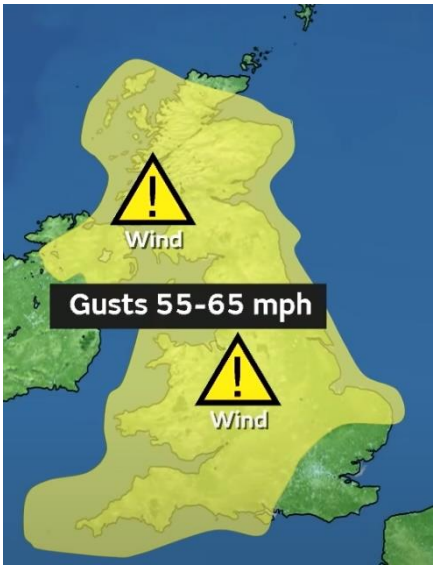
3. Background to Storm Arwen

This section provides an overview of the storm as it swept through the UK.

3.1 Timeline of the storm forecast

On Thursday 25-November-2021, the Met Office named Storm Arwen and announced an amber wind warning for northeast Scotland and England with wider yellow warnings in place for Friday 26-November for Scotland, Northern Ireland and the west of England and Wales, excluding the southeast on Saturday. As shown in Figure 5 below.

Figure 5: UK wide wind warning – Thursday 25-November



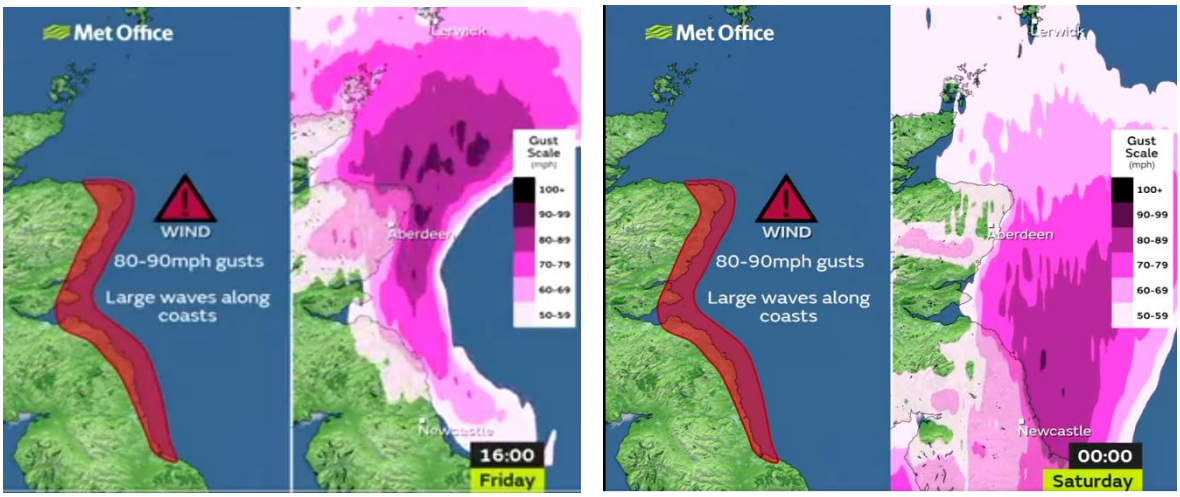
Source: Met Office

The weather warning predicted the strongest winds to be expected in costal locations with gusts in excess of 75 mph. The Met Office predicted that there would be a deep low-pressure system that would impact the northeast from Friday 26-November but would also bring wider impacts to the UK with high winds, rain, and some snow probable over the high ground[15].

On Friday 26-November, a rare red weather warning for coastal areas in the northeast of the UK was announced with wind gusts expected in excess of 80 mph, shown in Figure 6. The red warning was embedded within a wider amber wind warning for the northeast, southwest and northwest of the UK[16].

[15] https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2021/storm-arwen-named
[16] https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2021/rare-red-warning-issued-for-storm-arwen

Figure 6: Friday 26-November and Saturday 27-November red weather warning



Source: Met Office

On Saturday 27-November, the Met Office announced that Storm Arwen was abating with winds gradually easing, having recorded the top lowland gust at Brizlee Wood in Northumberland at 98 mph[17].

Some of the worst impacted areas included Aberdeenshire, Angus, Perthshire and the Moray coast. At this point there were still several severe weather warnings in force across the UK, these however had been downgraded to yellow wind warnings covering most of the UK until 6 pm on Saturday 27-November. As can be seen in Figure 7 the low-pressure system was forecast to progress across the UK over Friday 26-November and Saturday 27-November.

Figure 7: Storm Arwen prediction from Met Office weather forecast 26, 27 and 28-November

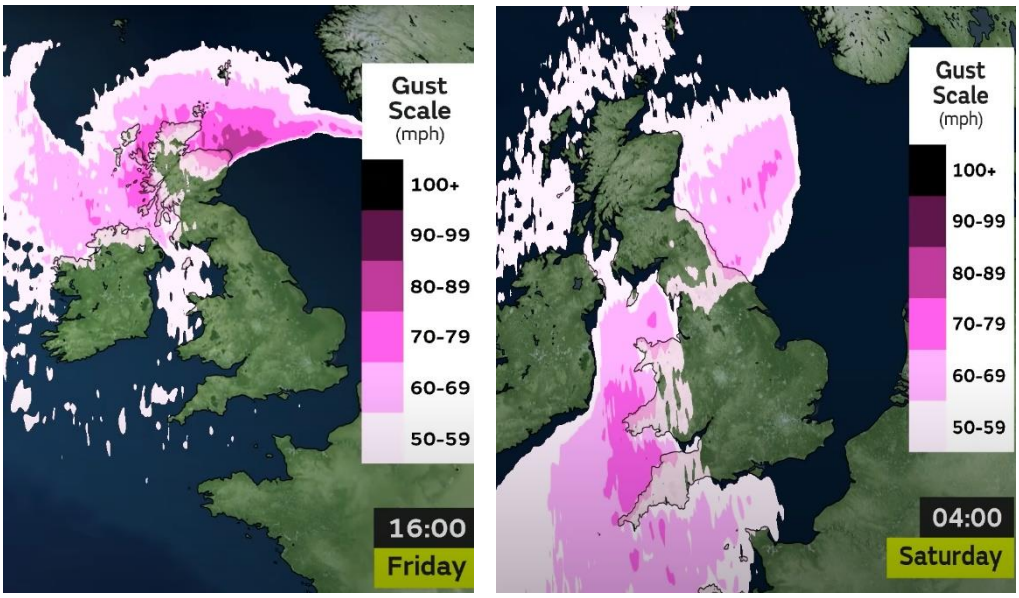
Source: Met Office

High windspeeds were predicted across the UK in the Met office's Thursday 25-November weather forecast, these were predicted to move from the east to the west of the UK over the weekend, with the highest windspeeds hitting the east coastal regions of the UK, particularly in the northeast of England and east of Scotland.

These high windspeeds were predicted to reach a yellow wind warning which can be seen in Figure 8. A Yellow warning was issued for a range of weather situations and associated impact levels and likelihoods, and many are issued when it is likely that the weather will cause some low-level impacts, including some disruption to travel in a few places.

[17] https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2021/storm-arwen-now-starting-to-abate

Figure 8: Met office forecast – wind speed – Friday 26-November and Saturday 27-November

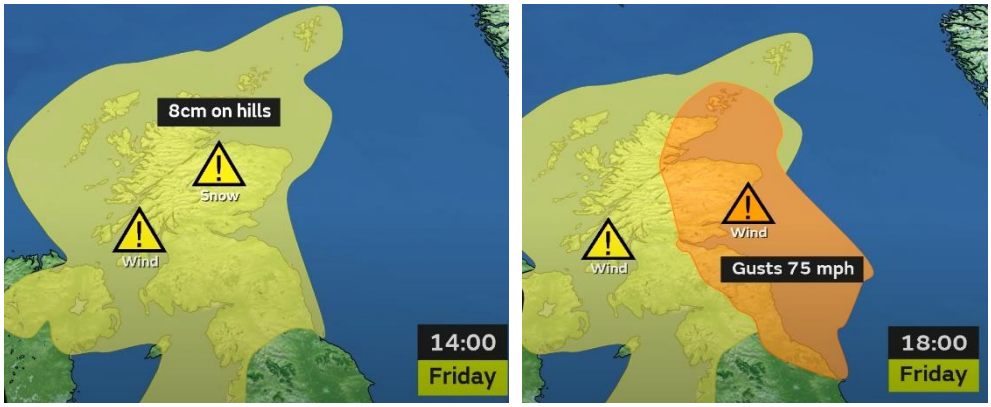


Source: Met Office

Along with the yellow weather warning covering most of the UK, the met office also predicted an amber wind warning for the east coast of Scotland and the northeast of England on Friday 26-November as can be seen in Figure 9. An amber weather warning indicates that there is an increased likelihood of impacts from severe weather which could disrupt plans.

This means there is the possibility of travel delays, road and rail closures, power cuts and the potential risk to life and property. It is at an amber weather warning that it is suggested people should consider changing their plans to take action to protect themselves and their property.

Figure 9: Weather warning Friday yellow and amber – 26-November

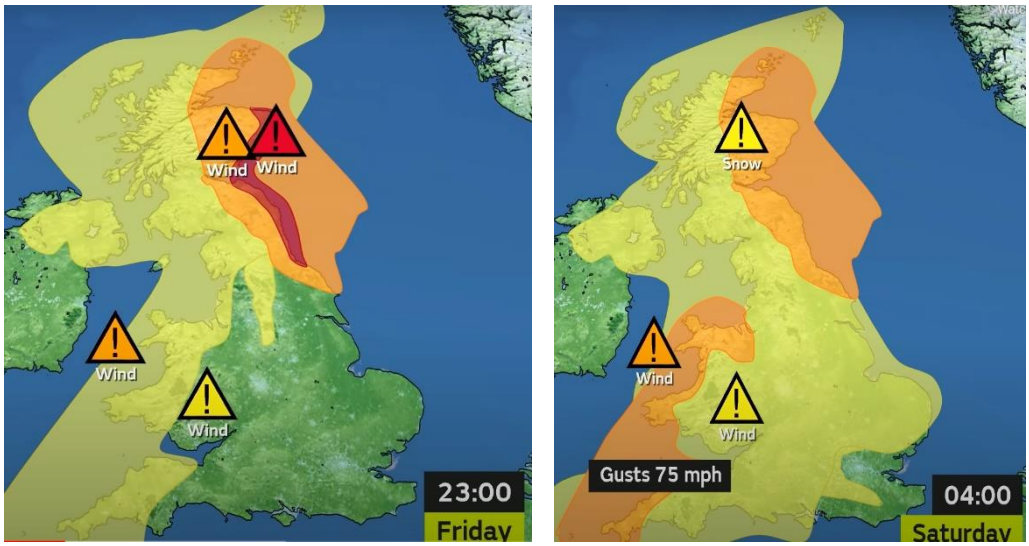


Source: Met Office

On Friday 26-November, a red weather warning was announced for the coastal areas in the northeast of the UK. Red weather warnings are announced when dangerous weather is expected and at this point if action to protect individuals and property hasn't been taken it should be now. It suggests it is very likely that there will be a risk to life, with substantial disruption to travel, energy supplies and possibly widespread damage to property and infrastructure.

The red weather warning announced on Saturday 27-November which can be seen in Figure 10 was predicted to commence on Friday 26-November at 23:00 and to last until the morning of Saturday 27-November.

Figure 10: Red warning weather alerts Friday 26-November and Saturday 27-November



Source: Met Office

Storm Arwen was an exceptionally severe storm, not without precedent in recent decades, but with some unusual features. This was relatively unusual; the normal prevailing wind direction for the UK, including for the majority of major Atlantic storms, being westerly.

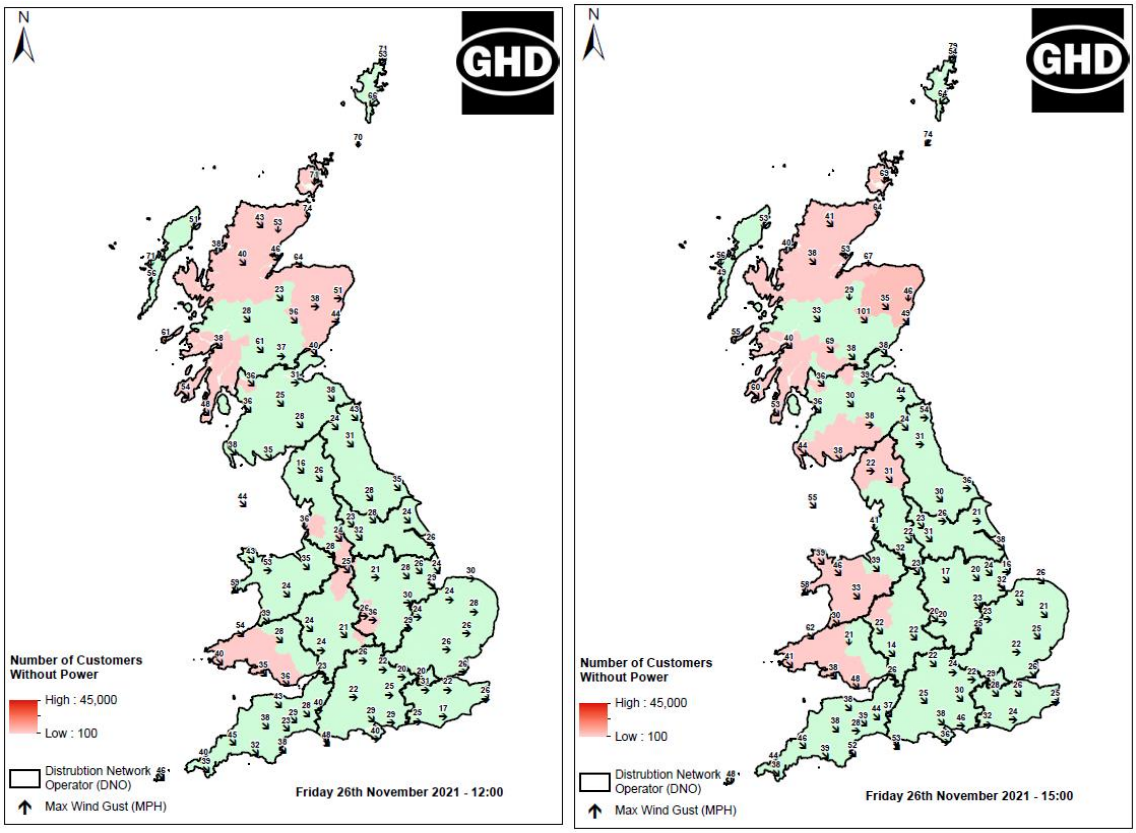
3.2 Weather outturn

The weather outturn of Storm Arwen progressed slightly more severely than the initial Thursday 25-November forecasts, although more closely aligned to the forecast given on Friday 26-November.

On the morning of Friday 26-November, the beginnings of the high windspeeds of Storm Arwen began. As can be seen in Figure 11, high wind speeds were occurring by 9am and began reaching the high 90 mph's in areas of Eastern Scotland. These high windspeeds, were in conjunction with the beginnings of customer supply loss. Initially most of these customer outages covered Scottish regions, with some mid England and southern Wales, however progressing through to midday on Friday 26-November and Wales had also experienced some losses.

By the afternoon of Friday 26-November, higher levels of customers off supply were beginning as can be seen in Figure 11. This was mainly around Eastern Scotland, and at this point were accompanied with windspeed gusts reaching 109 mph.

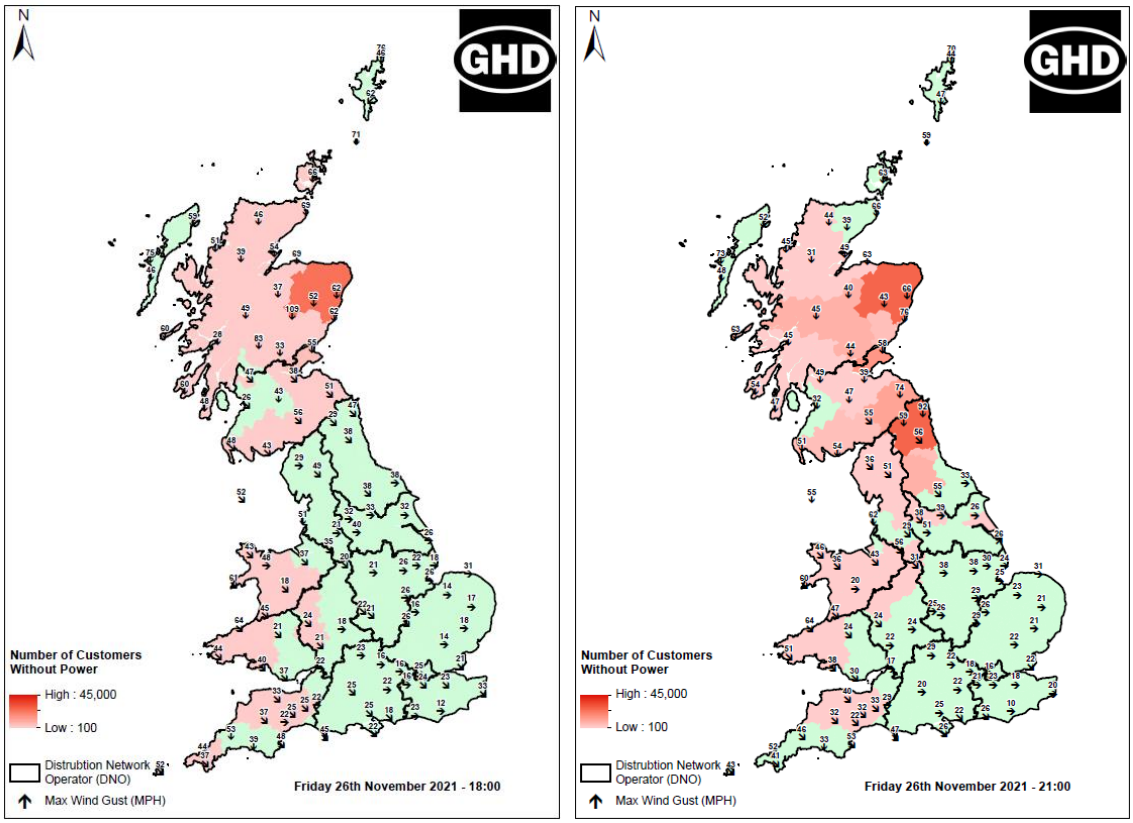
Figure 11: Friday 26-November morning and afternoon wind speed outturn



Source: GHD analysis and presentation of Met Office; Ofgem information request presentation 13/01/2022

Later, in the evening of Friday 26-November these gusts reduced, however more customers lost supply, notably within the northeast of England region and across southern Scotland, as can be seen in Figure 12.

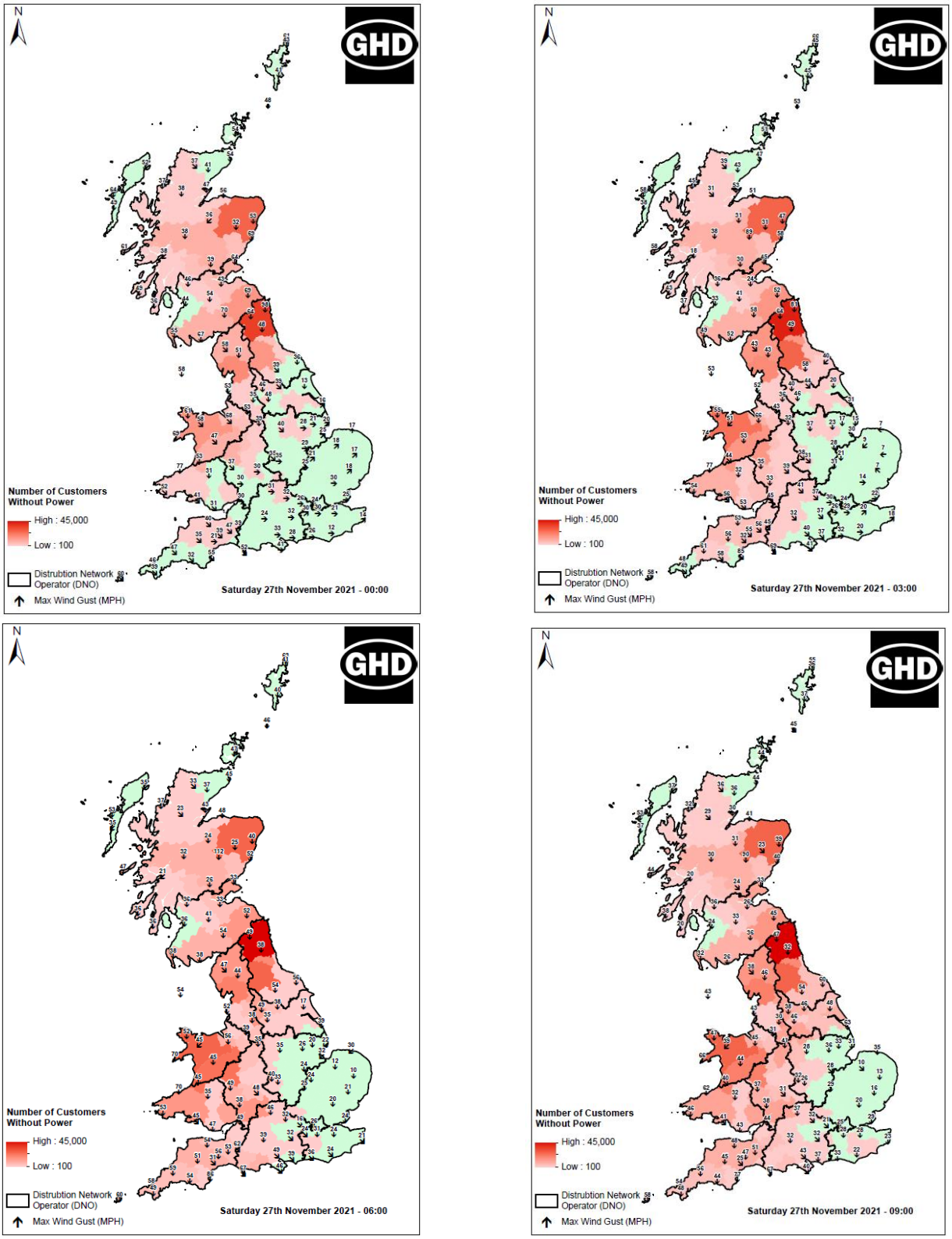
Figure 12: Friday 26-November evening wind speed outturn



Source: GHD analysis and presentation of Met Office; Ofgem information request presentation 13/01/2022

By the early hours of Saturday 27-November, the storm impact on customer supply had increased, with higher numbers of customers off supply which is particularly notable within the north of England and north of Wales. The beginning of storm impact across the southwest of England can be seen in Figure 13, and high early morning wind speeds.

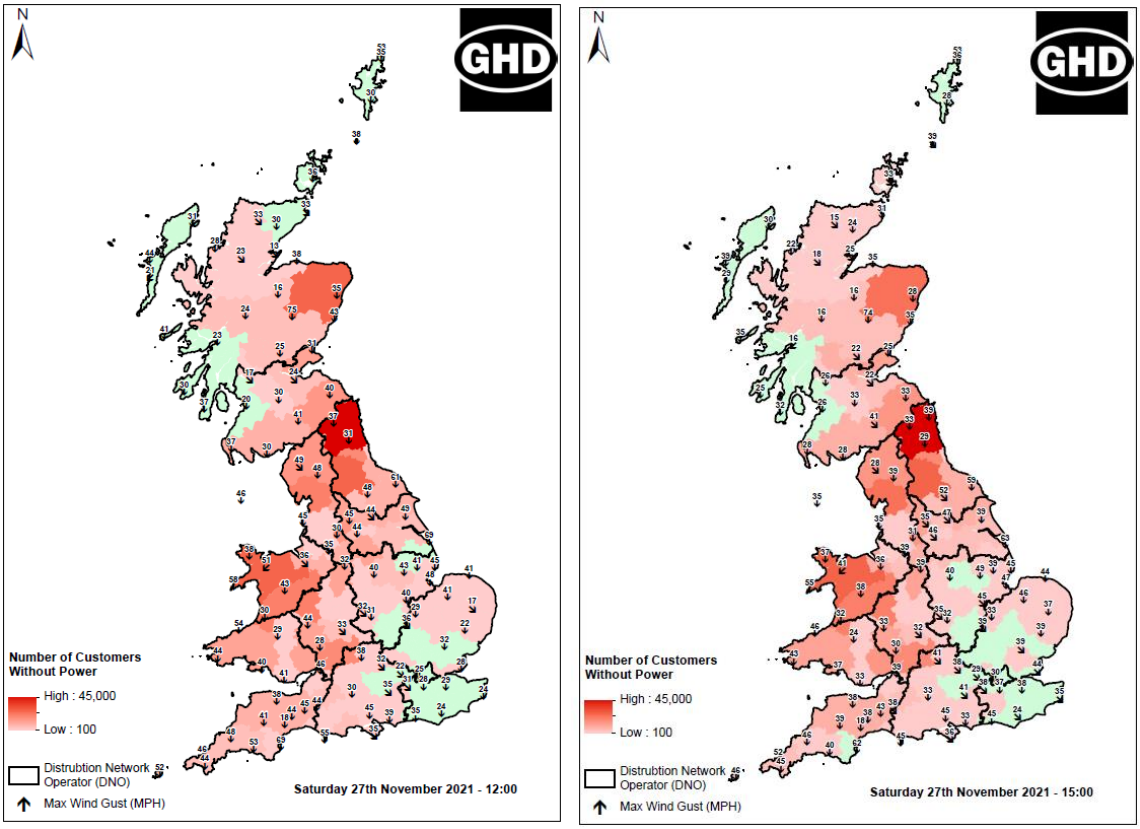
Figure 13: Saturday 27-November morning wind speed outturn



Source: GHD analysis and presentation of Met Office; Ofgem information request presentation 13/01/2022

As can be seen in Figure 14, high windspeeds were sustained throughout the afternoon of Saturday 27-November, however these were not as high (in general) as the original windspeeds shown on Friday evening.

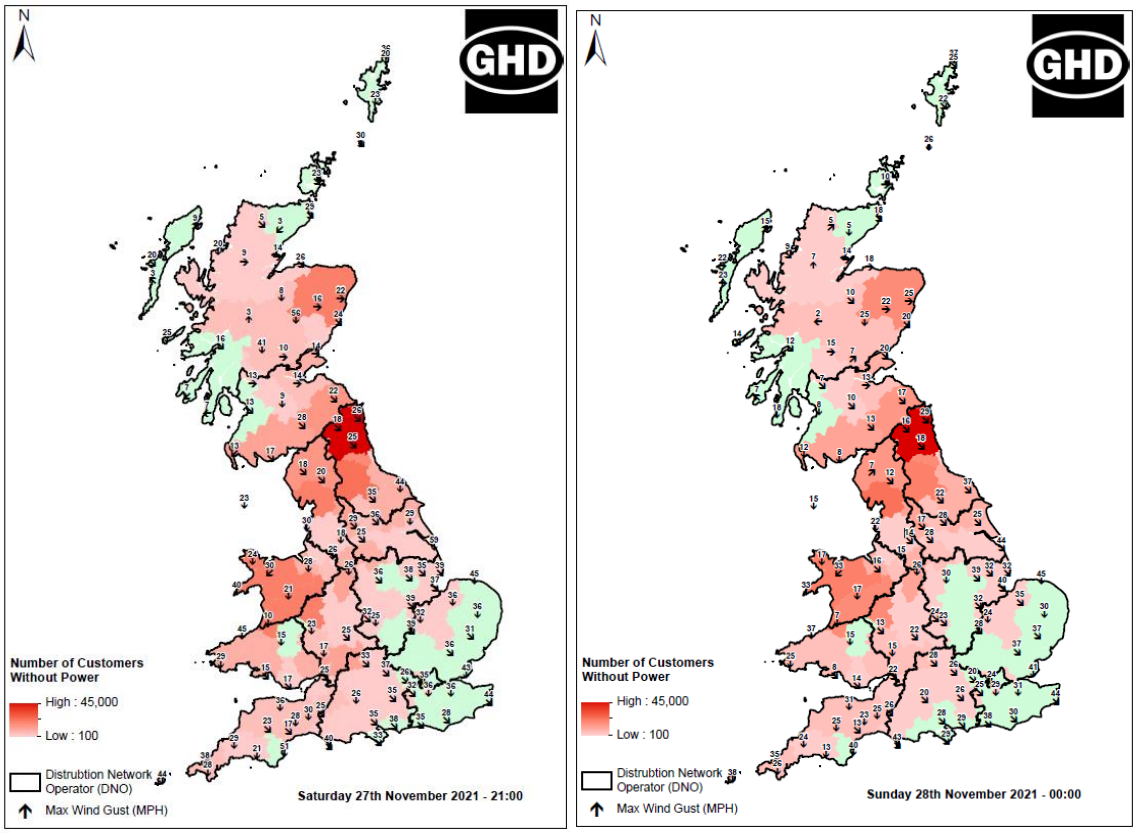
Figure 14: Saturday 27-November afternoon wind speed outturn



Source: GHD analysis and presentation of Met Office; Ofgem information request presentation 13/01/2022

Many customers remained off supply. By late Saturday 27-November and moving in to Sunday 28-November, the wind speeds were high, but consistent across northern parts of the UK as shown in Figure 15.

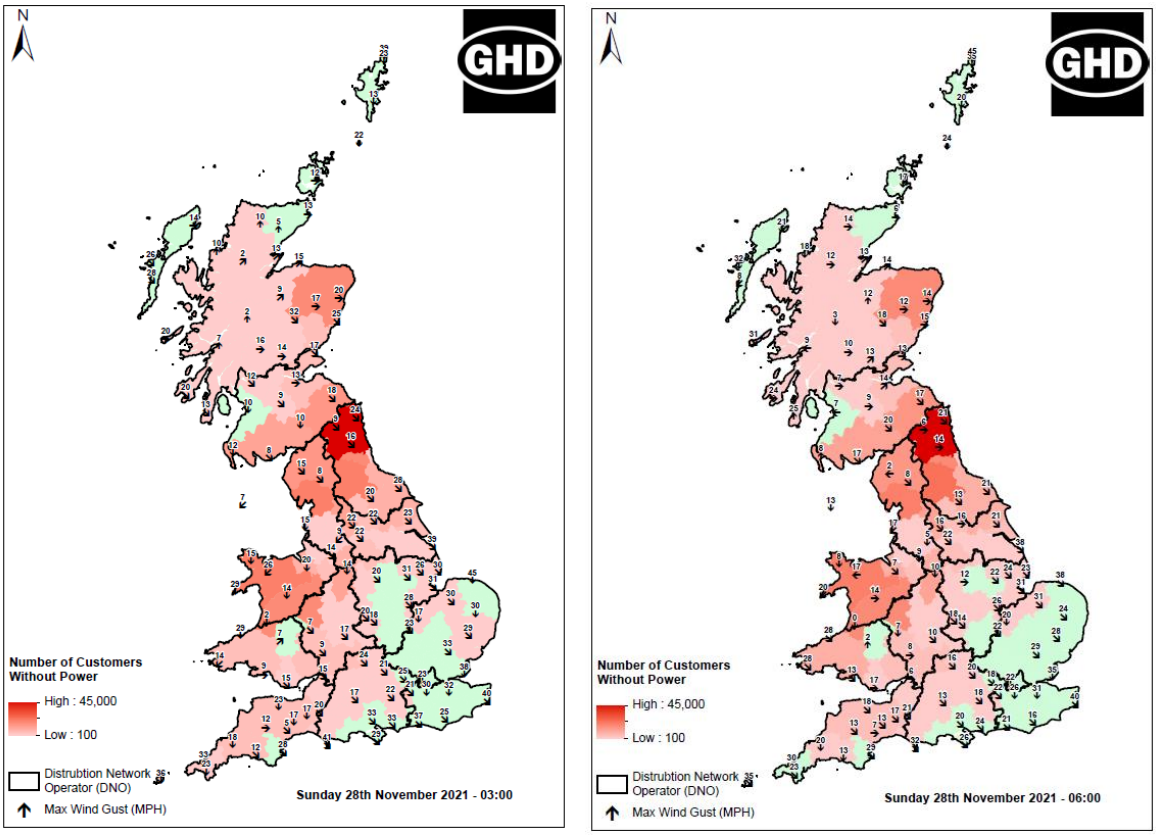
Figure 15: Saturday 27-November evening wind speed outturn



Source: GHD analysis and presentation of Met Office; Ofgem information request presentation 13/01/2022

By 06.00 on Sunday 28-November, wind speed can be seen to have decreased, as shown inFigure 16. The decrease of windspeed continued throughout Sunday, and into Monday, where some customers can be seen to have been restored.

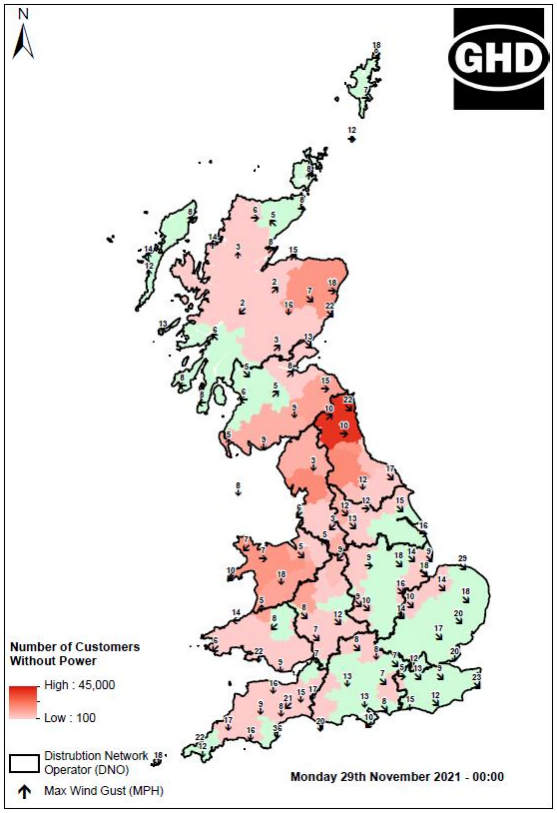
Figure 16: Sunday 28-November early morning wind speed outturn



Source: GHD; Met Office; Ofgem information request presentation 13/01/2022

By Monday 29-November Storm Arwen had passed across the UK, and the task in hand was to address the number of interruptions. Figure 17 shows the number of interrupted customers on that Monday, it is evident that the DNOs had started to restore supplies.

Figure 17: Monday 29-November early morning wind speed outturn



Source: GHD; Met Office; Ofgem information request presentation 13/01/2022

3.3 Summary

Storm Arwen proved to have a large impact across the UK, this consisted of impacts across the power transmission and distribution system and with human cost.

Human

Storm Arwen bore a human cost on the UK with 3 fatalities across the UK due to fallen trees. Additionally, a number of rail passengers in Aberdeenshire became stuck on a train overnight and many rail services were cancelled. There were severe disruptions on roads across the UK and on ferry services. The strong winds also created several incidents of structural damage to buildings.

Natural

Millions[18] of trees were damaged across the north of the UK, including large mature trees leading to major disruption.[19] This is hypothesized to partially be due to the unusual wind direction, northerly as opposed to the more common westerly which may have been an additional factor as trees show forms of adaptive growth in response to wind movement to counteract the increasing vulnerability to windthrow[20]. The national trust reported the loss of many mature trees including a 51 meter West Coast Redwood[21].

The large waves brought by the storm and dangerous conditions resulted in the loss of hundreds of grey seal pups along the beaches of the North Sea coast.

[18] https://www.bbc.co.uk/news/uk-scotland-south-scotland-60926691
[19] https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2021/2021_07_storm_arwen.pdf
[20] https://academic.oup.com/treephys/article/16/11-12/891/1663686?login=true
[21] https://www.nationaltrust.org.uk/press-release/irreplaceable-trees-lost-in-storm-arwen-says-national-trust

Power transmission and distribution

Just under one million homes experienced power loss[22] and over 100,000 homes suffered several days without power.

The last-named storm with a red weather warning was storm Dennis in February 2020, however this warning consisted only of a red rain warning. The last storm with a red wind warning was Storm Gertrude in January 2016.

In terms of wind speed, the UK has experienced storms with a similar number of stations exceeding 70 mph, for example on 9 February 2020 over 30 stations recorded gusts exceeding 70 mph from storm Ciara, however Storm Arwen did have a different wind direction, which has been argued to have increased its impact.

Storm Arwen did take a slightly different turn to the predictions originally made, due to the higher wind speeds and the unusual wind direction. The weather warnings issued by the Met Office were a good reflection of the level of the storms impact and the necessary preparation needed for the storm.

[22] https://www.gov.uk/government/publications/storm-arwen-electricity-distribution-disruption-review/storm-arwen-electricity-distribution-disruption-review-terms-of-reference

4. Network Condition and investment

This section provides background to design standards in place with UK DNOs with a close focus on overhead lines, which suffered most of the damage during Storm Arwen.

4.1 Industry standards

All DNO's construct and maintain their networks to British and international standards (typically BS EN standards) and industry best practice (Energy Networks Association standards) in force at the time. They also carry out routine inspections, follow up with maintenance, and vegetation management to similar standards.

The DNOs reported that their overhead line networks were most affected by Storm Arwen in that damage was widespread and dominant in the interruptions to customers. The mode of failure is reviewed in Section 4.6, this section focusses on the design standards of the overhead line networks and if they have been implemented correctly. In the case of Storm Arwen there are four standards of note:

- **ENATS 43-40** – Specification for single circuit overhead lines on wood poles for use at high voltage up to and including 33 kV
- **BS EN 50341** – Overhead electrical lines exceeding AC 1 kV. National Normative Aspects (NNA) for Great Britain and Northern Ireland (based on EN 50341-1:2012)
- **ENATS 43-8** – Overhead Line Clearances
- **ENA ETR-132** - Improving resilience of overhead networks under abnormal weather conditions using a risk-based methodology

When considering overhead lines, DNOs do own both metal towers and wooden poles, where the metal towers are typically only used for the higher voltage of 132 kV[23]. In the main, the DNOs overhead line network is dominated by wooden poles.

Overhead lines are all designed to withstand a range of mechanical influences applied to them during their operation. These influences come from the weight of the conductor, other equipment installed on the poles and importantly in reference to this report, certain weather-related forces such as wind, ice build-up (ice accretion), and changes in temperature. A factor of safety is also applied to ensure that the line and its supports have been 'over-engineered' to cater for unforeseen events.

The pole sizes and grades of strength, conductor types and sizes utilised by all DNO's, fall into predetermined industry categories of Light, Medium, Stout and Extra Stout which matches the physical requirements of the circuit route and the electrical characteristics of the line.

4.2 Asset condition of the affected assets

The impact of Storm Arwen was predominantly on the overhead line network with damage to conductors and poles. This section focuses on the condition of those assets prior to the Storm.

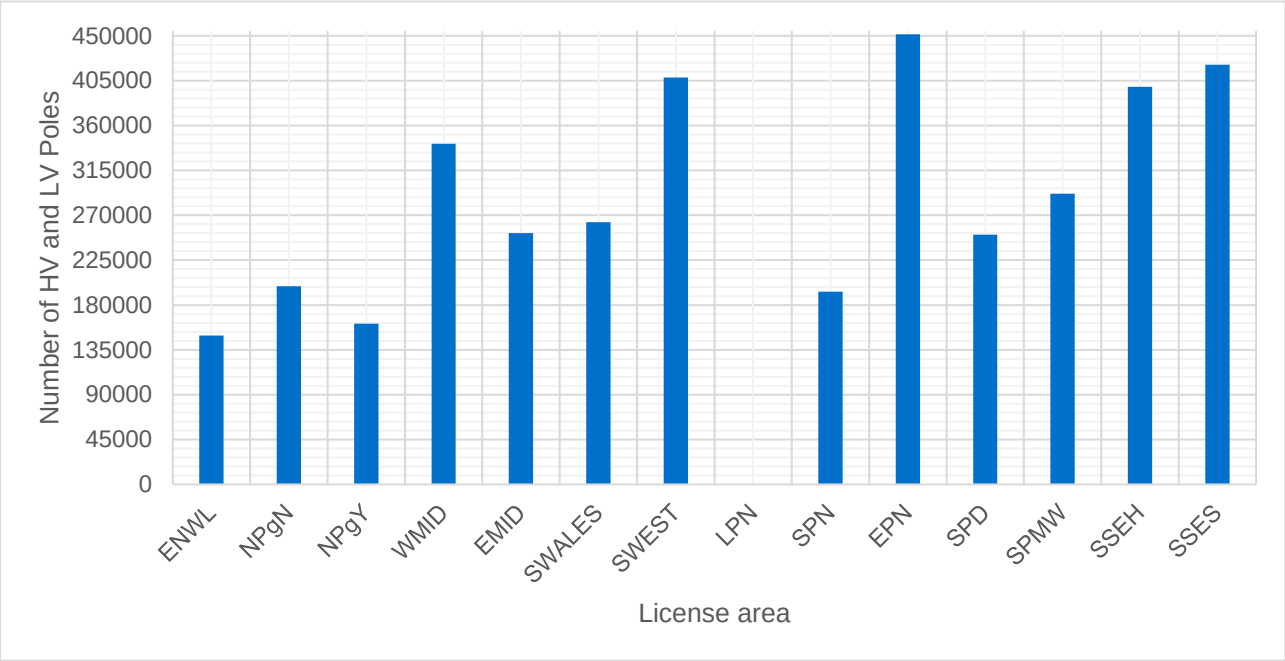
4.2.1 Health Index reporting

The condition of assets, in this case wood poles, is expressed in terms of a Health Index (HI). The index ranges from HI1 – HI5 with 1 being the best condition (i.e. brand new) and 5 the worst (i.e. needing replacing). Age is not necessarily a major factor in the condition assessment process. The age of the overhead line poles explored in more detail in section 4.6.4.

To provide some context into the relative size of each DNO's overhead line network Figure 18 below shows the populations of HV and LV poles in each DNO licence area. Overall, ENWL and NPg have the smallest total populations of wood poles.

[23] At 132 kV all towers are currently metal, but composites materials are starting to be used. However, these are only starting to be rolled out across the UK.

Figure 18: HV and LV poles per license area



Source: Ofgem RRP data set – AP1 Age Profiles

Further detailed information on the health and age of damaged poles is also contained within section 4.6.2 and section 4.6.4.

4.2.2 Overhead line expenditure

All companies submit data annually to Ofgem on expenditure and volumes of assets, known as the Regulatory Reporting Pack (RRP). One area classed as '*CV18 overhead line clearances*' which is explored in more detail below. The reported expenditure is shown below in Table 1.

Table 1 RIIO-ED1 allowances for overhead line clearance expenditure (£m)

DNO	Licence	RIIO-ED1 Allowances	RIIO-ED1 Spend to Date	RIIO-ED1 forecast spend	LV Poles	HV Poles	EHV Poles
		(£m)	(£m)	(£m)	Volumes to date		
ENWL	ENWL	6.07	17.01	20.81	2,897	528	1
NPG	NPgN	0.00	5.36	5.36	102	39	0
	NPgY	0.00	3.85	3.85	63	42	0
WPD	WMID	0.00	19.96	29.61	438	228	5
	EMID	0.00	23.43	28.27	632	114	60
	SWALES	0.00	21.31	27.05	1,304	123	5
	SWEST	19.15	44.40	62.15	2,624	81	6
UKPN	LPN	0.00	0.00	0.00	0	0	0
	SPN	28.00	17.68	25.91	881	53	0
	EPN	44.58	70.43	81.14	5,299	216	7
SPEN	SPD	65.71	75.65	80.45	17,144	550	12
	SPMW	72.45	76.37	85.99	14,726	838	5
SSEN	SSEH	2.98	8.80	10.38	963	327	46
	SSES	0.00	31.23	34.65	8,702	64	31

Source: Ofgem ED1 RRP data – CV18 OH Clearances.

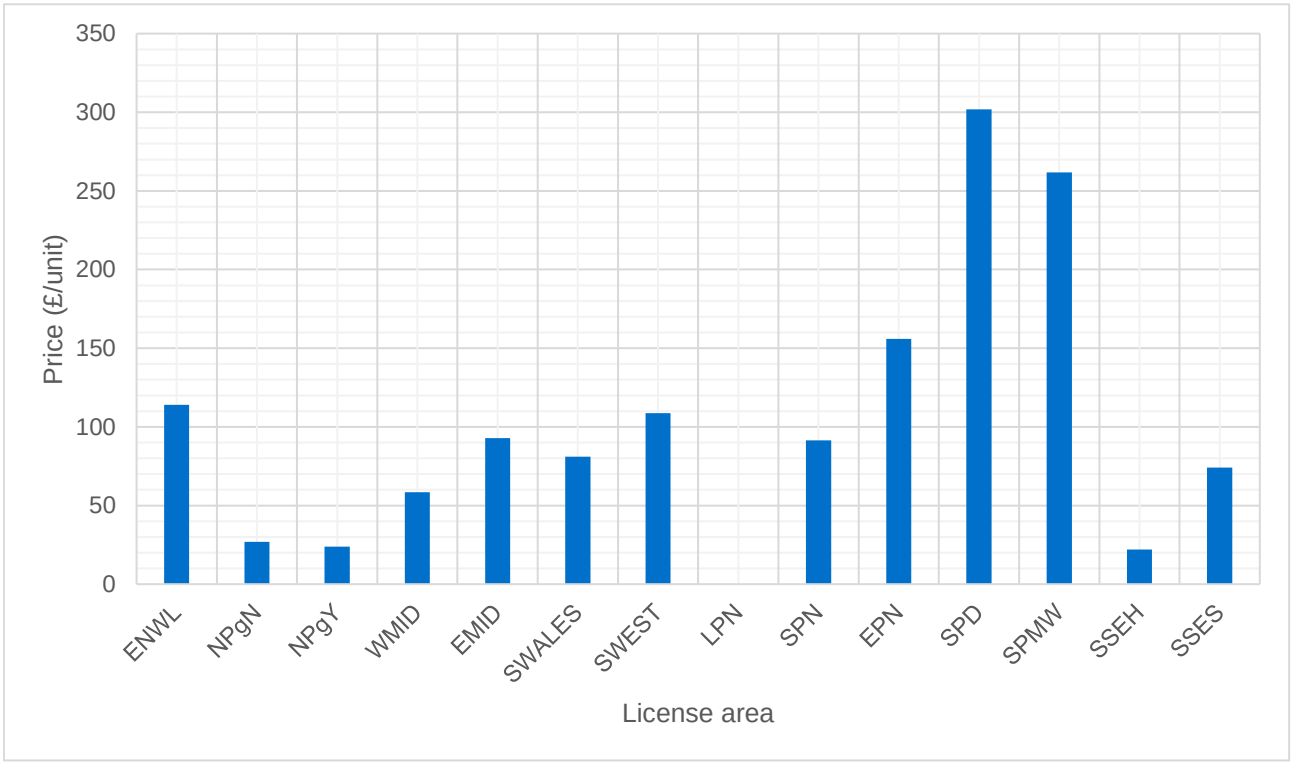
This data shows wide variances. NPg, WPD and SSEN (Scotland licence) have no allowance but have incurred expenditure and other DNOs have a RIIO ED1 allowance significantly less than their incurred expenditure - ENWL, WPD (SWEST) and UKPN (SPN) are in this category.

4.2.2.1 Expenditure on overhead line clearance

Figure 19 below shows the spend per pole on overhead clearance activity. Based on their total volume of LV and HV poles and the spend to date.

Overhead line clearance is one of the activities undertaken and is focused on meeting the ESQCR requirement to ensure that there is sufficient distance between trees and overhead lines for safety. Clearance does not mean that trees are cut back to prevent them coming into contact with overhead lines should they fall over.

Figure 19: RIIO-ED1 overhead line clearance spend, average spend per HV/LV pole



Source: Data collated from Ofgem ED1 RRP data CV18 OH Clearances (expenditure) and AP1 Age Profiles (volumes)

The graph indicates that NPg and SSEN licences have the lowest level of spend per pole in clearance activity. Although there are significant differences, this may reflect that expenditure in this category was done in previous review periods in the other companies. However, as there is significant expenditure in this period, it does raise questions about the DNOs forecasting expenditure

We would recommend that a more detailed understanding on how the costs are allocated in this area so to clarify the scale of the issue and the response of the companies.

4.3 Maintenance practices

The objective of undertaking routine maintenance and inspection activities is to ensure that they are kept in an acceptable condition for continued service. Accordingly, all DNO's have a duty to comply with the Electricity, Safety, Quality and Continuity Regulations 2002 (ESQCR) specifically.

Regulation 3(b) which states that distributors shall ensure equipment is: *"...so constructed, installed, protected (both electrically and mechanically), used and maintained as to prevent danger, interference with or interruption of supply, so far is as reasonably practicable"*

Regulation 5 which states that distributors shall: "...*inspect the network with sufficient frequency so that they are aware of what action is needed to be taken so as to ensure compliance with these Regulations"*

The general overhead line asset groups covered within this activity are:

– Overhead line conductors,
– Overhead line supports;
– Pole mounted plant;
– LV (Eaves main/wall mains systems); and
– Overhead line system supported pilot and telephone systems including fibre optic.

Routine inspections of overhead lines are undertaken by all DNO's. Depending on the timing the inspection can be a short visual check, or a more detailed test and inspection. The DNOs use a variety of methods to conduct the tests, including inspections by helicopter and foot patrols.

Helicopter inspections undertake routine inspections at periods between 2 and 4 years. The inspection is to identify damage to the pole or conductors, vegetation encroachment, changes in land levels and building works which may be too close to a line.

A more comprehensive condition assessment is undertaken by foot patrols, and these typically take place at intervals of between 6 and 10 years. This, more detailed inspection will also check for ground stability and rot at the base of the pole.

All DNO's have demonstrated that they manage maintenance, inspection and refurbishment of their overhead line networks and record the intervals in Codes of Practice. Whilst the frequency of inspection intervals varies between company's, the range of activities is similar.

4.4 Tree cutting procedures

All companies carry out periodic inspections on overhead assets generally between three to six years. They also have vegetation management policies which have been developed to maintain clearances between overhead conductors and adjacent tree branches primarily to prevent flashover. The DNOs undertake tree cutting as part of their normal maintenance routines. All the DNOs report on tree cutting expenditure in two categories:

– Safety Clearance (ESQCR)
– Resilience Clearance (ETR 132)

Each category is reviewed below.

4.4.1 Safety Clearance

Tree cutting with respect to safety clearance relates to the ESQCR. All DNO's have a statutory duty to comply with ESQCR and to maintain minimum distances between overhead lines and any structure – with Storm Arwen we are referring to trees. ESQCR, abridged version requires the Distributor to maintain a minimum distance between live conductors and someone climbing a ladder leaning against a structure, or at tree. Safety clearances from overhead lines, there captured in two relevant regulations:

Regulation 18(5): *"No overhead line shall, so far as is reasonably practicable, come so close to any building, tree or structure as to cause danger."*

And

Regulation 20A: *"A generator or distributor shall, so far as is reasonably practicable, ensure that there is no interference with or interruption of supply caused by an insufficient clearance between any of his overhead lines and a tree or other vegetation."*

Clearance between the overhead line conductor and that part of the tree under/adjacent to the line that is **unable** to support a ladder or be able to be climbed by a third party. The required clearance distances are:

– 0.8 m < 33 kV
– 1.0 m < 66 kV

– 1.4 m < 132 kV

Clearance between the overhead line conductor and that part of the tree under/adjacent to the line that is able to support a ladder or be able to be climbed by a third party. The required clearance distances are:

– 3.0 m < 33 kV
– 3.2 m < 66 kV
– 3.6 m < 132 kV

With a typical mature tree height in the UK of between 10 – 20 m, it is obvious that the safety clearance requirements will contribute little to enhancing network resilience during an abnormal weather event such as Storm Arwen.

All DNO's embody the requirements of this specification within their vegetation management policies and codes of practice.

4.4.2 Resilience Clearance

DNO's can also undertake a deeper '***Resilience Clearance***' of vegetation and trees, to limit vegetation related faults that can occur under abnormal weather conditions such as Storm Arwen, including problems caused by falling trees and wind-blown tree branches.

There is a guidance document that all the DNO's have been involved with writing that identifies various approaches to achieving greater Network Resilience is contained within Energy Networks Association Technical Report ENA ETR 132 Issue 2.

It should be noted that ENA ETR 132 is a voluntary guideline in that there is no obligation for the DNOs to follow its recommendations.

ETR 132 Issue 2, provides guidance for DNO's on how to improve network performance under abnormal weather conditions, which include high winds and ice, by adopting a risk-based methodology to identify the most effective locations to carry out additional resilience related activities including vegetation management, and/or other solutions. It focuses on vegetation management as the first and most important step in improving overhead line resilience and considers the combined effect of high winds and extreme rainfall.

However, it acknowledges that for several reasons there may be restrictions on the amount of tree cutting that can be carried out. To address these situations ETR 132 suggests other opportunities for enhancing resilience that could be applied alongside tree cutting. These include:

– Choice for construction standards of wood pole overhead lines;
– Choice for construction standards of tower lines;
– Enhanced network protection or automation; and
– Network diversion and undergrounding.

The principle of the risk-based approach is applied to each voltage level in turn working from highest (132kV) to lowest (LV) and considers a range of factors, including:

– The financial cost of improving performance;
– The level of relevant allowances;
– Areas where safety related Vegetation Management is to be undertaken;
– Areas that have been identified as at risk or that have suffered poor performance due to Vegetation;
– Areas with known Vegetation in the vicinity of Overhead Lines;
– The level of system security inherent in the network under consideration;
– Customer numbers;
– Sensitive customers; and
– Cost of repairs.

Whilst all DNO's have acknowledged that they embrace resilience philosophy, the level of detail provided for this report does not allow any identification of which opportunities individual companies have chosen to adopt. As this

is specifically designed to build resilience into overhead networks for events like Storm Arwen, this is an area where more detailed analysis is required on the timescale and the actions planned and being delivered by the companies to increase resilience.

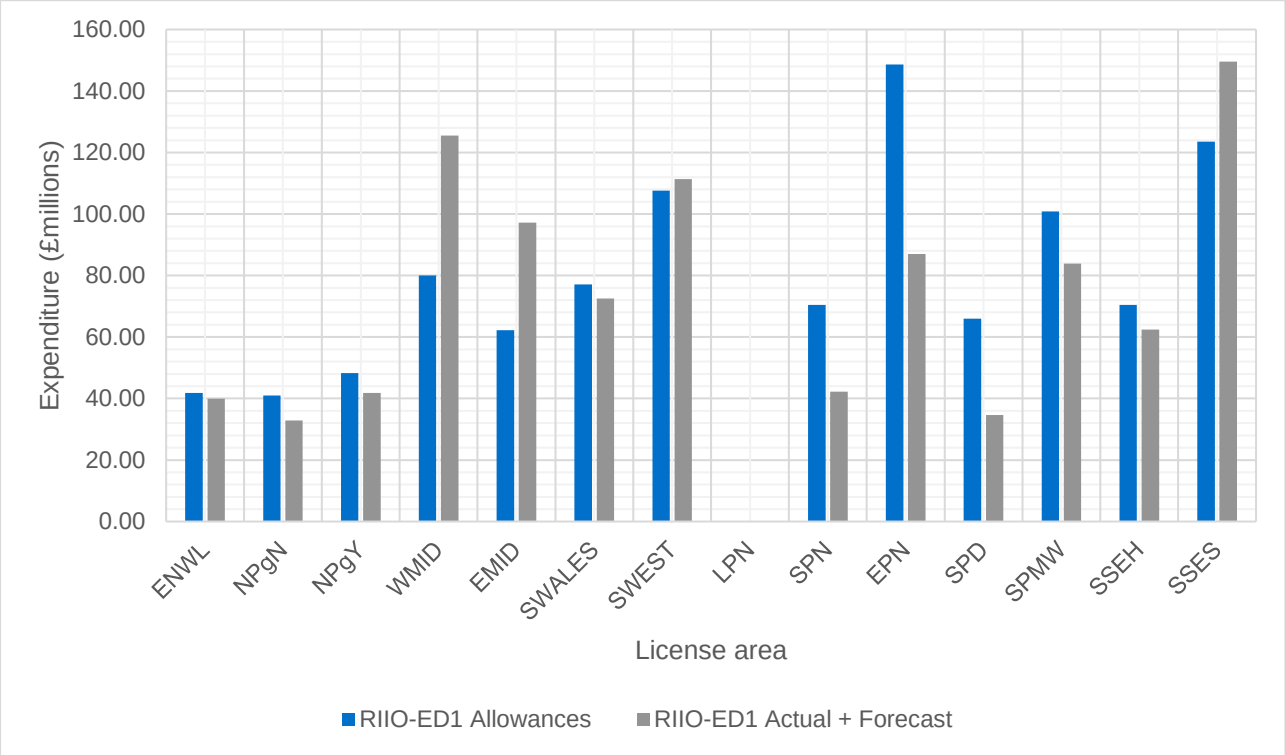
The overwhelming amount of tree cutting expenditure undertaken by DNO's is to maintain safety clearances and ensure their statutory compliance with ESQCR, not to ensure that trees are cut back far enough to ensure that they would not touch the line should the tree come down.

4.5 Expenditure on tree cutting

In terms of total tree cutting expenditure, the DNOs allowances were set for ED1. The DNOs have reported in 2021 their expenditure to date plus their forecast expenditure for the end of ED1 as shown in Figure 20.

There are large variations in expenditure both allowed and forecast, which may reflect several issues, from the time period over which the tree cutting is being planned, to the costs incurred on contracts for this work.

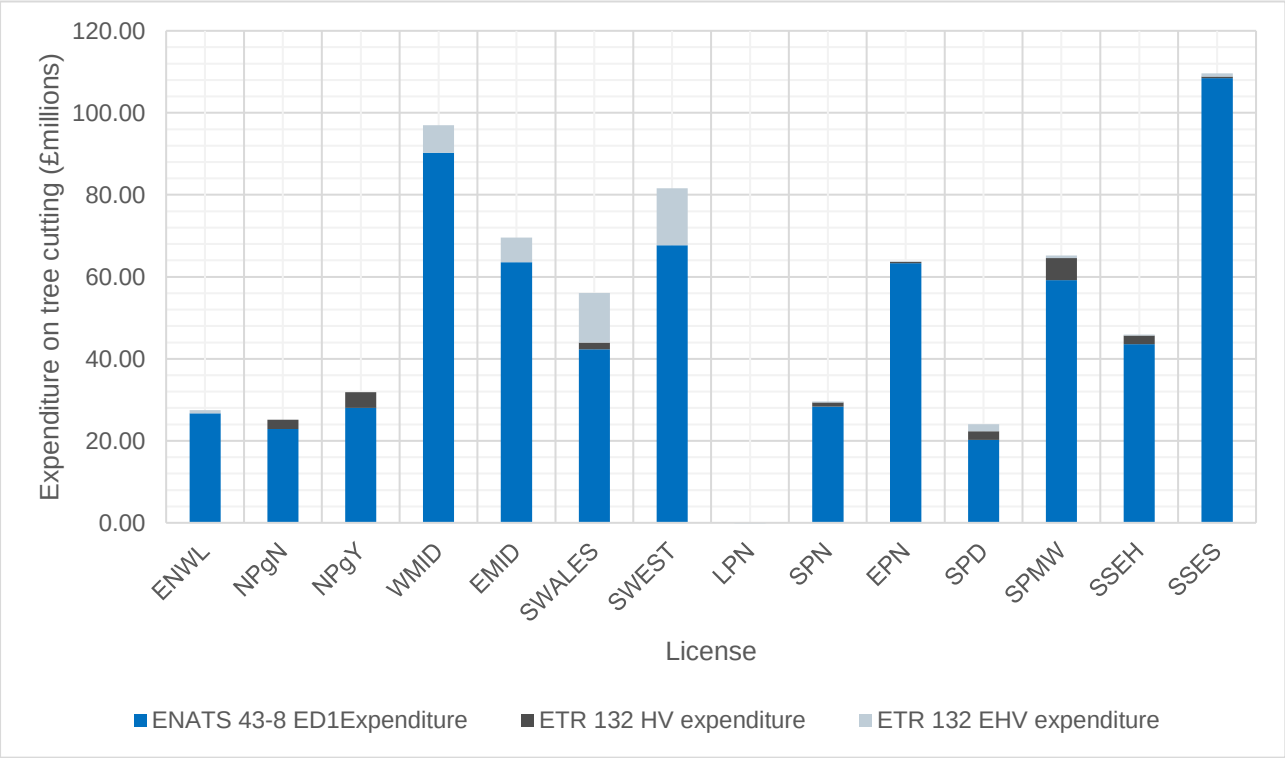
Figure 20: Tree Cutting Expenditure ED1



Source: Ofgem RRP CV29 data – Tree Cutting ED1 Expenditure

The expenditure is reported in two subcategories, the ENATS 43-8 Safety Clearance and the ETR 132 Resilience Clearance activity is shown in Figure 21 and confirms that the overwhelming focus of all companies is on Safety Clearance vegetation management although expenditure varies quite significantly.

Figure 21: Comparison between ENATS 43-8 and ETR132 expenditure.



Source: Ofgem RRP CV29 data – ETR 132 ED1 Expenditure

Whilst it clearly shows that expenditure on ETR 132 Resilience is significantly smaller, it does not quantify if options other than tree clearance have been utilised to achieve greater network resilience.

4.5.1 Review of expenditure relating to resilience clearance

There is a mixed approach to network resilience with some companies focussing expenditure on the HV network, whereas others, such as WPD and ENWL, have targeted their EHV networks. Generally, the higher the voltage the more customers are connected on each circuit, therefore the more resilient the higher voltage networks are, the fewer customers would be affected due to storm damage.

In comparison, expenditure on the 132 kV network is negligible, although this may be due to the legacy transmission tower style of construction utilised, which is inherently less prone to damage by trees.

Based on the ETR 132 ED1 RRP data returns, the following headlines have been assimilated:

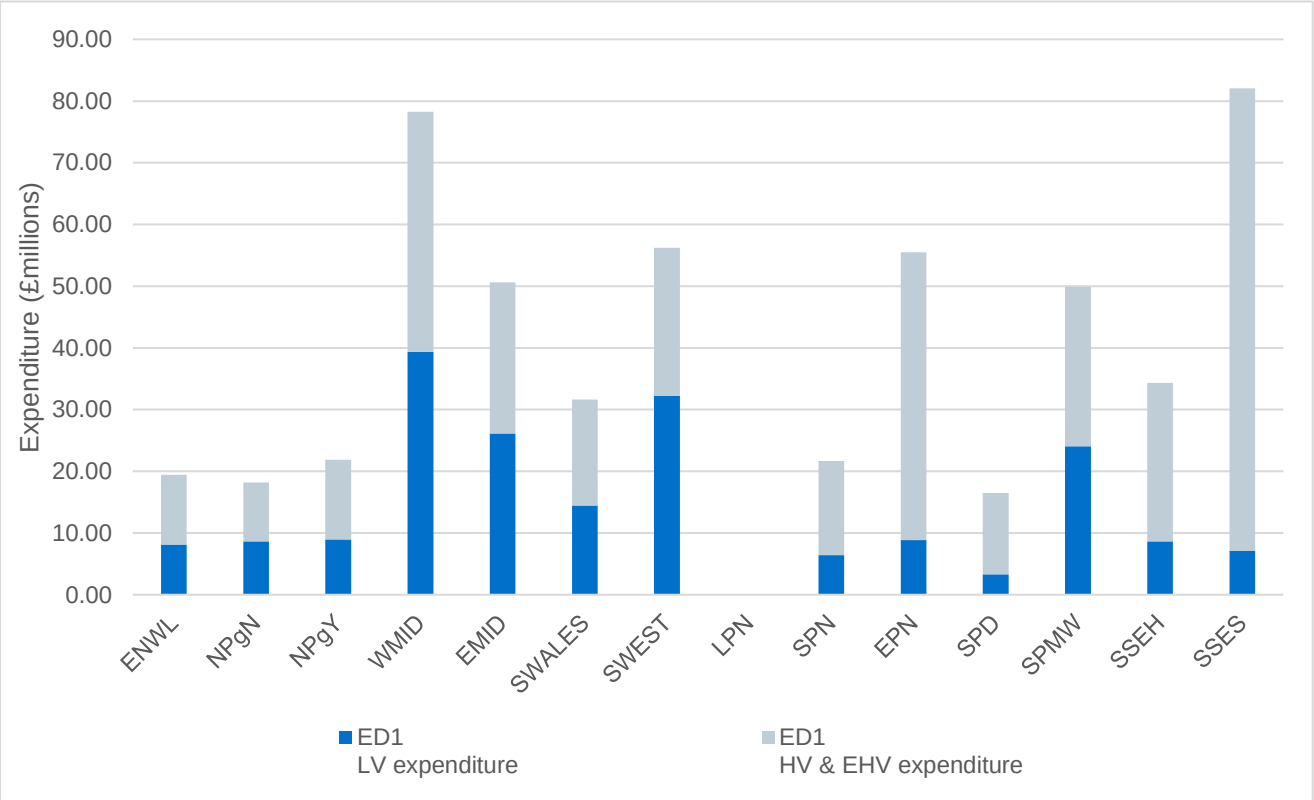
– Northern Powergrid has no ETR 132 expenditure during ED1 on their EHV or 132 kV networks.
– There is no expenditure by any DNO, at any voltage in the '*Other declared compliant spend*' category.
– ENWL, UKPN and SPEN have small values of expenditure in the 132 kV Physical Cut category.

4.5.2 Review of expenditure relating to safety clearance

The expenditure undertaken for Safety Clearance tree cutting in accordance with ENATS 43-8, is split between LV and HV & EHV. Where LV is below 1000 volts typically supplying houses in rural villages, HV is between 1000 volts and 22,000 volts and is typically the overhead lines across the countryside supplying small towns and villages, and EHV is over 22,000 volts where the overhead lines supply the larger primary substations supplying multiple towns and villages.

The differing approach between the companies is clearly identified in Figure 22 and shows that a greater emphasis in some is on the LV network and others on the HV network.

Figure 22: Comparison between ENATS 43-8 LV and HV/EHV Tree Cutting Expenditure



Source: Ofgem RRP CV29 data – ENATS 43-8 ED1 Expenditure

Improving resilience on the HV network will reduce the number of customers affected during severe storms, as each HV circuit typically supplies significantly more customers than each LV circuit.

4.6 State of the network

All DNO's specify, construct, and maintain their overhead line networks to the latest international standards (typically BS EN standards) and industry best practice (Energy Networks Association standards) in force at the time.

They all carry out routine inspections, follow up maintenance and vegetation management to similar standards, the most critical being ENATS 43-40; BS EN 50341; ENATS 43-8 and ENA ETR-132.

Their overhead lines are all designed to withstand a range of mechanical influences applied to them during their operation. These influences come from the weight of the conductor and other apparatus installed on the poles, weather related forces such as wind, ice, and temperature. They all utilise pole sizes and grades of strength, conductor types and sizes, which generally fall into predetermined industry categories of Light, Medium, Stout and Extra Stout.

Once these factors have been taken into consideration, a factor of safety is also applied to ensure that the line and its supports have an additional safety factor added to cater for unforeseen events and match the physical requirements of the circuit route and the required electrical characteristics of the line.

4.6.1 Cause of damage to overhead lines from Storm Arwen

The overwhelming Cause of Damage category in the Unplanned Outages and Restoration tab, was Wind and Gale (excluding Windborne Material).

There was very little supporting evidence provided in their 2021-December-16 BEIS Information Request submission spreadsheets to substantiate the claim that falling trees and ice were a major contribution to damage.

We do recognise that this data was a very early release and had not been audited and verified. Notwithstanding that, some damage has been caused by trees.

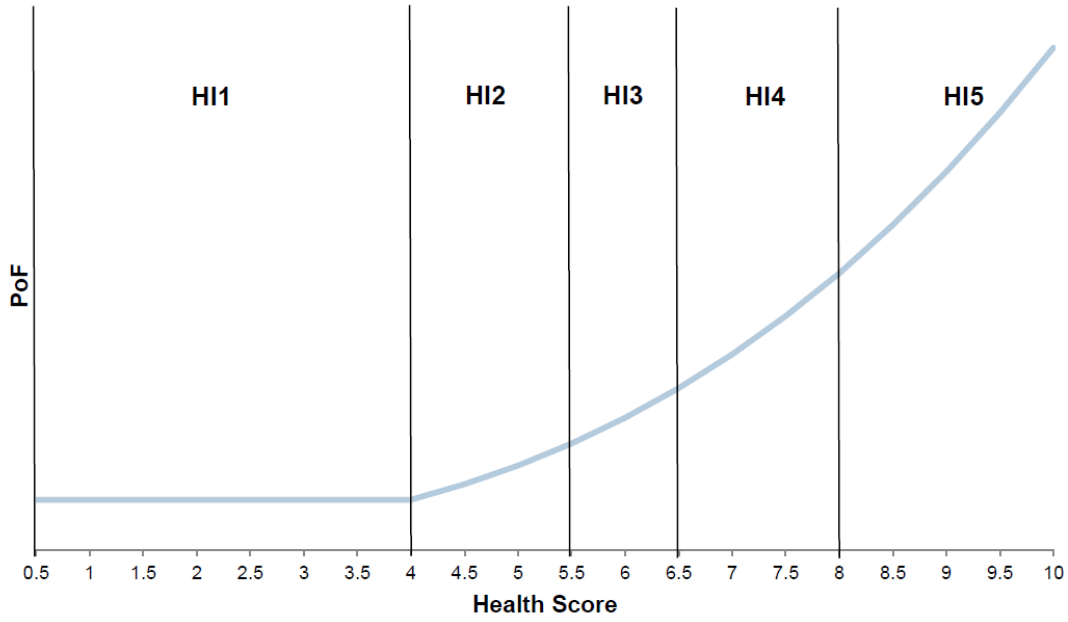
The conclusion to be drawn, is that a substantial number of poles that failed, were in open areas unaffected by trees and vegetation.

4.6.2 Condition of damaged poles

DNOs record and report the condition of assets, including wood poles, in terms of a Health Index (HI)[24]. The Health Index ranges from HI1 – HI5 with 1 being the best condition (brand new asset) and 5 the worst (needing replacing) and draws on a statical method to understand the Probability of Failure.

Figure 23 is an extract from the methodology for calculating and using the Health Index and shows as the Health Score increases the Probability of Failure also increases.

Figure 23: Heath Score and the Probability of Failure (PoF)



Source: Ofgem , DNO Common Network Asset Indices Methodology, 30-Jan-2017; Version 1.1; Page 27

Age itself is not necessarily a driving factor in the replacement of assets.

In general, poles with ratings of HI4 and HI5 will be prioritised for replacement as they are deemed to be in the poorest condition, although other factors are taken into consideration such as customers who can be supplied from an alternative feed.

4.6.3 Condition of damaged poles

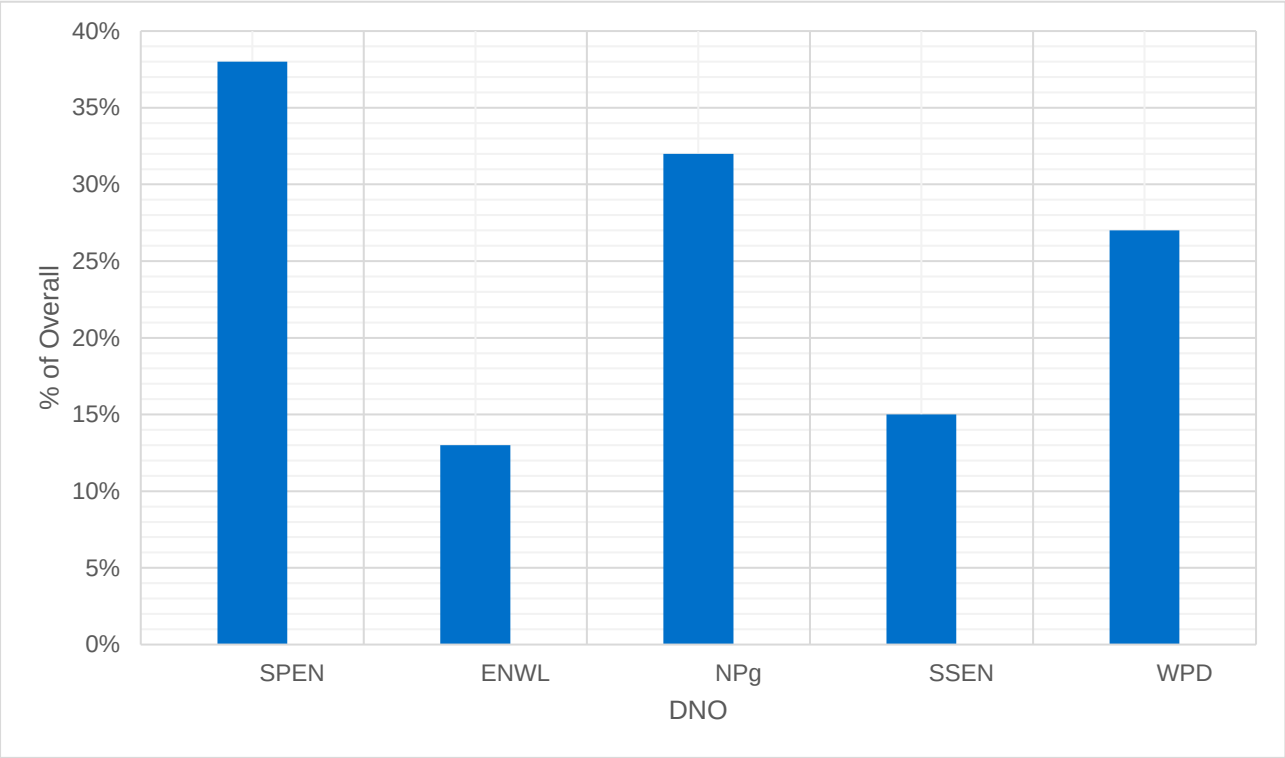
The condition of wood poles is assessed by regular inspections and testing, predominantly for signs of rot at the base and structural damage along its length such as splitting or signs of impact, which obviously reduces the strength of the pole. There is currently no standard site test to ascertain the residual mechanical strength of a pole during its operational lifetime.

The assumption is that the most poles damaged in the storm would be rated at HI4 and HI5. However, evidence provided by the companies does not universally support this assumption, but rather suggests that the age of the pole may be a more influential factor.

[24] https://www.ofgem.gov.uk/sites/default/files/docs/2017/05/dno_common_network_asset_indices_methodology_v1.1.pdf

GHD requested companies to provide information on the proportion of poles damaged during Storm Arwen that were rated at a HI4 or above. Responses were varied in both detail and format; however, the following collation has been distilled from the data provided Figure 24.

Figure 24: Proportion of damaged poles rated at HI4 and above



Source: GHD Questionnaire;

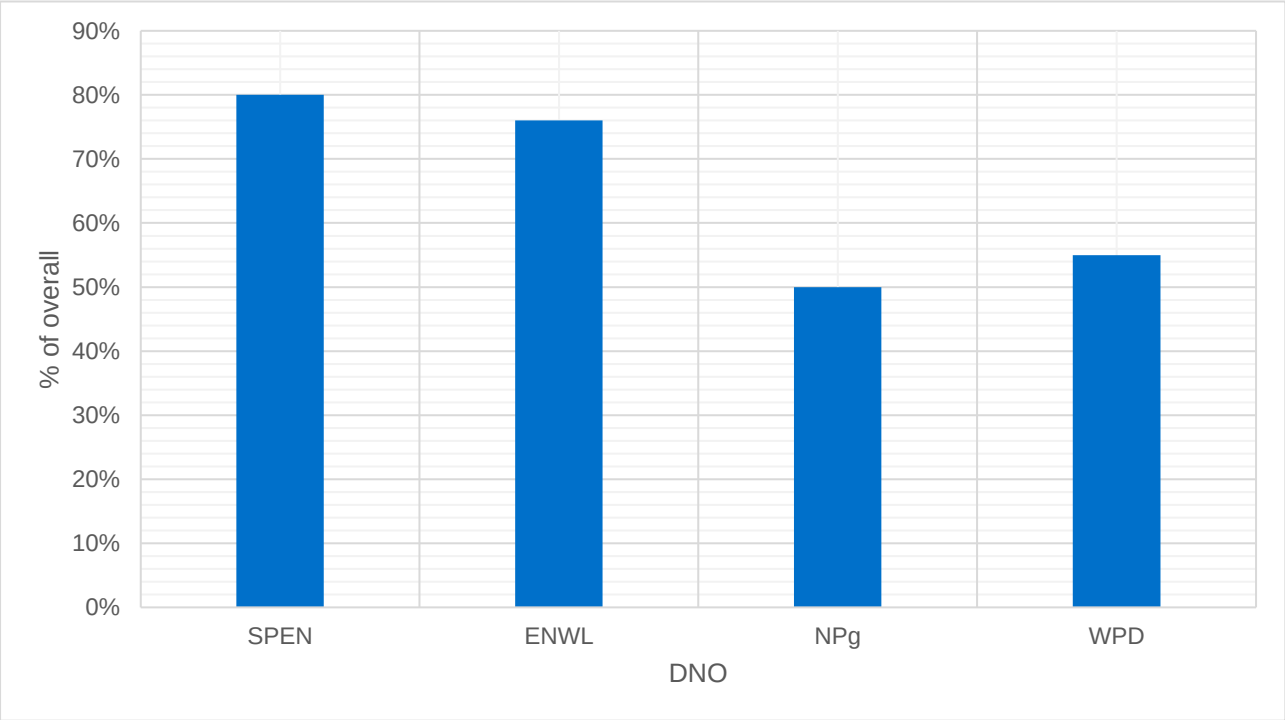
This shows a broad spectrum of results across companies and not the expected common link between condition and failure rate.

4.6.4 Age of damaged poles

GHD also requested companies to provide information on the age profile of poles that failed during Storm Arwen.

Again, responses were varied in both detail and format; however, Figure 25 is a collation which has been distilled from the data provided, to act as an illustration:

Figure 25: Proportion of damaged poles over 40 years old

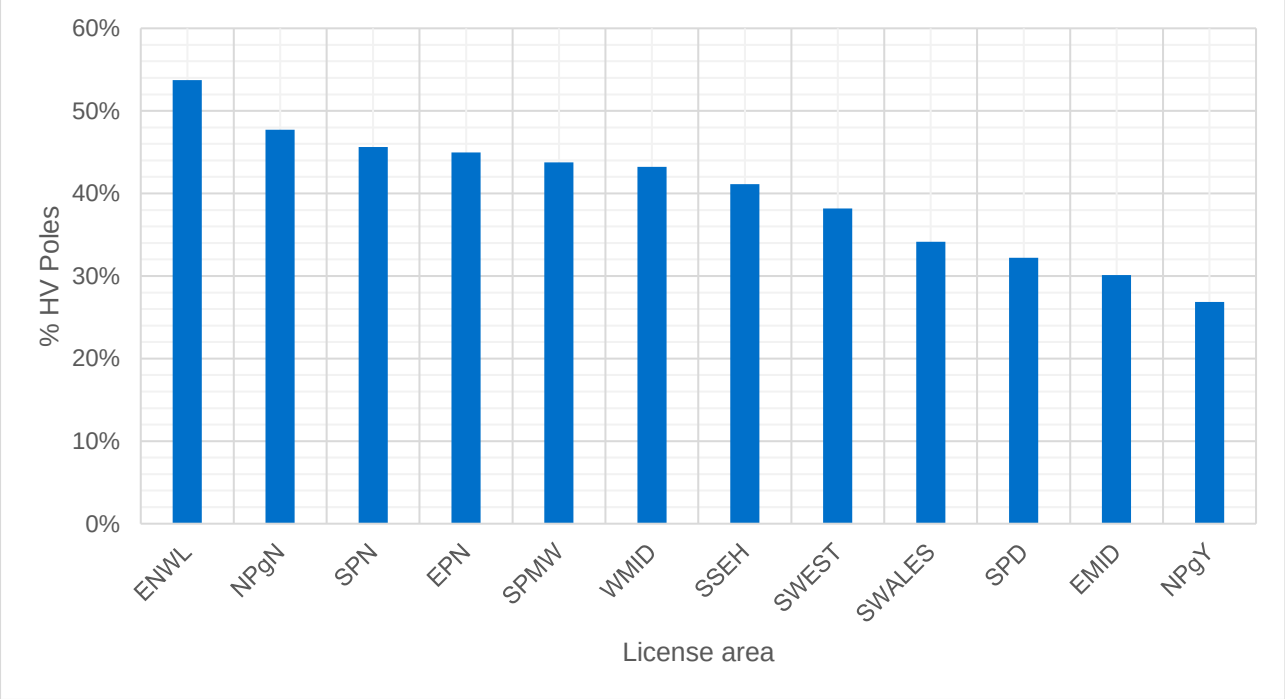


Source: GHD questionnaire responses

SSEN data was not able to be included in the Figure 25. However, they have stated that the average age of damaged poles on their network was 51 years.

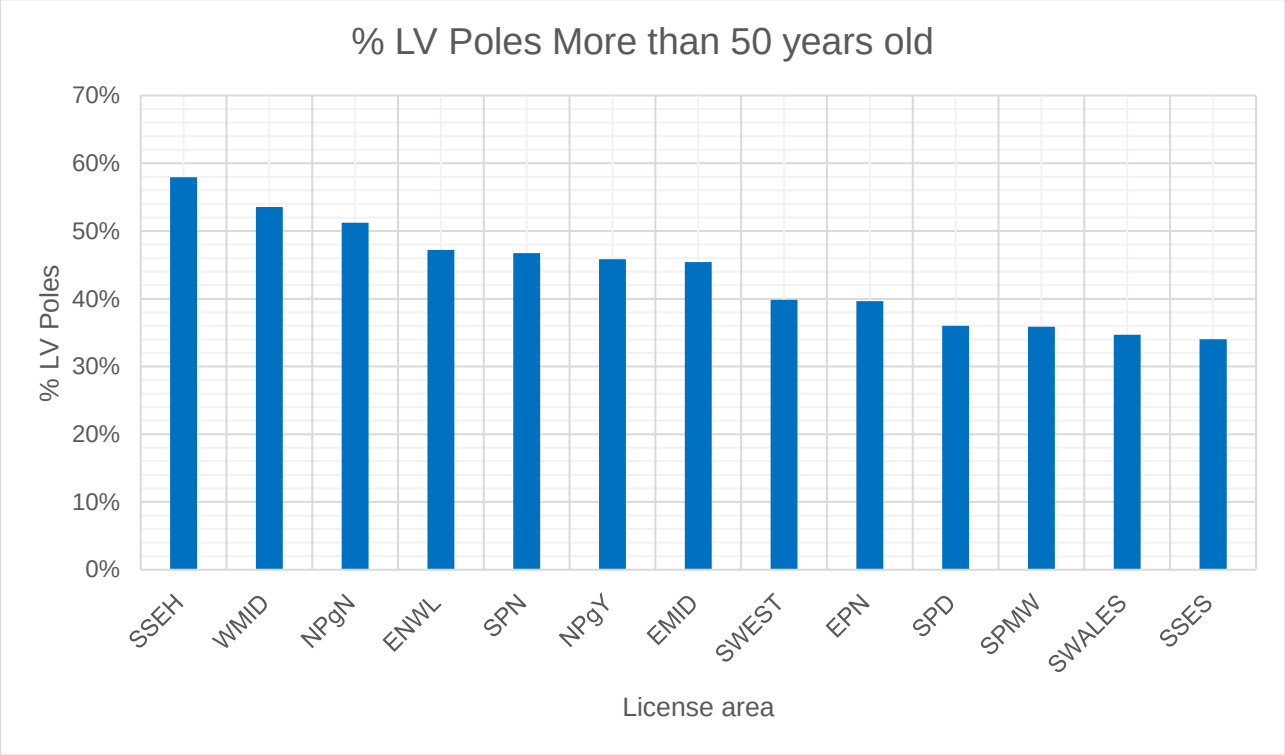
In a wider context, there are significant populations of HV and LV poles within all licences, which are over 50 years old as shown in Figure 26 and Figure 27 below.

Figure 26: % of HV Poles more than 50 years old



Source: Ofgem RRP AP1 data – Age Profiles HV Poles

Figure 27: % of LV Poles more than 50 years old



Source: Ofgem RRP AP1 data – Age Profiles LV Poles

From the information provided by DNOs, there is sufficient weight of evidence to suggest a relationship between pole age and the numbers that failed. The conclusion drawn is that poles aged >40 years old, may be more susceptible to failure in abnormal weather conditions than is currently understood.

If the link between age and deteriorating pole strength is established through future investigations, then the approach and frequency to inspection and testing of poles may need to be targeted depending on pole age.

4.6.5 Summary of the review of the damaged poles

Whereas ageing does not necessarily provide a direct correlation to health and vulnerability, it's potential to organically degrade the mechanical strength of the pole should be considered in the review process of Storm Arwen, to understand if this was a contributory factor.

Whilst pole replacement purely on age would not necessarily be efficient, an improved inspection and testing regime for older poles may have to be considered in future, to ascertain their residual mechanical strength to target those not meeting a required standard, for replacement.

It should be noted that the age of the assets in the areas of the network that were affected were most likely installed at the same time, therefore any asset that was affected will be of a similar age.

As previously stated, there is no standard industry site test to ascertain the residual strength of a wood pole as it ages and therefore the potential link to failure in abnormal weather conditions.

There is scope for further investigation into this scenario beyond the boundaries of this report.

5. Preparedness for the storm

This section summaries the network operator's preparedness plans prior to Storm Arwen.

5.1 Planning for a storm by the DNOs

All companies have detailed Emergency Plans which cater for extreme events including weather related events. Known as major Incident Management Plans. The plans have been developed over many years and have evolved following each incident to better improve the response. In the case of Storm Arwen, the plan was triggered by advance weather warnings.

5.1.1 Pre storm preparation

The triggering of the plan would normally occur once weather warnings are forecast, and the companies begin a preparedness phase while continuing to monitor forecasts. The companies mobilise resources, ensuring staff are notified to prepare. This also includes postponing routine maintenance or planned connections and requesting operational staff to be available (i.e. those who are off or on holiday).

Call centres and control rooms will have additional staff ready to supplement the usual staff numbers. All companies use contract staff for field work particularly tree cutting and overhead line construction. Under these contracts the contract companies will also make their staff available.

The reason is to increase resources in anticipation of increased work needed to repair the network. Helicopters will also be placed on standby to assist with reconnaissance of the area to identify damage.

The DNOs have their own supply of mobile generators and are also able to call upon additional generators from contract hire companies. This will be a pre agreed contract in place for such a scenario.

Notifications are sent to customers, media, and local resilience forums of the potential risk to energy supplies and for customer to prepare for possible supply loss.

The UK DNOs can share Field Services Engineers through the NEWSAC agreement, the details are discussed in section 6.3.2. When the major incident is triggered, part of the agreement is early discussions on the expected areas which are expected to feel the force of the incident and for those who are least affected, the option of providing staff. The meetings are held at regular intervals as the incident approaches.

5.1.2 During the storm

Once the storm hits the severity of the weather will determine the impact on the network. As the networks have significant lengths of overhead lines in rural areas, they will be the most impacted. The storm can cause damage to the overhead network and result of loss of supply to customers and there are various options to attempt to reconnect customers. These include:

– automatic reconnection of the overhead lines in cases where the fault is a flash over.
– remote-controlled switching by the control room to reconnect supplies to alterative parts of the network.

If the damage is permanent e.g. conductors broken or snapped poles, and there are no alternative points of connection then the supplies remain off until the workforce can attend and make a repair.

During the storm where winds are extreme, then some restoration can occur through switching but, in most cases, the high winds prevent activity on repairing the lines, or using helicopters for reconnaissance. The initial response will be information gathering by staff driving to areas without supply to identify the reason and the extent of the damage, reporting back to local command centres, where the resources and materials are prioritised. The faults affecting the greater numbers of customers are prioritised to get most customers reconnected as soon as possible.

5.1.3 Review of preparedness of the DNOs

The DNOs demonstrated their preparation for the storm event initiating emergency plans, communicating with staff and customers and between companies through NEWSAC set up through with the ENA involves all distribution companies, and is designed for mutual aid. This was enacted several days before the storm and operated successfully throughout. In the event of a storm those companies worst affected will request resource to assist from the companies least affected.

5.2 Damage assessment procedures

All companies operate an IMS (incident management system) which combines customers location to the point on the network they are connected to, and the connectivity of the network through the different voltages from LV point through the transformers to HV feeder up to the primary substation. This system allows the company to know when a circuit breaker trips, which customers are off supply.

When a LV fuse operates on more remote points on the network, information is not normally communicated back to control centres and the IMS. Only when customers contact the call centre or web site will the company know there is an interrupted customer. More recently, the IMS systems have built in intelligence that can assess from the customer calls where the fault could potentially be on the network and therefore knows all other customers that have been disconnected, even if only a small number of customers have contacted the company.

Where supplies can be restored by switching field staff are deployed and began the restoration process. This includes switching customers onto alternate supplies and isolating damaged sections. The damage assessment teams will then be deployed to determine the extent of the damage, from a broken conductor through to multiple snapped poles. This information is passed to the emergency management centres to determine what materials and equipment is needed and the skill and number of staff required to repair the damage. The faults are then prioritised based on numerous factors including the numbers of customers affected and the resources required. The teams are then dispatched to carry out the repairs and restore the supplies.

All information relating to the incident is recorded to assist restoration and to allow post event analysis to understand why the fault occurred and what components were damaged, and did they fail due to the severity of the storm alone, or also the age and condition of the components or the environment it was in e.g. clearances to trees. This information allows the companies to improve their understanding of how to help prevent similar impacts occurring in the future.

Storm Arwen was handled similarly to many other previous storms of differing intensities. The difference with this storm was the extent of the damage and the time taken to repair and restore supplies.

The companies all performed in accordance with their emergency plans and worked with assistance from contractors and NEWSAC donated staff.

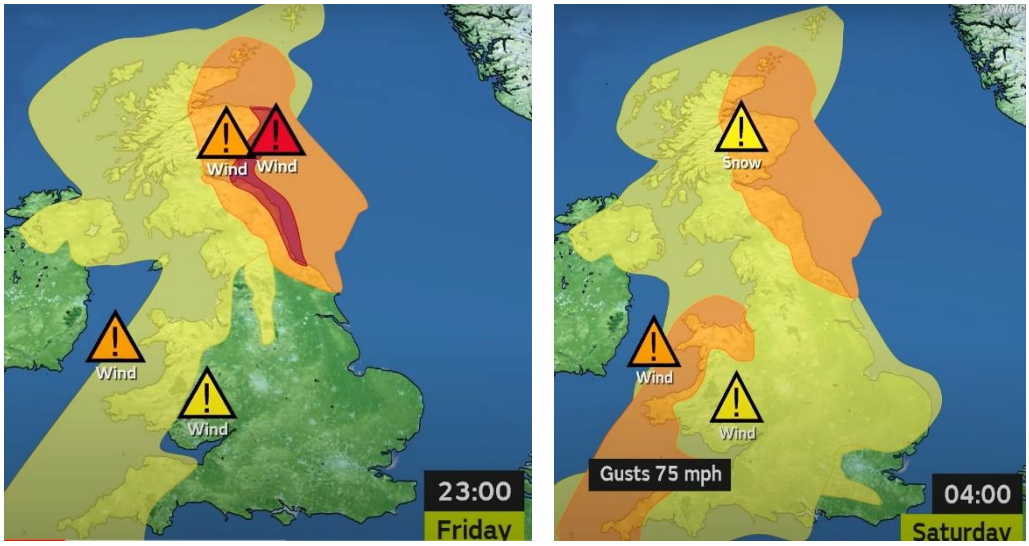
6. Response to Storm Arwen

This section reviews the DNOs response to Storm Arwen.

6.1 Recap of the Storm

On the morning of Friday 26-November, high windspeeds began. As can be seen in Figure 28, high wind speeds warnings were in force by 9am, and began reaching the high 90 mph's in areas of eastern Scotland.

Figure 28: Weekend weather alerts



Source: Met office

By Friday afternoon there were a large number of customers off supply, mainly around Eastern Scotland and north of England,. Windspeed gusts had been recorded at 109 mph. In the evening of Friday 26-November the gusts reduced, however more were interruption occurred as the storm moved south, notably within the northeast of England region and across southern Scotland.

6.2 Cause of interruptions to customers

Following a storm and once all customers are restored, the DNOs collate data on the faults, including the cause, duration and number of customers interrupted. The data is extracted from the Incident Management System, which logs the times circuit breaker operates and the times customers call to notify they are off supply.

The cause of the fault is entered based on initial reports, that is what is known at the time. Once the incident has passed, staff who worked on site may change the cause of the interruption once more details are known. The initial data is therefore sometimes not as accurate as there is some latitude in the interpretation as to the cause as some faults could be classed as more than one cause. Although the cause may change, the timing is generally accurate as the interruption start and stop times are automatically recorded form the control system or the call log system. Table 2 below show the cause information provided by the companies.

Table 2 Cause of interruptions during Storm Arwen

Causes of the interruption	Number of Customers	% Customers
06 Wind and Gale (excluding Windborne Material)	677,708	68%
(blank)	87,119	9%
23 Falling live trees (not felled)	86,379	9%
03 Snow, Sleet and Blizzard	58,731	6%

Causes of the interruption	Number of Customers	% Customers
71 Deterioration due to Ageing or Wear (excluding corrosion)	18,994	2%
21 Windborne Materials	13,831	1%
75 Operational or Safety Restriction	8,659	1%
Other	47,629	5%

Source: Ofgem information request presentation 13/01/2022

The primary cause of incidents by all companies was wind and gale as being responsible for 68% of all customer interruptions. Only 9% were reported as due to falling trees 6% snow sleet and blizzard. Only 1% of interruptions were due to windborne material e.g. tree branches. The initial assumptions immediately after the storm suggested that falling trees and windborne material were a significant contributor. However, this is not played out in the data submitted by the DNOs.

It is important to understand the cause of the interruptions as, in the case of Storm Arwen if the cause is due to trees and windborne material from trees then the tree clearances may need addressing to improve reliability. However, if damage is due to wind alone, then it would suggest the improving the design standard could be a factor.

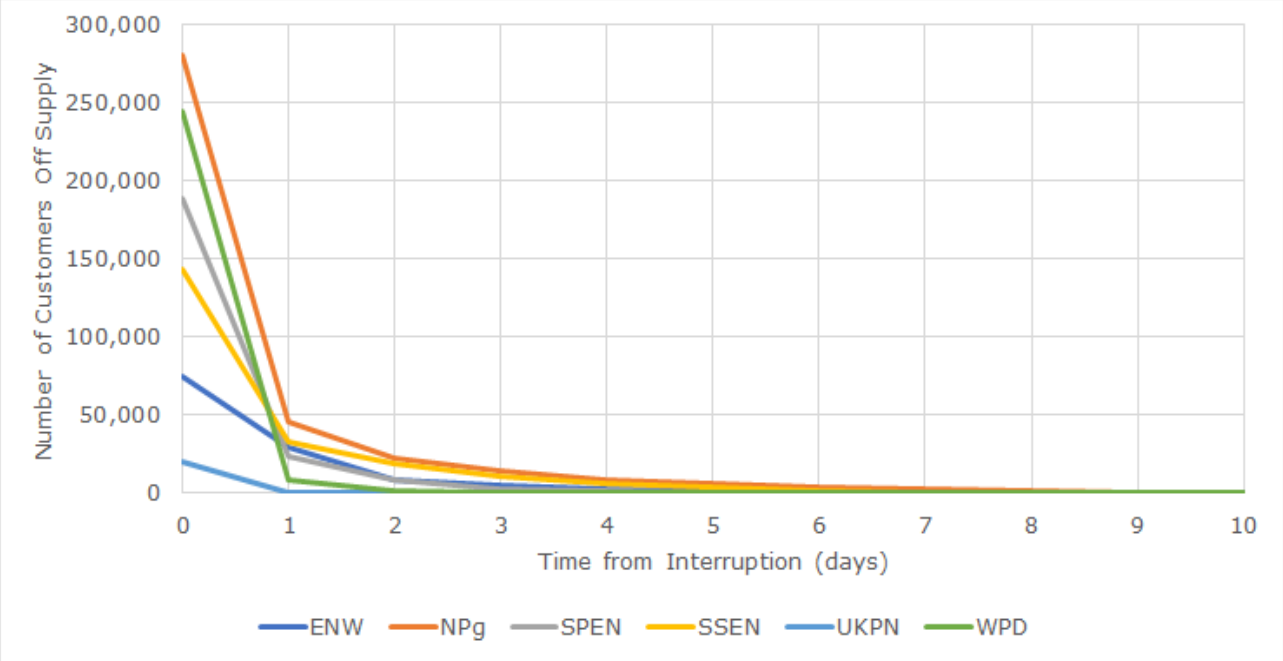
According to the data provided by the DNOs, the major contributing factor to interruptions was wind and gale, not falling trees, which would suggest that the design standard may be factor in the resilience of the network.

6.2.1 Number of customers interrupted

The total number of customers affected was over 950,000 and Figure 29 shows the breakdown by DNO. NPg and WPD seeing the largest number of 280,867 and 243,930 respectively. NPg had 2,537 customers still off supply after 7 days, whereas WPD had restored all but 26 customers after 3 days.

SPEN and SSEN had 189,133 and 143,749 customers off respectively and after 7 days all SPEN customers were restored and SSEN had 299 customers remaining off. ENWL had initially 74,983 customers off supply with 196 remaining off supply after 7 days. UKPN had 19,552 customers off supply initially with all but 22 restored within 1 day.

Figure 29: Number of customers off supply



Source: Ofgem information request presentation 13/01/2022

The approach by all companies was similar in enacting the emergency plan procedures. Reductions in the first 24 hours of interrupted customers is largely due to switching circuits back in where no damage was found, or switching to alternative feeds.

Overall, over 85% of customers were restored within 24 hours. With UKPN and WPD, the least affected by the storm, 99.9% and 96.6% restored.

ENWL, SSEN, NPg and SPEN was 61%, 77% 84% and 87% respectively. This was during the period when the winds remained strong and access issues would restrict some repairs. The number of customers who were off supply at the end of each day is shown in Table 3 below.

Table 3 Number of customers remaining off supply at the end of each day

DNO	Total customer interrupted	Number of customers remaining off supply at the end of each day												
		01	02	03	04	05	06	07	08	09	10	11	12	13
ENWL	74,983	29,249	8,408	4,812	2,602	1,436	443	196	12	0	0	0	0	0
NPg	280,867	45,900	22,046	13,796	8,792	5,717	4,094	2,537	1,744	791	202	39	4	0
SPEN	189,133	23,885	8,238	2,592	1,114	474	106	0	0	0	0	0	0	0
SSEN	143,749	32,476	19,272	11,235	6,638	3,741	1,101	299	54	16	3	1	0	0
UKPN	19,552	22	0	0	0	0	0	0	0	0	0	0	0	0
WPD	243,930	8,214	1,137	26	1	1	1	0	0	0	0	0	0	0
Total	952,214	139,746	59,101	32,461	19,147	11,369	5,745	3,032	1,810	807	205	40	4	0

Source: Ofgem information request presentation 13/01/2022

The first 24-hour response is driven mainly through automatic, remote and manual switching, rather than repairs. The effectiveness of the application of emergency plans and management of the repairs phase is indicated more through the profile of the restoration from that point until the final customers are restored. the number of customers restored in the first 24 hours is shown in Table 4 below.

Table 4 Customers restored within 24 hours

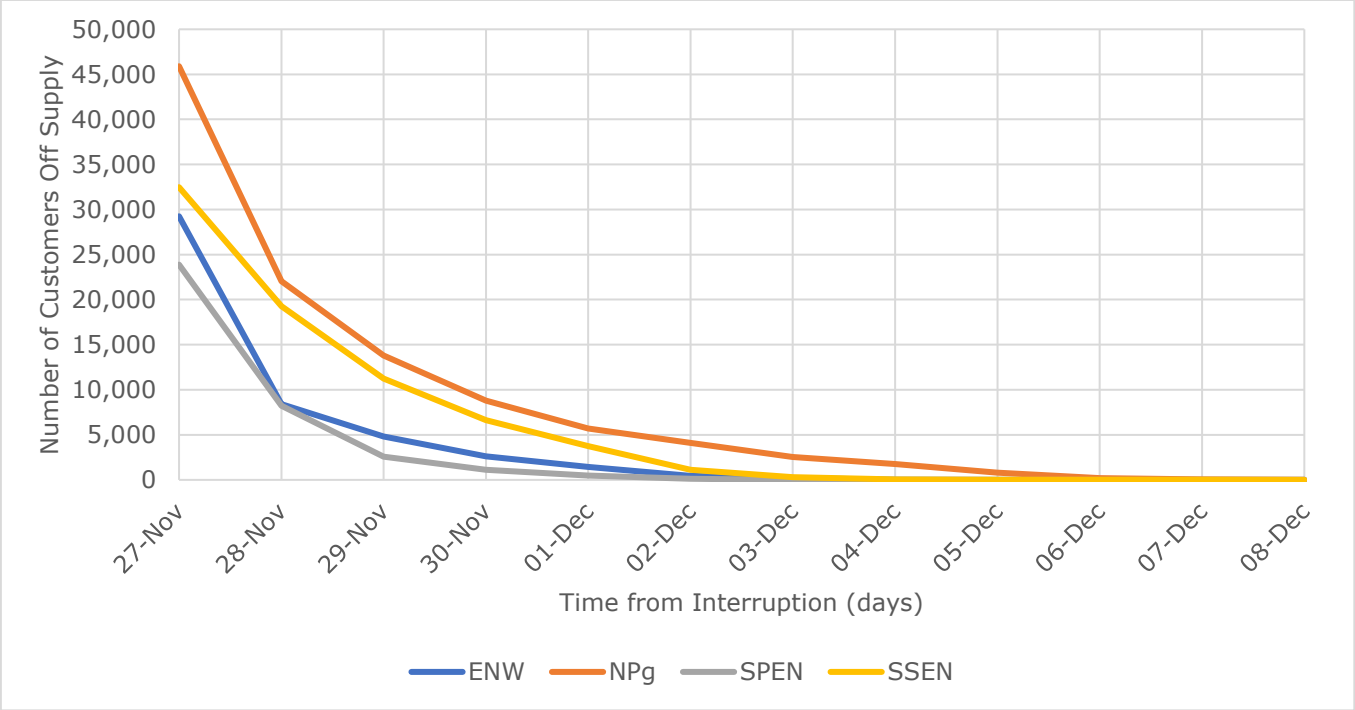
DNO	Total customers interrupted	% Restored in 24 hours
ENWL	74,983	61.0%
NPg	280,867	83.7%
SPEN	189,133	87.4%
SSEN	143,749	77.4%
UKPN	19,552	99.9%
WPD	243,930	96.6%
Total	952,214	85.3%

Source: Ofgem information request presentation 13/01/2022

Customers who experienced interruptions over multiple days reflects the volume of faults and where more significant damage has taken place. Progress to resolve these interruptions is largely driven by number of repairs needed, the extent of the damage, the resources available and the utilisation of the resource effectively.

In Figure 30 we show the number of customers still off supply and it shows a rapid reduction by ENWL and SPEN in the initial three days. It would appear the restoration responses by NPg and SSEN were slower. As mentioned above, there may be mitigating factors that means the response was slower, for example more significant damage.

Figure 30 The restoration phase from 27th November after the first 24 hours



Source: Ofgem information request presentation 13/01/2022

As the numbers in UKPN and WPD over this period were minimal, we have removed them from the graph.

A key criterion for understanding the delays in restoration is to consider the number of incidents/faults affecting the customer. Those companies with high customer numbers and lower incidents reflects that on average the overhead lines affected had more customers connected per incident, and restoration is driven by the incidents and extent of damage. Generally higher numbers of incidents will utilise greater numbers of resources. SSEN had the highest number of incidents with 2,273, (32%) followed by WPD with 1,642 (23%). NPg and SPEN had similar

numbers with 1,246, (18%) and 1,331, (19%) respectively. ENWL had 364 incidents, (5%). These are shown in Table 5 below.

Table 5 Total number of incidents per DNO

DNO	Total No. of incidents	% of total incidents by DNO
ENWL	364	5%
NPg	1,246	18%
SPEN	1,331	19%
SSEN	2,273	32%
UKPN	243	3%
WPD	1,642	23%
Total	7,099	

Source: Ofgem information request presentation 13/01/2022

It should be noted that these numbers may see some minor changes as the DNOs finalise the fault data.

6.2.2 Summary of the response to Storm Arwen

In reviewing the customer numbers and the number of incidents combined, UKPN had very little impact (243 incidents) and resolved their faults mainly within 24 hours. WPD (1,642 incidents) resolved their incidents quickly with most restored through switching and overall, an effective response.

The other companies had a much longer period in restoring all supplies, with SPEN having 1,331 incidents affecting 189,133 customers restored 87.4 % largely through switching and reducing to 2,592 after 3 days restoring all customer within 7 days. This represented a good response both through the first 24 hours and then through the repair phases on subsequent days.

SSEN impact 143,749 customers off was in a single licence area in northern Scotland and they had by far the largest number of incidents (2,273) which would have been a major contributory factor in the time to restore customers, although they took 8 days to restore all but 20 customers, which again represents a good response.

NPg had 1,246 incidents and restored 83.7% within 24 hours, which would be mainly through switching activities. The slower restoration over subsequent days with 4,094 customers remaining off supply after 6 days (Figure 30) at which point all other companies combined had 1,651 off supply indicates a much slower response in restoring supplies and would represent the period where the effective application of the resources phase of the emergency plan was influencing progress. The final customers were restored after 13 days. It would suggest that in the post event review the focus in NPg should be on that area to identify improvement plans.

ENWL had the fewest number of incidents with 364, affecting the fewest 74,983 customers, with 61% restored in 24 hours. They did reduce their customer numbers rapidly with 1,436 remaining off after 5 days and all customers restored in 8 days.

6.3 Response to the Storm

All companies initiated their emergency plans as detailed in section 5.1. The effectiveness of the emergency plans can be interpreted through assessment of several factors, namely

– the resources used
– mobile generators utilised
– extent of the damage.

These are reviewed in more detail below.

6.3.1 Deployment of resources to effect repairs

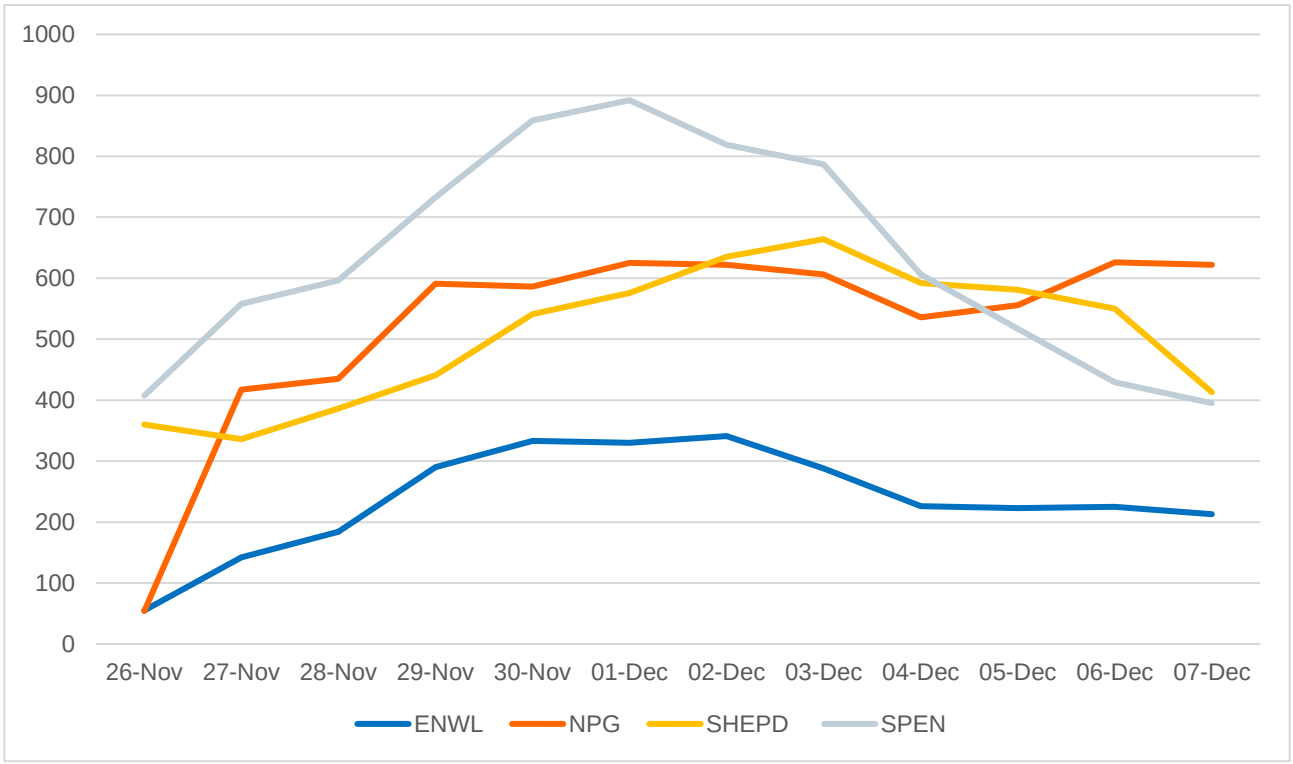
The DNOs have two main staffing routes to affect repairs, namely

– Their own resources, be that staff employed by the DNO or third-party contractors
– Mutual aid from other DNOs through NEWSAC

Information was provided by the DNOs on the resources deployed to deal with the storm over the extended restoration timescales. As the incidents were largely resolved in UKPN with 22 customers off supply after 24 hours and in WPD 26 customers off supply after 72 hours, they are removed from Figure 31.

The information is by Company except for SSEN where the impact in Southern was minimal and the data is for SHEPD only in northern Scotland. The data shows single licence figures for SHEPD and ENWL and the two combined license areas each for NPg and SPEN.

Figure 31: Number of Field Staff, Engineers, Contractors, NEWSAC deployed to restore customer supplies



Source: Ofgem information request presentation 13/01/2022; GHD information request 22/01/22

The staff presented are only field staff involved in directly restoring supplies and excludes call centre and other support staff and management involved in the event. All those other staff contribute to the process, but this information is targeting the staff in the field repairing and restoring supplies.

On 26-November SHEPD and SPEN had 360 and 407 staff mobilised to address the faults, which may be partly due to the faults affecting the DNOs in the Scotland initially but also demonstrates the ability to react as soon as

possible during the initial phase where switching restores most customers and information gathering on damage is used to organise the response in the following days.

NPg and ENWL had far fewer resources deployed initially but increase rapidly over the following days but may have been delayed due to information gathering to assist the organisation of repairs. All companies ramped up the resources utilising contractors and NEWSAC staff when available. The number of days to achieve the peak staffing is largely driven by the additional NEWSAC staff arriving to assist the licensee and contract staff deployed, as shown in Figure 32.

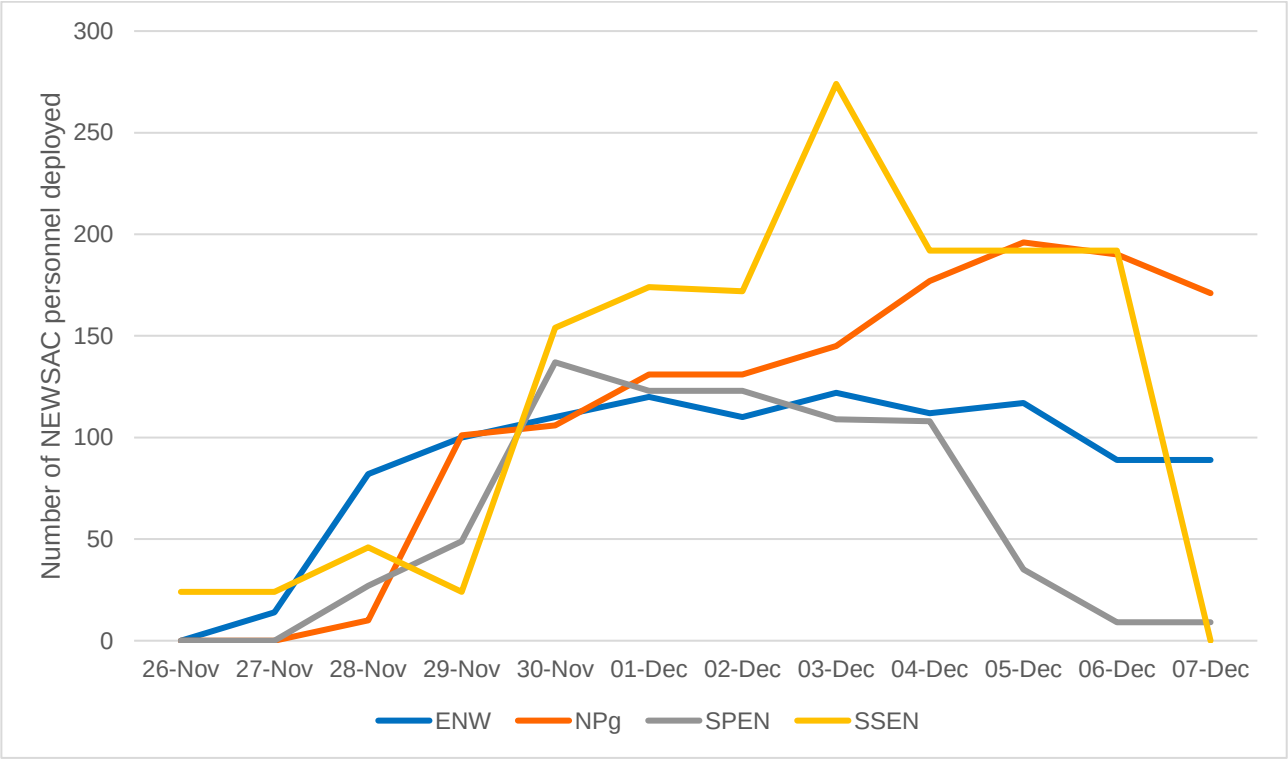
6.3.2 North East West South Area Consortium (NEWSAC)

NEWSAC set up through with the ENA involves all DNOs. It is designed for provide mutual aid in the event of a major incident, in this case a storm. It is recognised that the DNOs are resourced efficiently for the normal and increased activities during bad weather within their license area. In the case of an extreme weather event there is not be sufficient resource to undertake all the repair and restoration activities as quickly as would be liked. If the DNOs were to increase resources for extreme weather events, this would drive up costs which would need to be recovered.

Under the NEWSAC arrangement, in advance of storms, all companies communicate to review the potential requirements. If a storm event is forecast to impact some companies and not others, resources may be requested in advance of the storm and released. However, when the storm is forecast to hit most DNOs, then they will not release resources until it becomes clear what affect the storm has on each license area.

Figure 32 shows the number of personnel deployed under the NEWSAC arrangement and to which DNO they were deployed.

Figure 32: Number of NEWSAC Personnel Deployed



Source: Ofgem information request presentation 13/01/2022

All DNOs communicated in advance of Storm Arwen, and when it was apparent that UKPN were not badly hit with minimal damage, they started to release resources to other license areas. Over the following days resources were released primarily from UKPN and SSE (Southern) and from WPD to assist the licenses worst affected in the north of England and Scotland.

Table 6 below also shows the resources deployed through the NEWSAC mechanism, with a peak of 650 staff deployed into other license areas from where they are normally based. This identifies the DNO benefitting most with SSEN using 274 (03-December), NPg 196 (06-December).

There would have been NEWSAC staff moved to one DNO to assist initially and as the faults were repaired, they would then move on to another DNO to support their repair efforts.

Table 6: NEWSAC Personnel deployed

DNO	November					December						
	26	27	28	29	30	01	02	03	04	05	06	07
ENW	0	14	82	100	110	120	110	122	112	117	89	89
NPg	0	0	10	101	106	131	131	145	177	196	190	171
SPEN	0	0	27	49	137	123	123	109	108	35	9	9
SSEN	24	24	46	24	154	174	172	274	192	192	192	0
Total	24	38	165	274	507	548	536	650	589	540	480	269

Source: Ofgem information request presentation 13/01/2022

The NEWSAC mechanism was reported by all companies to have worked well and was instrumental in being able to maximise the available resource nationwide in major storms. It should also be highlighted that UKPN and WPD were donating the resources and excluded from this graph which demonstrates the cooperation achieved through NEWSAC.

6.3.2.1 Call centre mutual support

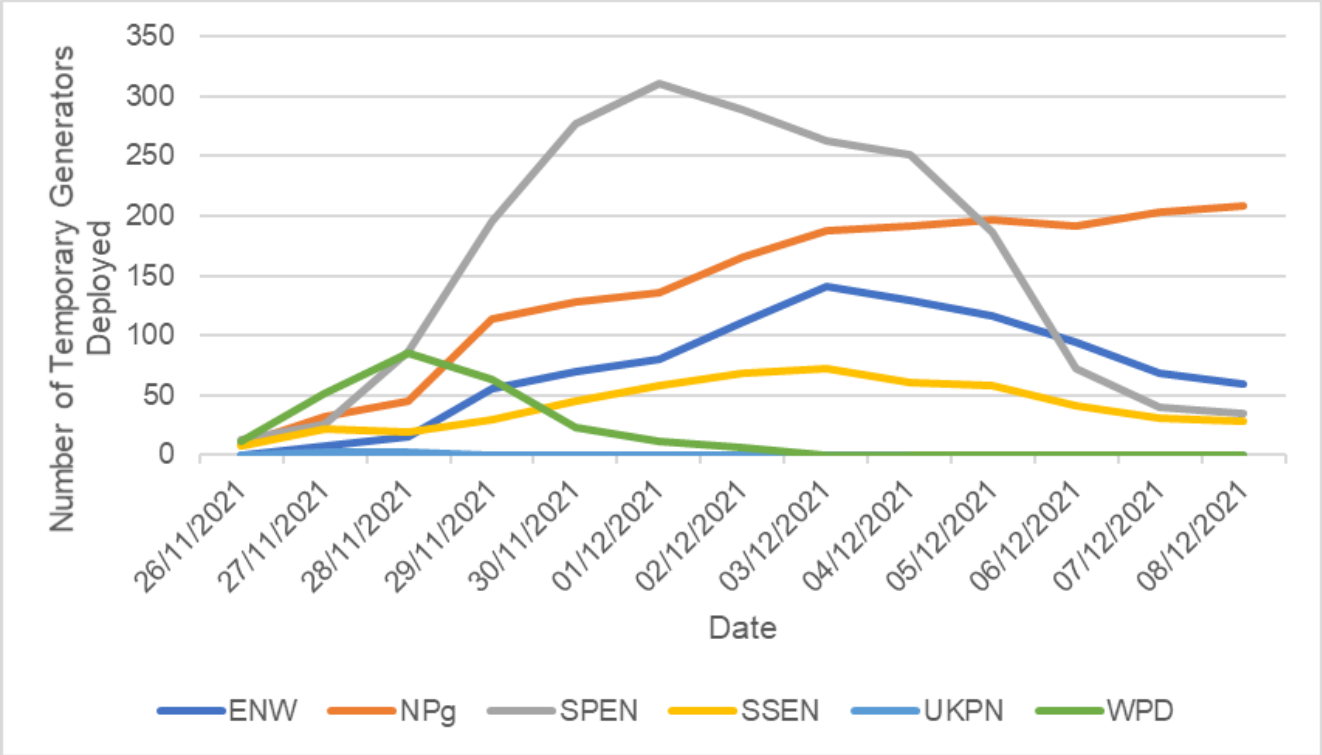
As part of the support across DNOs, UKPN, who were one of the least affected DNOs by Storm Arwen were able to provide call centre facilities and support to NPg. This is a relatively new arrangement and sits outside the NEWSAC consortium. It is a good example of the DNOs working with each other to be able to provide support in times of need.

6.4 Temporary generator plans and use

In restoring customer supplies DNOs can use mobile, temporary generators in situations where the permanent repair may take an extended period. This happens under normal ‘business as usual’ fault conditions, and particularly following major storms where the inability to resource overhead line repairs leading to extremely long interruption time. Once a mobile generator has been connected, customers have their supply restored and this also frees up the repair resource to continue restoring supplies to other customers.

Figure 33 below shows the number of generators deployed by each DNO. SPEN had 311 generators connected by 01-December reducing to 251 by 04-December, and 73 by 06-December when all customers were on supply.

Figure 33: Number of temporary generators deployed



Source: Ofgem information request presentation 13/01/2022; GHD information request 22/01/22

Of the DNOs with a high number of incidents and customers off supply, they utilised a high number of mobile generators. The utilisation by WPD similarly showed a rapid rise in generator connections to 85 by 28-November, reducing rapidly with all customers restored. ENWL utilised 141 and SSEN 72. Table 7 shows the number of generators that were being used each day.

Table 7 Number of mobile generators days used[25]

DNO	November					December							
	26	27	28	29	30	01	02	03	04	05	06	07	08
ENW	0	8	15	55	70	80	111	141	130	116	94	68	59
NPg	9	32	45	114	128	136	166	188	192	197	192	203	208
SPEN	13	26	87	196	277	311	289	263	251	186	73	40	35
SSEN	8	22	19	29	45	58	68	72	61	58	41	31	28
UKPN	0	2	2	0	0	0	0	0	0	0	0	0	0
WPD	11	52	85	63	23	11	6	0	0	0	0	0	0
Total	41	136	228	423	440	502	518	510	450	388	222	167	136

Source: Ofgem information request presentation 13/01/2022; GHD information request 22/01/22

It can be seen that the networks which were affected the most by Storm Arwen, were also utilising more of the mobile generators.

[25] This number is a sum of all the generators that were running each day. In some cases a generator may be moved on one particular day, and that would be counted as two.

6.5 Resilience of communication systems

There was significant disruption to mobile telecoms services during the storm. When supplies were lost to mobile phone masts, without a backup battery they ceased to function. The impact this caused was that customers could not inform the DNO of an interruption, which is the main mechanism that a DNO is informed of a fault in remote areas (discussed in detail in section 5.2. In addition, the company field staff use of mobile phones to communicate with control centres, emergency management centres and each to be able to operate effectively. In many instances this required staff to drive some distance to obtain a signal.

There was some difficulty finding who the appropriate contact was within the mobile phone companies. The resilience of the operation of the masts is an issue that will require further investigation to determine how that resilience can be provide either by supply security improvement from the distributor or having back up supplies on site provided by the mobile phone companies. Either approach will involve costs which will need to be built into the current funding mechanisms. We understand this will become a bigger issue when BT switches off the entire PSTN network as planned in 2025.

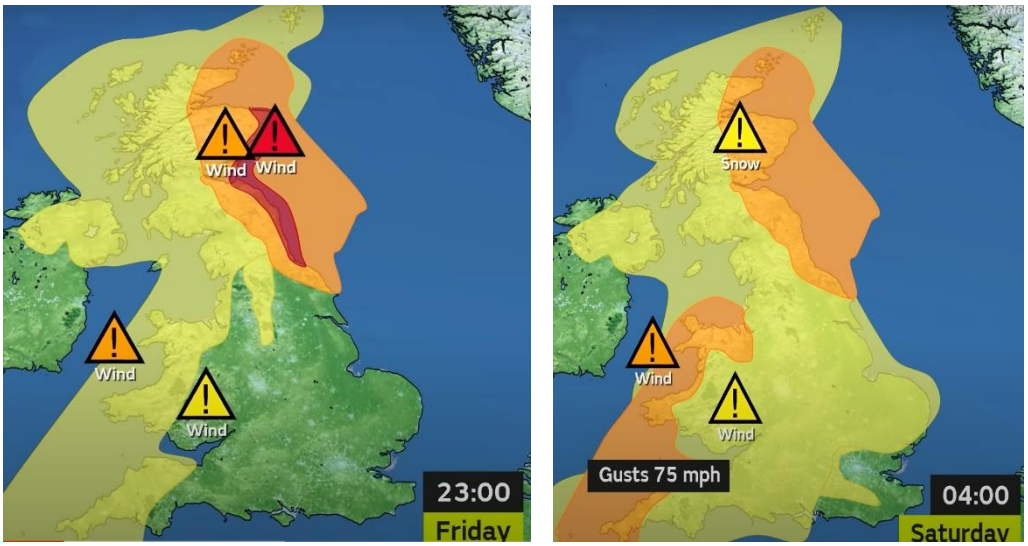
7. Conclusion

This section provides a summary and conclusion to the review of the preparedness of the network operators to Storm Arwen.

7.1 Summary of the weather

Storm Arwen progressed more severely than the initial forecast on Thursday 25-November, although closely to the forecast given on Friday 26-November. On Friday 26-November, a red weather warning was announced for the coastal areas in the northeast of the UK. As can be seen in Figure 34, high wind speeds were in predicted to commence on Friday 26-November at 23:00 and to last until the morning of Saturday 27-November.

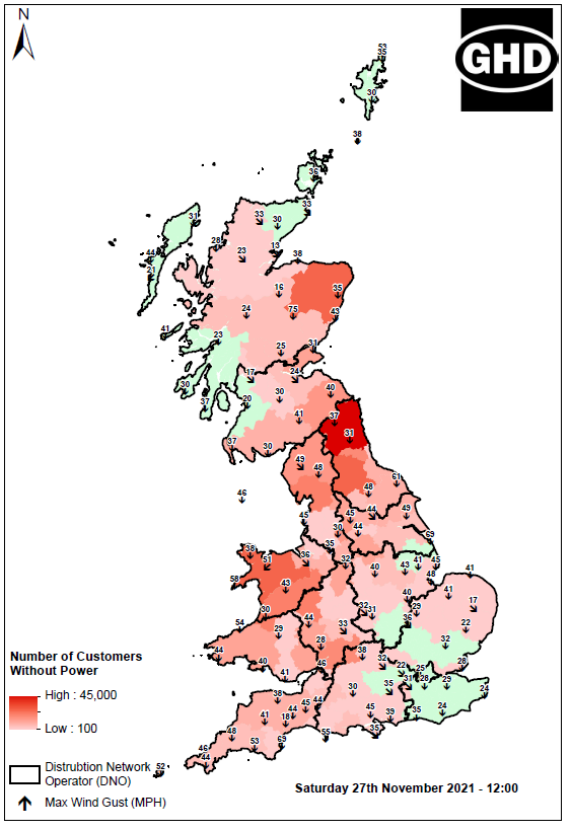
Figure 34: Met office weather forecast 26/11/2021 - weekend weather alerts



Source: Met office

By the afternoon of Saturday 27-November, there were high number of interrupted of customers mainly around Eastern Scotland and northern England. Figure 35 shows the number of interrupted customers and the recorded windspeeds.

Figure 35: Saturday 27-November afternoon wind speed outturn



Source: GHD analysis and presentation of Met Office; Ofgem information request presentation 13/01/2022

Windspeed gusts were recorded reaching 109 mph.

Human

Storm Arwen bore a human cost on the UK with 3 fatalities across the UK due to fallen trees. Additionally, several rail passengers in Aberdeenshire became stuck on a train overnight and many rail services were cancelled. There were severe disruptions on roads across the UK and on ferry services. The strong winds also created several incidents of structural damage to buildings.

Natural

Thousands of trees were felled across the north of the UK, including large mature trees leading to major disruption.[26] This is hypothesized to partially be due to the unusual wind direction, northerly as opposed to the more common westerly which may have been an additional factor as trees show forms of adaptive growth in response to wind movement to counteract the increasing vulnerability to windthrow[27].

Power transmission and distribution

Just under one million homes experienced power loss[28] with over 100,000 homes experience several days without power.

The last-named storm with a red weather warning was storm Dennis in February 2020, however this warning consisted only of a red rain warning. The last storm with a red wind warning was Storm Gertrude in January 2016.

[26] https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2021/2021_07_storm_arwen.pdf
[27] https://academic.oup.com/treephys/article/16/11-12/891/1663686?login=true
[28] https://www.gov.uk/government/publications/storm-arwen-electricity-distribution-disruption-review/storm-arwen-electricity-distribution-disruption-review-terms-of-reference

In terms of wind speed, the UK has experienced storms with a similar number of stations exceeding 70 mph, for example on 9 February 2020 over 30 stations recorded gusts exceeding 70 mph from storm Ciara, however Storm Arwen did have a different wind direction, which has been argued to have increased its impact.

Storm Arwen did take a slightly different turn to the predictions originally made, due to the higher wind speeds and the unusual wind direction. The weather warnings issued by the Met Office were a good reflection of the level of the storms impact and the necessary preparation needed for the storm.

7.2 Summary of network asset condition

All DNO's construct and maintain their networks to British and international standards and industry best practice. They also carry out routine inspections, follow up with maintenance, and vegetation management to similar standards.

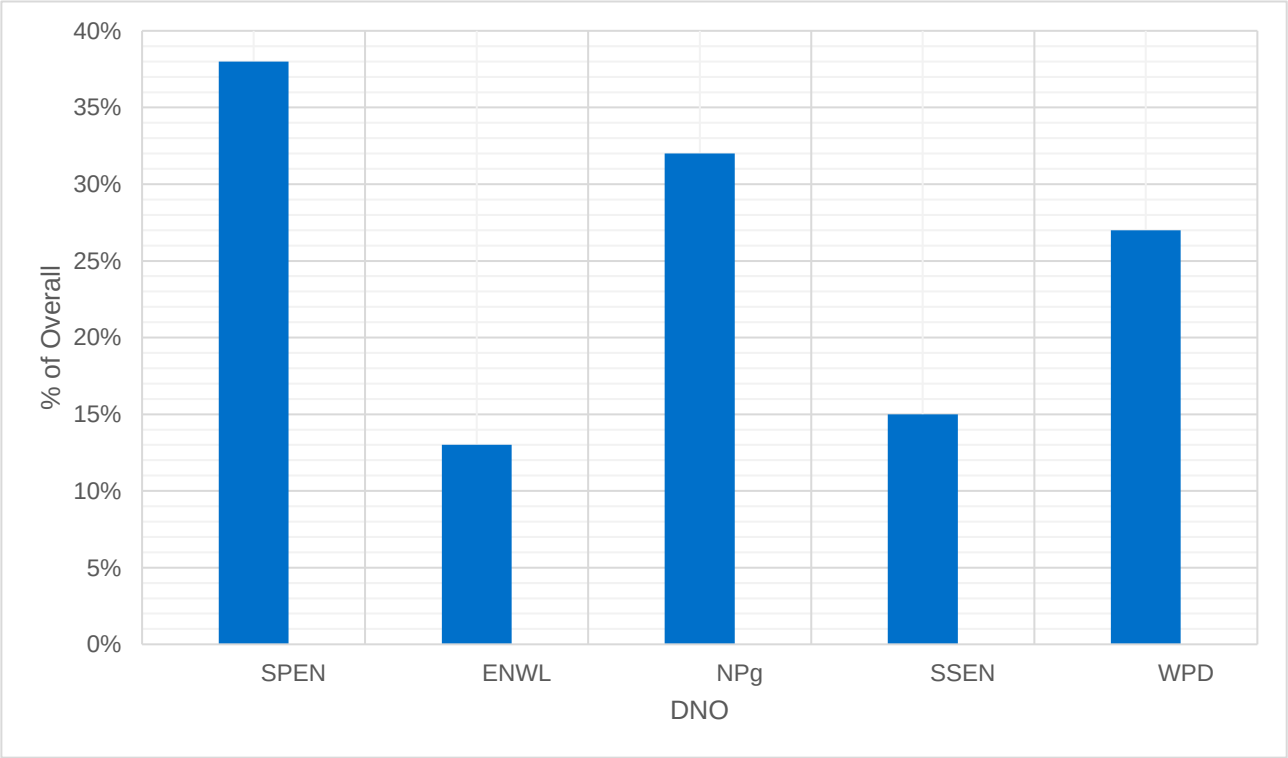
The impact of Storm Arwen was predominantly on the overhead line network with damage to conductors and poles. This review focuses closely on these assets.

7.2.1 Condition of damaged poles

The condition of assets, in this case wood poles, is expressed in terms of a Health Index (HI). The index ranges from HI1 – HI5 with 1 being the best condition and 5 the worst. Age is not necessarily a major factor in the condition assessment process.

GHD requested companies to provide information on the proportion of poles damaged during Storm Arwen that were rated at a HI4 or above. Responses were varied in both detail and format; however, the following collation has been distilled from the data provided Figure 36.

Figure 36: Proportion of damaged poles rated at HI4 and above



Source: GHD Questionnaire;

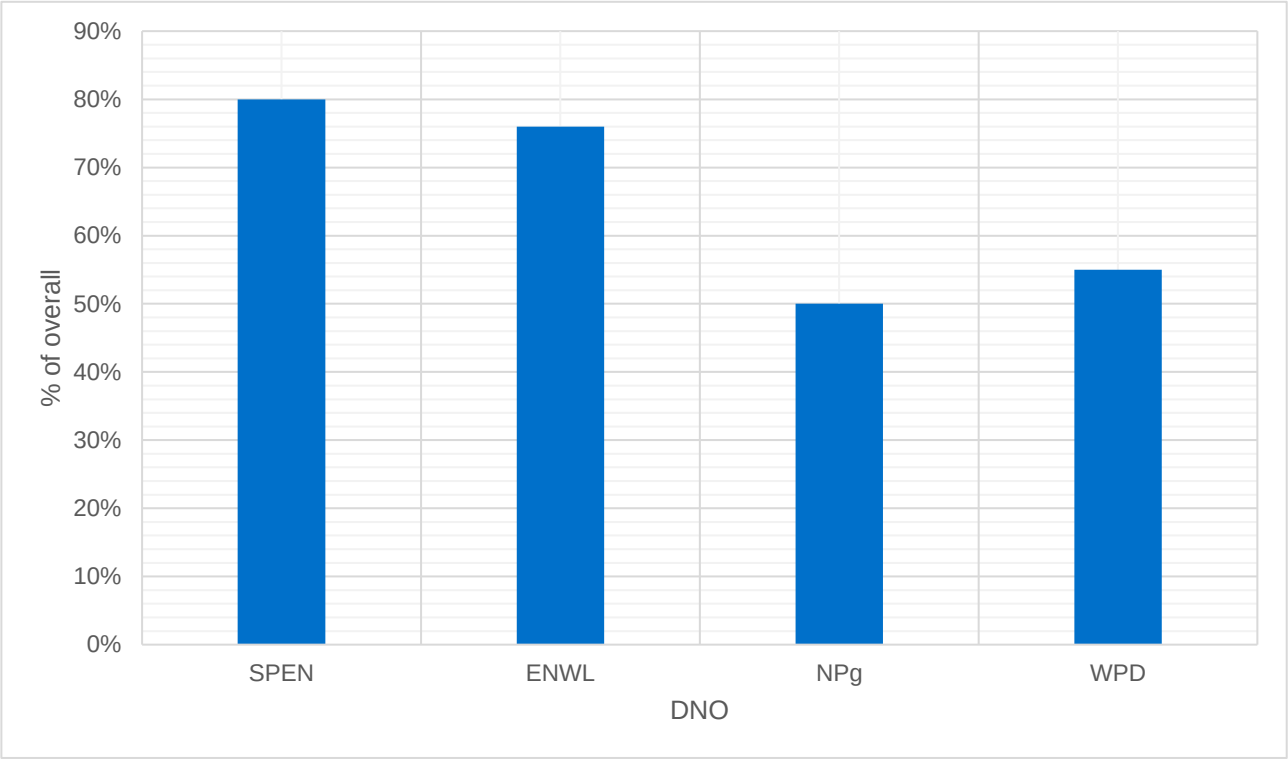
This shows a broad spectrum of results across companies and not the expected common link between condition and failure rate.

7.2.2 Age of damaged poles

GHD also requested companies to provide information on the age profile of poles that failed during Storm Arwen.

Again, responses were varied in both detail and format; however, Figure 37 is a collation which has been distilled from the data provided.

Figure 37: Proportion of damaged poles over 40 years old



Source: GHD questionnaire responses

From the information provided, there is sufficient weight of evidence to suggest a relationship between pole age and the numbers that failed. The conclusion drawn is that poles aged >40 years old, may be more susceptible to failure in abnormal weather conditions than is currently understood.

There is equipment available that can test the residual strength of a pole, which have been trialled under the innovation program, however the use of this equipment is not common or widespread across the UK DNOs.

We do recommend that there is a need to investigate and understand if older poles are more susceptible to failure, and if so, develop the necessary polices to test for these weakened poles.

7.2.3 Maintenance of overhead lines

All companies carry out periodic inspections on overhead assets generally between three to six years. They also have vegetation management policies which have been developed to maintain clearances between overhead conductors and adjacent tree branches primarily to prevent flashover.

All DNO's have a statutory duty to comply with ESQCR and to maintain minimum distances between overhead lines and any structure – with Storm Arwen we are referring to trees. ESQCR, abridged version requires the Distributor to maintain a minimum distance between live conductors and someone climbing a ladder leaning against a structure, or at tree. Safety clearances range from 3.6 m to 3.0 m depending on voltage of the overhead line.

With a typical mature tree height in the UK of between 10 – 20 m, it is obvious that the safety clearance requirements will contribute little to enhancing network resilience during an abnormal weather event such as Storm Arwen.

DNO's can also undertake a deeper resilience clearance of vegetation and trees, to limit vegetation related faults that can occur under abnormal weather conditions such as Storm Arwen, including problems caused by falling trees and wind-blown tree branches.

The overwhelming amount of tree cutting expenditure undertaken by DNO's is to maintain safety clearances and ensure their statutory compliance with ESQCR, not to ensure that trees are cut back far enough to ensure that they would not touch the line should the tree come down.

7.2.4 Overhead line expenditure

All companies submit data annually to Ofgem on expenditure and volumes of assets, known as the Regulatory Reporting Pack (RRP), the expenditure for 'overhead line clearance' is shown in Table 8.

Table 8 RIIO-ED1 allowances for overhead line clearance expenditure (£m)

DNO	Licence	RIIO-ED1 Allowances (£m)	RIIO-ED1 Spend to Date (£m)	RIIO-ED1 forecast spend (£m)
ENWL	ENWL	6.07	17.01	20.81
NPG	NPgN	-	5.36	5.36
	NPgY	-	3.85	3.85
WPD	WMID	-	19.96	29.61
	EMID	-	23.43	28.27
	SWALES	-	21.31	27.05
	SWEST	19.15	44.40	62.15
UKPN	LPN	-	-	-
	SPN	28.00	17.68	25.91
	EPN	44.58	70.43	81.14
SPEN	SPD	65.71	75.65	80.45
	SPMW	72.45	76.37	85.99
SSEN	SSEH	2.98	8.80	10.38
	SSES	-	31.23	34.65

Source: Ofgem ED1 RRP data – CV18 OH Clearances.

This data shows wide variances in the forecast expenditure to that incurred, and that forecast to the end of RIIO-ED1 (2023). SPEN and UKPN are expected to spend slightly more than their allowance, whereas NPg, WPD, ENWL and SSEN (Scotland licence) have no allowance but have incurred large expenditure.

The data indicates that NPg and SSEN licences have the lowest level of spend per pole in clearance activity. Although there are significant differences, this may reflect that expenditure in this category has not been correctly assigned, thus leading to apparent overspend.

We would recommend that this area is reviewed in more detail to clarify how the expenditure is being allocated.

7.3 Causes of interruptions due to the storm

All companies have detailed Emergency Plans which cater for extreme events including weather related events. Known as major Incident Management Plans. The plans have been developed over many years and have evolved following each incident to better improve the response. In the case of Storm Arwen, the plan was triggered by advance weather warnings.

The DNOs demonstrated their preparation for the storm event initiating emergency plans, communicating with staff and customers and between companies through NEWSAC. This was enacted several days before the storm and operated successfully throughout. In the event of a storm those companies worst affected will request resource to assist from the companies least affected.

The companies all performed in accordance with their emergency plans and worked with assistance from contractors and NEWSAC donated staff.

7.3.1 Cause of customer interruptions

For the DNO, the duration of the storm and the level of damage imposed across its network can cause delays in being able to affect repairs in a safe manner. This includes the ability to be able identify where faults have occurred which includes roads being blocked by trees falling across the road and limiting access to these areas.

Table 9 below shows the cause information provided by the companies.

Table 9 Cause of interruptions during Storm Arwen

Causes of the interruption	Number of Customers	% Customers
06 Wind and Gale (excluding Windborne Material)	677,708	68%
(blank)	87,119	9%
23 Falling live trees (not felled)	86,379	9%
03 Snow, Sleet and Blizzard	58,731	6%
71 Deterioration due to Ageing or Wear (excluding corrosion)	18,994	2%
21 Windborne Materials	13,831	1%
75 Operational or Safety Restriction	8,659	1%
Other	47,629	5%

Source: Ofgem information request presentation 13/01/2022

The primary cause of incidents was wind and gale as being responsible for 68% of all customer interruptions. Only 9% were reported as due to falling trees 6% snow sleet and blizzard. Only 1% of interruptions were due to windborne material e.g. tree branches. The initial assumptions immediately after the storm suggested that falling trees and windborne material were a significant contributor. However, this is not played out in the data submitted by the DNOs.

According to the data provided by the DNOs, the major contributing factor to interruptions was wind and gale, not falling trees, which would suggest that the design standard may be factor in the resilience of the network.

7.3.2 Number of customers interrupted

The total number of customers affected was over 950,000 with NPg and WPD seeing the largest number of 280,867 and 243,930 respectively. NPg had 2,537 customers still off supply after 7 days, whereas WPD had restored all but 26 customers after 3 days.

Customers affected by Storm Arwen

Just under one million homes experienced power loss[29] and over 100,000 homes suffered several days without power. Storm Arwen had the greatest affect in the northern parts of the UK. Four distribution companies (six licence areas) were severely impacted by the storm.

A summary of the number of customers affected is given below.

Scottish Power Electricity Networks recorded 189,133 interrupted customers across their two licenced areas (Scottish Power Distribution – Scotland, and Scottish Power Manweb – west of England / north Wales). They had restored 87.4 % of the interrupted customers in 24 hours and 99.99% of customers[30] by 29-November. All customers were back on supply by 02-December.

[29] https://www.gov.uk/government/publications/storm-arwen-electricity-distribution-disruption-review/storm-arwen-electricity-distribution-disruption-review-terms-of-reference

[30] 1,114 customers remained interrupted past 29-November.

Scottish Power deployed 407 Field Services Engineers from the 26-November rising to a peak of 892 by 01-December. They recorded 1,331 incidents during Storm Arwen. In addition, they deployed up to 311 generators providing temporary supplies in advance of repairs.

This represented a good response both through the first 24 hours and then through the repair phases on subsequent days.

Scottish & Southern Electricity Networks recorded 143,749 customers interruption, with the bulk of the interrupted customers residing in northern Scotland (Scottish Hydro Electricity Power Distribution licence) They had restored all but 54 customers by 03-December, with the final customer restored on 06-December.

Scottish & Southern Electricity Networks deployed 360 Field Services Engineers on the 26-November rising to a peak of 625 by 01-December. They recorded 2,273 incidents across their network and deployed up to 72 generators to provide supplies in advance of repairs.

Given the high number of incidents this was a good response in reducing the customer numbers quickly.

Northern Powergrid had 280,867 customers interrupted across their two licenced areas (Northern Powergrid – Northern and Northern Powergrid – Yorkshire). Northern Powergrid restored 98%[31] of interrupted customers by 30-November, reducing to 39 customers by 06-December and the final customer restored on 08-December.

Northern Powergrid deployed 410 Field Services Engineers on 27-November[32] rising to a peak of 664 by 03-December. This includes an additional 101 NEWSAC resources deployed from the 29-November rising to 196 by 05-December. They recorded 1,246 incidents across the two licenced areas.

Northern Powergrid's approach was to focus on restoring customer supplies via the main network rather than providing temporary generation. This is driven by the deployment of staff and the philosophy that if the staff are connecting generators, they are not affecting repairs.

The low level of generator use appears to be a contributing factor to the time taken to restore interruptions.

Electricity North West Ltd reported 74,983 interrupted customers for the duration of Storm Arwen dropping to 443 customers off supply by 01-December. All customers were back on supply by 04-December.

Electricity North West had 290 Field Services Engineers deployed by 28-November[33] rising to a peak of 341 by 02-December. This included additional support via NEWSAC, with an additional 122 Field Services Engineers deployed across their licenced area. In total Electricity North West reported 364 incidents across their network and deployed 141 generators to provide supplies in advance of repairs.

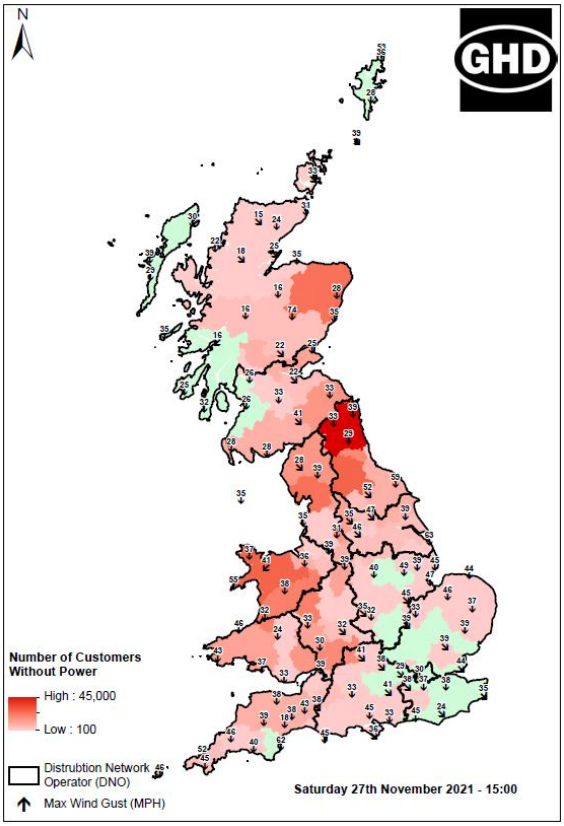
Figure 38 shows the number of interrupted customers and their approximate location at the peak of the Storm on Saturday 27-November.

[31] 5,717 customers remained interrupted past 30-November.

[32] Northern Powergrid deployed 54 Field Services on Friday 26-November. Storm Arwen affected the north of Scotland early on Friday 26-November and moved south over the day, affecting the north of England on Saturday 27-November. Northern Powergrid did not need to deploy staff large numbers of staff on the Friday

[33] Electricity North West deployed 55 Field Services on Friday 26-November and 149 Field Services on Saturday 27-November. As mentioned earlier Storm Arwen affected the north of Scotland early on Friday 26-November and moved south over the day, affecting the north of England on Saturday 27-November and moving east to west over the day. Electricity North West Ltd did not need to deploy staff large numbers of staff on the Friday and Saturday, but were deploying staff from Saturday 27-November with full deployment on Sunday 28-November.

Figure 38: Saturday 27-November morning wind speed outturn



Source: GHD; Met Office; Ofgem information request presentation 13/01/2022

Two companies were not as severely affected by the storm, UK Power Networks and Western Power Distribution. A summary is below for each of these distribution companies on how Storm Arwen affect their customers.

UK Power Networks were, in the most, unaffected with a total of 19,552 customers interrupted across the three licenced areas. All but 22 customers were reconnected in less than 24 hours, with the final 22 customers resupplied the next day.

Due to the low number of interruptions, UK Power Networks considers the Storm Arwen weekend more akin to a busy day for faults, but not an exceptional event. Over the weekend, UK Power Networks deployed 2 mobile generators, which represents the lower impact the storm had on their network.

Once the severity of Storm Arwen was established, UK Power Networks provided additional Field Services Engineers to the four worst affected distribution network operators.

WPD had the second largest number of customers interrupted due to Storm Arwen of 243,930 customers in total. The damage to the network was not a severe as seen in the north of the UK, and they restored 96.6% of customers within 24 hours. All but one customer was restored by the end of day 3.

Western Power Distribution recorded 1,642 incidents and they were able to resolve these incidents relatively quickly. WPD deployed 65 mobile generators at the peak to restore customers.

7.3.3 Mutual aid via NEWSAC

The NEWSAC arrangement was very effective and operated by all companies with those worse affected seeing excellent support from UKPN and WPD.

Overall, NEWSAC performed well and provided additional operational skills in a timely fashion.

7.3.4 Communications

The loss of communications from mobile phone masts affected customers communicating with the company and the communication by field staff in the areas affected.

The resilience of the operation of the masts is an issue that will require further investigation to determine how that resilience can be provide either by supply security improvement from the distributor or having back up supplies on site provided by the mobile phone companies. Either approach will involve costs which will need to be built into the current funding mechanisms. We understand this will become a bigger issue when BT switches off the entire PSTN network as planned in 2025.

7.4 Recommendations

A Summary of the findings of this review are given below.

– We collected data on the absolute age of the damaged poles, and we did see that between 50% and 80% of damaged poles that were over 40 years old. The conclusion drawn is that poles aged over 40 years old may be more susceptible to failure than is currently understood. We do recommend that there is a need to investigate and understand if older poles are more susceptible to failure, and if so, develop the necessary polices to test for these weakened poles.
– The data indicates that NPg and SSEN licences have the lowest level of spend per pole in clearance activity. Although there are significant differences, this may reflect that expenditure in this category has not been correctly assigned, thus leading to apparent overspend. We would recommend that this area is reviewed in more detail to clarify how the expenditure is being allocated.
– NPg had 1,246 incidents and restored 83.7% within 24 hours, which would be mainly through switching activities. The slower restoration over subsequent days with 4,094 customers remaining off supply after 6 days at which point all other companies combined had 1,651 off supply indicates a much slower response in restoring supplies and would represent the period where the effective application of the resources phase of the emergency plan was influencing progress. It would suggest that in the post event review the focus in NPg should be on that area to identify improvement plans.
– The loss of communications from mobile phone masts affected customers communicating with the company more than within the companies themselves. This meant that customers were not able to report loss of power, which is a mechanism used by the network operators to identify faults. We would recommend that this is reviewed in a larger context to determine how that resilience can be provide either by supply security improvement from the distributor or having back up supplies on site provided by the mobile phone companies. We understand this will become a bigger issue when BT switches off the entire PSTN network as planned in 2025

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