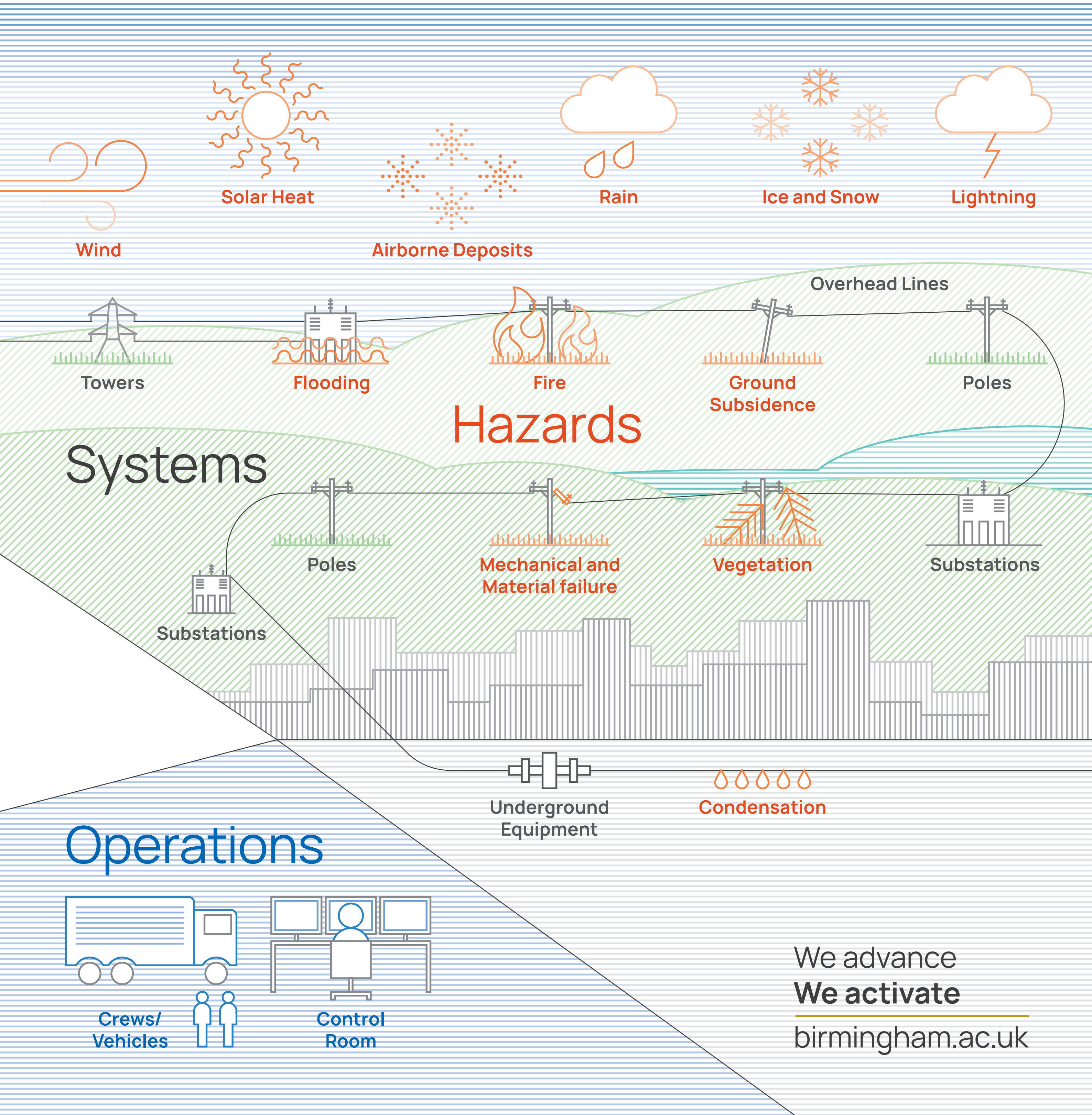
UNIVERSITY OF BIRMINGHAM

Informing standards for electricity distribution network resilience

Insight from IEEE Distribution Resiliency Guide and Metrics



We advance
We activate

birmingham.ac.uk

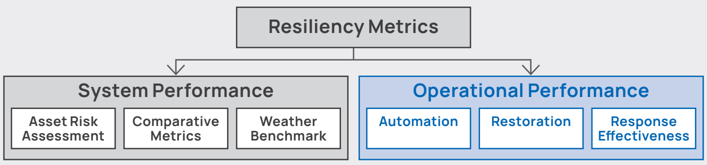
Why do we need to be resilient?

Electricity distribution underpins society including communication, health, transport and water. Therefore, a resilient network is essential. However, power outages during storms such as Arwen (2021)[1], Dudley, Eunice and Franklin (2022)[2], and Darragh (2024)[3] highlight the ongoing weather-related threats facing Distribution Network Operators (DNOs). These threats are expected to increase in frequency and magnitude as climate change brings more extreme heat and storms.

How can collaboration help?

The UK energy sector is actively working together to ensure a suitable level of climate resilience. While resilience metrics have yet to be developed in the UK, significant international efforts to define distribution resilience metrics have been underway via the *Institute of Electrical and Electronic Engineers (IEEE)*[4] Distribution Resiliency Taskforce with the metrics shown in Fig. 1. This policy briefing applies the approach laid out by IEEE to data from UK DNOs as shown in Fig. 2, offering insight to the development of resilience metrics in the UK.

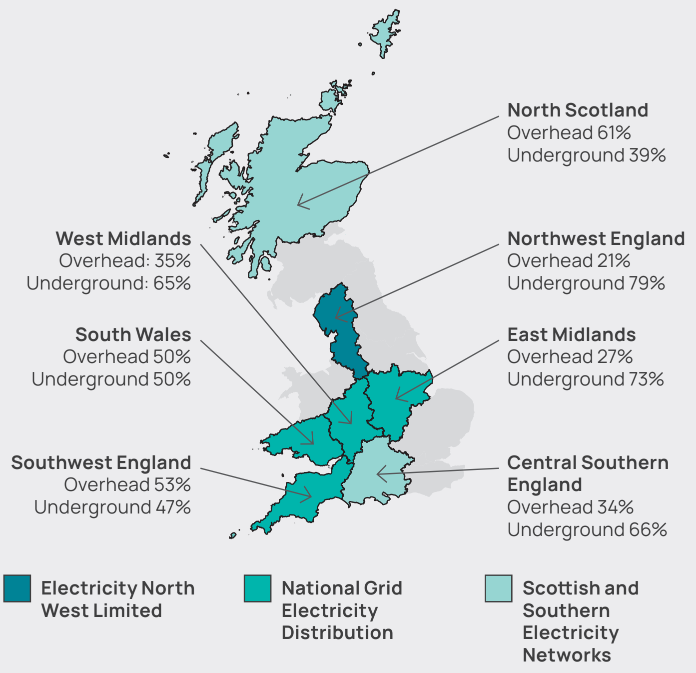
Fig. 1 **IEEE Distribution Resiliency Metrics**



Metrics currently under development by IEEE Distribution Resiliency TaskForce

The first step is to understand the relationship between hazards and electrical **assets that may be at risk** as shown in Fig. 3. DNOs have robustly assessed weather and climate related hazards through four rounds of climate change adaptation and vulnerability assessments[5] alongside annual Quality of Service filings. Ofgem provides a standard set of codes mapping failures on the distribution network to specific hazards[6]. Table 1 shows weather related categories and impact informed by DNO Adaptation Reports[5].

Fig. 2 **Data was collected across seven License Areas and three Distribution Network Operators with different composition of overhead and underground networks**



Supported by National Energy SO Open Data

Fig. 3 **Weather caused 20% of outages but 49% of Customer Minutes Lost (CML)**

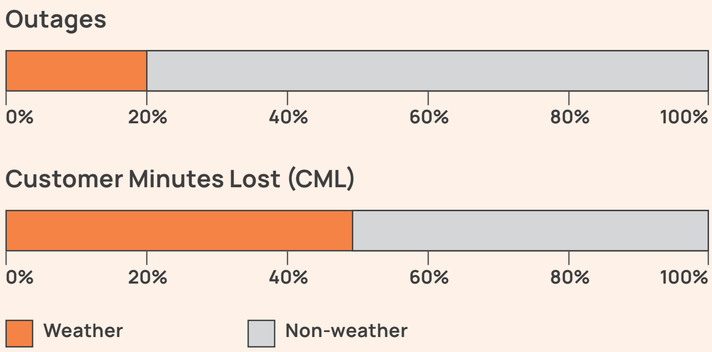


Table 1 **Weather and environment related hazards affecting electricity distribution networks**

Category (Ofgem ID)[6]	**Impact**[5]
Airborne Deposits (10)	Deposits create conductive paths which lead to short circuits and equipment failure and increase the weight of lines.
Condensation (14)	The presence of water can degrade components, lower efficiency, and lead to faults.
Fire (19)	Extreme heat can damage or destroy infrastructure, and smoke reduces dielectric strength of the air leading to faults.
Flooding (18)	Water can damage physical equipment as well as causing faults within assets and network components.
Ground Subsidence (17)	Movement increases forces on cables, joints, leading to damage or failure of equipment.
Ice and Snow (03, 04, 05)	Snow sleet and blizzard, freezing fog, frost and ice increase loading on equipment, causing damage or failure.
Lightning (01)	Surges in current due to lightning cause the disconnection of lines and generation and damage assets in extreme cases.
Mech. & Material Failure (15, 16, 22, 26)	Corrosion, mechanical shock or vibration, can lead to the failure of equipment.
Rain (02)	Water can damage physical equipment as well as causing faults within assets and network components.
Solar Heat (07)	Thermal expansion increases the sag of lines and reduces efficiency.
Vegetation (23, 24, 25)	Growing and falling trees can reduce clearance distances or contact equipment leading to faults and physical damage.
Wind (06, 21)	Wind, gale and windborne materials cause material to contact lines, causing faults, as well as damage to poles and towers.

References

1. Ofgem (2022) Link
2. Met Office (2022) Link
3. Met Office (2024) Link
4. IEEE Distribution Resiliency Guideline Link
5. ARP4 Reports Link
   ARP3 Reports Link
6. Ofgem (2023) Link

How can a suite of IEEE metrics help?

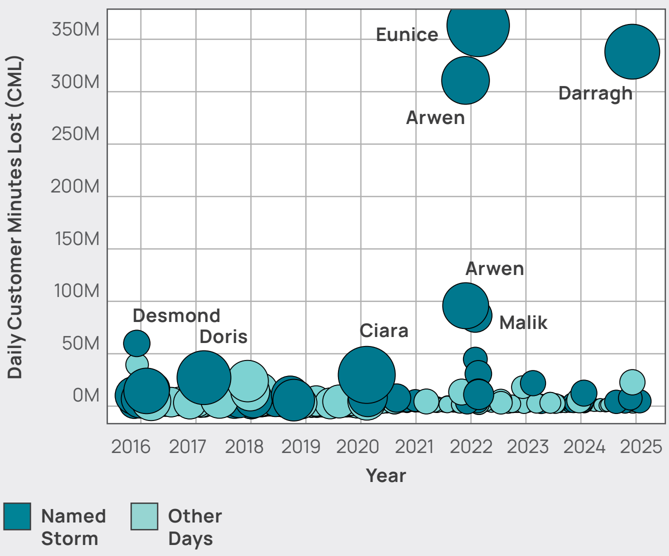
Comparative metrics provide a way to evaluate changes that take place over time when comparing similar types of events, offering insight into the trajectory of resilience (degrading, maintaining, or improving). This builds upon prior IEEE work in the area of distribution reliability[7]. When tracked over a longer period, comparative metrics provide a means to determine where adaptation may be most effective, and whether past adaptation efforts are providing benefit. IEEE recommends comparison of each of the standard components which comprise risk: e.g. hazard (magnitude, duration, and extent), exposure (assets), vulnerability (damage and performance), as well as the risk response (restoration). Fig. 4 shows the daily customer minutes lost across a 10-year period, demonstrating most extreme impacts are a result of named storms. Fig. 5 shows a comparison between different individual named storms.

Weather benchmarking is the next aspect of the suite of metrics proposed by IEEE. An overview is shown in Fig. 6. This metric includes taking each weather parameter of interest and determining whether there is a statistical relationship between the parameter and the number of outages observed on the network. Extensive analysis has been completed for the UK in this area[8] but has primarily focused on wind due to its link with high impact events. These relationships vary regionally and are compounded by other factors including season, wind speed and wind direction[9]. Therefore, analyses should move towards predictive analytics to capture these and other features.

Automation was a fundamental shift in distribution network design in the 1970s that led to enhanced performance[10]. As that automation has advanced with smarter grids, digital communication, and deployment of modern equipment, this provides further benefit for distribution network resilience through outage avoidance. When considering metrics for resilience, investigation of the extent to which automation reduced the magnitude of outages, such as the use of microgrids, batteries, and flexibility is a critical consideration. This can be used to create a counterfactual which further informs the business case for automation investment, as well as indication of the true picture of event impact.

> "... comparative metrics provide a means to determine where adaptation may be most effective, and whether past adaptation efforts are providing benefit."

Fig. 4 **The largest impact to distribution networks has come from days with named storms**



Size of bubble shows number of outages. Named storms from Met Office starting in 2015/16. Link

Fig. 5 **Comparison across storms can reveal trends in storm response across a single DNO**

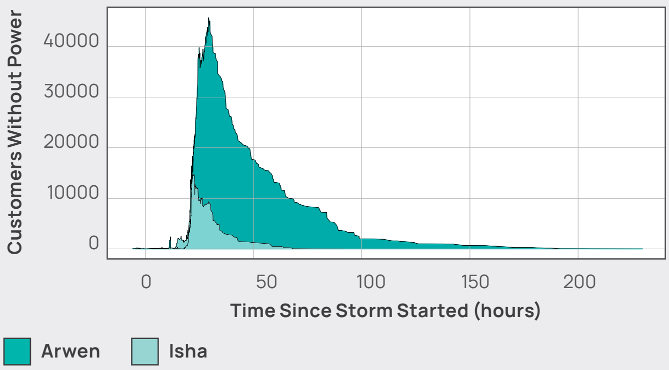
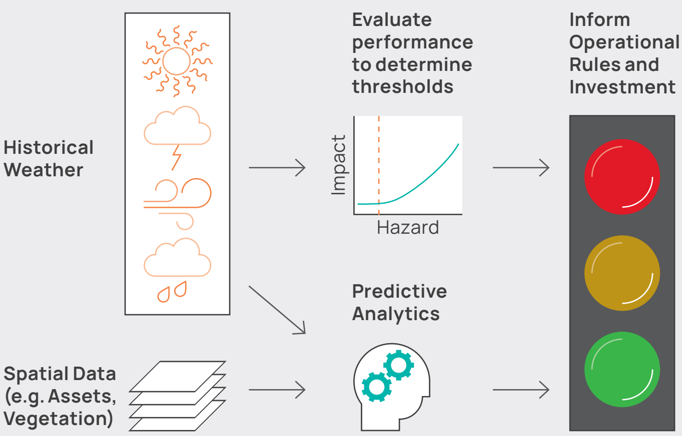


Fig. 6 **Weather benchmarking provides insight into historical asset performance and is shifting towards predictive analytics to capture additional features and impact of compounding hazards**



References

7. IEEE 1366 Link, IEEE 1782 Link
8. Dunn et. al 2018 Link
9. Donaldson et. al. 2023 Link, Manning et. al. 2025 Link
10. Gers 2013 Link
11. Notice of Rights Link
12. Predict4Resilience Link, CReDo+ Link
13. ENWL Link, SPEN Link, SSEN Link, UKPN Link

Restoration of customers within a specific period of time is a further means to evaluate the response. However, the ability to respond will vary significantly across hazards and regions. Fig. 7 shows regional differences in restoration. One means to address this presented by IEEE is through clustering hazards by severity and assigning thresholds for response time to each. This is similar to the current approach within the Interruption Incentive Scheme (IIS) whereby high voltage outages are used to split severe weather events into medium (8x average) and large (13x average)[11]. While the approach to calculate a threshold is consistent across DNOs, the thresholds themselves will differ significantly due to the heterogeneity across regions (e.g. differences in hazard, assets, terrain).

Emergency response effectiveness captures the effect of the resources that are deployed in response to a given event. This includes comparing the rate of restoration, and the average crew hours per customer restored or outage. By excluding the extreme values, insight is given into the typical rate of response, for a given district, and can lead to better insight into where investment or pre-positioning of resources may lead to further benefit for customers.

What should DNOs/policymakers do?

When applied, these metrics quantify the magnitude of impact to electricity distribution networks from weather and climate related hazards. This provides insight into where investments could be made to improve overall resilience, but the right level of resilience remains an open question that should be refined in collaboration between DNOs, Ofgem, academia and other key energy sector stakeholders.

Develop predictive analytics: Traditional fragility-based approaches often do not account for compounding effects and other factors such as asset health, design criteria, and vegetation. This prompts the need for more advanced methods as depicted in Fig. 5. UK DNOs are making significant headway using the latest technology to further understand these relationships[12]. Furthermore, while the correlation between historical weather and impacts to the system can be determined, as the climate changes these past relationships may not be a suitable indicator of future performance. This demonstrates the need for further predictive measures of performance.

Enhance data collection: Comparative metrics and statistical benchmarks require sufficient historical data to provide meaningful insight into performance trends. The National Fault Incident Recording System (NAFIRs) and the Ofgem Interruption Incentive Scheme provide a means for tracking of these statistics across DNOs on a common base. With growing dependence on the electricity sector, a more systematic mechanism to link weather and impact data nationally would support the UK's clean energy mission. Many DNOs already publish this information[13] and making this data more readily available to researchers and policymakers would support further national benchmarking exercises.

Fig. 7 **Restoration can be understood for a single event such as Storm Arwen using resilience curves that demonstrate the storm's progression and impact across DNO license areas**

Guidance document by Daniel L. Donaldson, and Saif Al Omairi at the University of Birmingham in collaboration with Electricity North West Limited, National Grid Electricity Distribution, Scottish and Southern Electricity Networks, Shikhar Pandey (Chair – IEEE Distribution Resiliency Task Force), Heidemarie Caswell and Tyler Jones (IEEE Distribution Reliability Working Group).

Funded under Research England QR funding provided to the University of Birmingham [PSF-57], and EPSRC Supergen Energy Networks Hub EP/Y016114/2. This document should be cited as: Donaldson, DL., and Al Omairi, SA., (2025) *Informing standards for electricity distribution network resilience: Insight from IEEE Distribution Resiliency Guide and Metrics*. University of Birmingham, UK. https://doi.org/10.25500/epapers.bham.00004399.

electricity north west — Bringing energy to your door · nationalgrid · Electricity Distribution · Scottish & Southern Electricity Networks