

From Risk to Resilience: Advancing visibility and performance across the electricity network

Independent expert analysis by:

Dr Aidan Rhodes
Dr Fei Teng
Kaylen Camacho McCluskey
Dr Yi Wang
Dr Raffaele Della Croce

From Imperial College London

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DNOs should reconsider traditional resilience paradigms, moving from a reactive “fix-on-fail” approach towards a proactive “predict-and-prevent” strategy enabled by digital monitoring technologies.

Executive Summary

DNOs are navigating a complex landscape of resilience challenges, characterised by an ageing asset base, increasing electrification and dependence on electricity, and more severe extreme weather events. The UK’s existing electricity networks were largely built during the post-war expansion of the 1950s and 1960s. Today, this translates to an expansive and mature asset base, including over 800,000 kilometres of overhead lines and underground cables.

Given that these assets were traditionally rated for 40 to 60 years of use, a significant portion of the grid is nearing or has exceeded its operational design lifetime. Concurrently, the replacement of these assets has become progressively slower and more expensive due to inflationary pressures in the supply chain. For example, the lead times for large, high-voltage transformers have significantly increased, extending from a few weeks to several years. Furthermore, the escalating peak demand resulting from increased electrification of the grid, the proliferation of distributed generation assets, and the heightened reliance of customers on uninterrupted electricity supplies have exerted substantial strain on the networks.

These vulnerabilities are significantly exacerbated by the escalating threat of extreme weather events. The period from 2021 to 2026 has seen an almost unprecedented sequence of destructive winter storms, including Arwen, Darragh, and Éowyn. Storm Arwen alone left approximately one million customers without power and exposed the challenges for DNOs identifying and responding to “nested faults” on lower-voltage networks. DNOs should therefore reconsider traditional resilience paradigms, moving from a reactive “fix-on-fail” approach towards a proactive “predict-and-prevent” strategy enabled by digital monitoring technologies.

As the UK resilience context changes – driven by policy targets, increasing risks from climate change and a growing system-wide dependence on electricity – the regulatory and policy frameworks governing distribution network resilience must also change.

Resilience in the current regulatory framework: RIIO ED2

Since 2013, RIIO (Revenue = Incentives + Innovation + Outputs) has been Ofgem's regulatory framework for driving improvements in the UK's energy networks. For each five-year RIIO price control period, DNOs submit business plans with agreed targets to Ofgem and can be financially rewarded for meeting and exceeding them.

RIIO ED2 began in 2023 and will run until 2028. Regulatory incentives in ED2 and previous price controls have driven measurable improvements in overall distribution network resilience and DNO customer service. The Interruptions Incentive Scheme (IIS), for example, has been demonstrably effective in catalysing improvements in network reliability – since its introduction, Consumer Interruptions (CI) have more than halved, falling from 86.60 to 39.71 customers interrupted per 100 connected customers¹.

The reception of RIIO ED2's resilience approach has been mixed. Under ED2, interventions that serve the long-term interests of consumers are challenging to justify, particularly in the context of measures to enhance resilience. In such cases, value is frequently associated with consumer outcomes that occur within the short-term regulatory cycle rather than those that deliver longer-term enduring value. Early indications, for instance, suggest that DNOs have not significantly increased load-related expenditure to prepare for higher future peak demand.

There have also been unintended distortions. Despite its strong historic track record, the IIS contains a design feature that, from a climate resilience perspective, inadvertently weakens incentives: severe weather events are excluded from the scheme. DNOs therefore have limited financial incentives to invest in resilience against the kinds of outages that are expected to become more frequent as a result of climate change².



Looking ahead: resilience in RIIO ED3

While not yet finalised, resilience outcomes in the proposed ED3 framework (2028 – 2033) are more strongly aligned with longer-term strategic goals, including Clean Power 2030 and Net Zero 2050, reflecting clearer government positioning on policy priorities. This longer-term approach is also supported by a more coherent and consistent view of what it means for UK networks to be resilient. The question now is how effectively that intention translates into incentives which provide network operators with the clarity to make investment decisions from here through to 2050.

Key changes from ED2 to ED3 resilience strategy

- Stronger focus on aligning investment in the price control period with short and long-term resilience needs and broader government strategic ambitions. Emphasis on “touching the network once”, enabled by transitional Regional Energy Strategic Plans (tRESPs) – long-term, regionally-tailored plans mapping DNO optimal cost and risk profiles through to 2050.
- Stronger focus on making resilience investments more tailored to regional specificities, requirements and ambitions, also enabled by tRESPs.
- Stronger focus on climate resilience and preparing the network to be resistant to extreme weather events. Existing incentives from ED2, including IIS, Network Asset Risk Metric (NARM) and Guaranteed Standards of Performance (GSOP), will be adapted to more actively incorporate climate resilience.
- Stronger focus on ensuring security of supply for all consumers, particularly Worst Served Customers (WSC). DNOs will be expected to publish more detailed data on customers and regions experiencing persistent unplanned interruptions. DNOs will also be expected to minimise the impact of even very short (<3 minutes) power cuts.

While the language and ambition of ED3 shows a strong commitment to resilience, how this is to be practically enacted through incentives is less clear. Four potential risks to network resilience planning in ED3 are highlighted below:

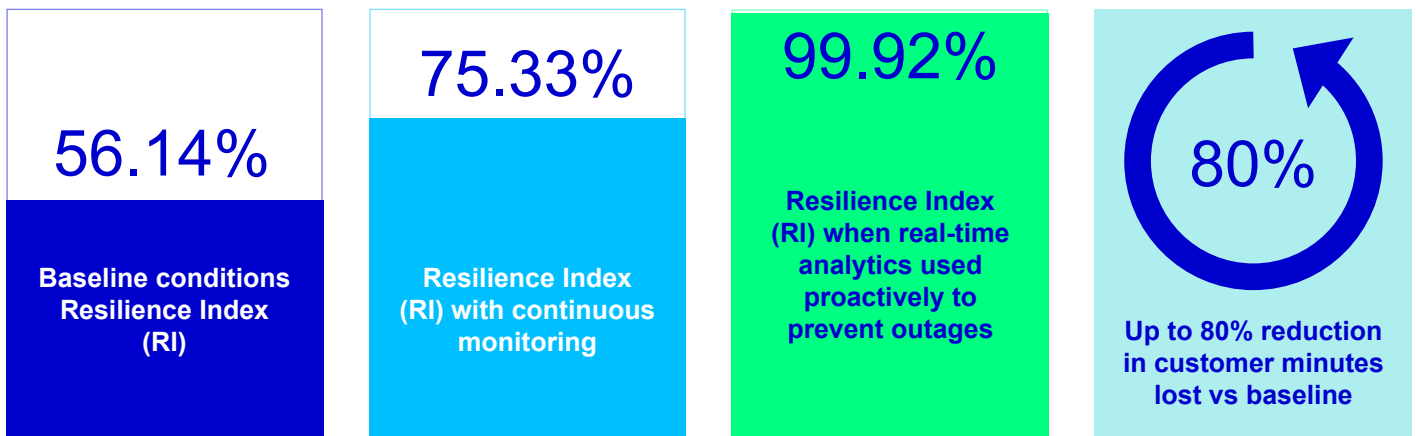
- **Gaps between the strength of the narrative and the strength and scope of the proposed incentives:** While financial incentives like the IIS have proven effective, reputational incentives to improve resilience (e.g. Climate Resilience Strategies) have been less so. ED3 does not propose to materially change this approach; particularly in relation to IIS storm exemptions. Given the monopoly status of DNOs, we would also question the efficacy of reputational incentives as a mechanism for motivating DNOs to invest in resilience.
- **Tension between short-term funding cycles and long-term system resilience investment needs:** Regulation has to balance the goal to reduce unit cost (i.e. delivering outputs as efficiently as possible within the regulatory cycle) and the goal to maximise whole system value (i.e. delivering outputs with the greatest system-wide customer benefits over the long-term). One roundtable participant suggested that incentives in ED3 are still largely set around minimising unit costs within period as opposed to touching the network once to deliver optimum value for customers.
- **The absence of metrics, standards or indicators to measure progress against resilience goals:** It was established that a set of Climate Resilience Metrics and Indicators (CRMIs) would be ready to be incorporated into DNO business plans and tRESPs by ED3. However, stakeholders have flagged that the development of CRMIs is lagging behind and unlikely to be complete in time³. ED3 risks being an extension of ED2 in this sense – with climate resilience strategies falling by the wayside or being measured so differently across different network operators that comparison is challenging.
- **Missed opportunities to reward investments that deliver co-benefits:** While new customer outcomes built on resilient, smart and net zero networks show closer alignment with policy ambitions, the associated incentives do not look to appropriately reward investments which deliver value across several outcomes. For instance, in ED3 there is a discrepancy between the narrative recognition that digitalisation has a role to play in supporting the development of a smart *and* resilient grid, and the resilience-related incentives, which do not actively guide DNOs to invest in ways that prioritise technologies with wider system value.

Digitalisation for network resilience

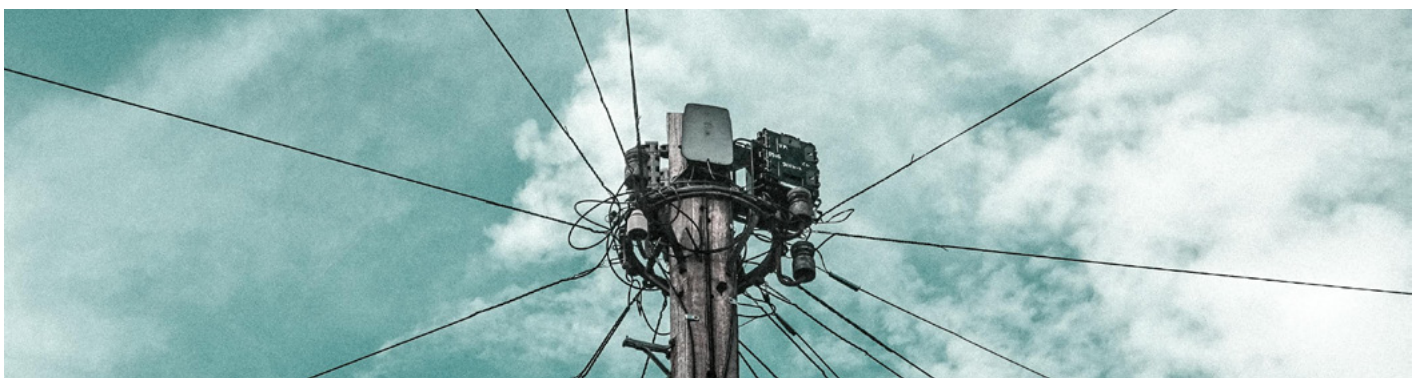
There are various prospective technologies which can support network resilience. Drone-based visual inspections are highly effective but are inherently intermittent and constrained by severe weather conditions, as well as line-of-sight regulations. Mobile storage units and Distributed Energy Resources (DERs) are valuable for localised load restoration but offer limited diagnostic visibility across the wider system. Machine learning analytics and digital twins provide unparalleled decision-making speeds and operational flexibility, provided they are fed by robust, real-time data.

Among these, continuous line monitoring stands out as an important new foundational capability. Permanently installed advanced line sensors provide real-time data on network conditions, enabling automated fault detection and proactive asset management regardless of weather conditions. A quantitative analysis, based on a large 1,725-bus distribution system model, underscores this value. Under baseline conditions without advanced monitoring, the system achieves a Resilience Index (RI) of only 56.14% during severe storm disruptions. By utilising continuous monitoring to eliminate response delays and enhance fault detection accuracy, the system's RI improves substantially to 75.33%. Furthermore, when real-time analytics are used proactively to prevent outages before they occur, total system resilience reaches 99.92%, accounting for both storm days and blue sky days. This is equivalent to a 58% reduction in customer minutes lost versus the baseline scenario. When accounting for future ageing assets, the benefit from continuous monitoring is even more significant, with an 80% reduction in customer minutes lost observed. These improvements are unaffordable using traditional asset heavy solutions and the results suggest that DNOs should prioritise investment in continuous monitoring as a foundational capability to enhance network visibility and resilience.

The results suggest that DNOs should prioritise investment in continuous monitoring as a foundational capability to enhance network visibility and resilience.



Resilience Index (RI) based on 1,725-bus distribution system model analysis



Policy recommendations

1. Strengthen incentives to drive long-term resilience

- a. Ofgem should move more decisively toward financial incentives for resilience measures.
- b. Incentives must better reflect long-term value.
- c. Incentives should go further to reward outcomes delivered, rather than just the presence of resilience technologies.
- d. Storm-related exemptions on CI and CML should be progressively scaled back to drive improvements.
- e. Ofgem should enhance existing mechanisms and introduce new incentives on leading delivery indicators.

2. Support investment in high-impact technologies

- a. Ofgem should provide stronger and more prescriptive guidance on what constitutes effective resilience investment.
- b. Ofgem should more clearly prioritise investments that deliver multiple system benefits.
- c. The Innovation Roll-out Mechanism (IRM) should be adapted to support high impact scale-up technologies which can materially improve customer outcomes.

3. Improve transparency and accountability

- a. Ofgem should mandate centralised, standardised and comparable reporting across all DNOs.
- b. Clear metrics, indicators and standards (e.g. CRMIs) should be developed, implemented, and enforced as part of ED3 to guide investment, with comparative assessments published to measure performance and ensure accountability.
- c. A standardised qualitative framework for DNOs to justify climate resilience investments in business plans should be adopted with a mechanism to ensure accountability for delivery.

4. Provide clearer strategic direction from government

- a. The Department for Energy Security and Net Zero should ensure the forthcoming Energy Resilience Strategy provides clear direction to Ofgem and DNOs to prioritise long-term resilience, security of supply and public safety.
- b. NESO and DESNZ should improve understanding of critical connections to the energy system, mapping of dependencies between energy and other Critical national infrastructure (CNI) and accelerating the development of shared data products and analytical tools. As part of the Energy Resilience Strategy, DESNZ and the Cabinet Office should work across government departments considering options for embedding power resilience across all CNI sectors.

For full recommendations see p32

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Introduction

Electricity networks are undergoing a profound period of change and investment, driven by the transition towards a net-zero power system and the electrification demands of heating and transportation. Distribution networks especially are undergoing significant upgrades, with both the expansion of physical assets and the utilisation of new digital technologies required in order to handle the increased demands of electrification and distribution-connected generation. The UK has historically enjoyed some of the highest standards of electricity reliability in Europe, with excellent (above 99.9%) uptime over recent years. The timeline pressure of the Clean Power 2030 target, under which clean sources must produce at least 95% of Great Britain's electricity within four years, is driving rapid growth in the connection of distributed generation, anticipating new demand from electric vehicles and heat pumps, and facilitating the broader electrification of the economy. The National Infrastructure Commission (NIC's) February 2025 report estimated that between £37 billion and £50 billion of distribution network investment could be required to 2050⁴, representing at least a doubling of current annual allowances. A more volatile geopolitical environment, showcased by two major fossil-fuel supply chain shocks over the past four years, underscores the need for a more resilient energy system capable of utilising diverse and flexible sources, with the Iran crisis in particular expected to lead to a push for greater energy security through distributed renewable resources.

Maintaining the resilience of the network and its reliability to customers throughout this period of rapid and dramatic change is a significant challenge, exacerbated by the age of many network assets, the increasing costs of replacement due to supply-chain pressures and the need for a rapid expansion of skilled workforce. In addition to these everyday challenges, the need for resilience against high-impact low-probability (HILP) weather events such as storms, flooding and heatwaves is ever-present and may be exacerbated in the future due to the advance of climate change. Storms Arwen, Darragh and Eowyn caused significant disruption to regional networks over the past few years. Society has become increasingly dependent on electricity due to recent changes such as an increase in working from home and a greater reliance on digital communications for both working and other economic activities such as commerce. Furthermore, an increase in downed lines due to storms can pose potentially deadly public safety hazards.

In parallel to these resilience concerns, digital technology has advanced at an unprecedented rate over the last couple of decades, enabling considerable changes in the way devices can communicate, monitor, analyse and display data. Importantly, many of these technologies can increase operators' visibility of their networks, enabling efficient pre-fault detection, rapid location of faults and customer outages, and rich data-collection capabilities to enable advanced network and asset analytics. This has the potential to provide more security and resilience to networks as well as the development of new paradigms to develop and control energy systems. However, these technologies would need to be adopted by network operators on a large scale to provide maximal advantages and would need to be supported by policy and regulatory changes to aid adoption and unlock initial capital spend.

While national electricity network resilience strategies are to some extent localised based on local climate conditions and geological stability, the need for modern, resilient networks is emerging as a priority among many nations in recent years as systems age, extreme weather events increase in frequency and new distributed generation systems and digital technologies become available to markets. At the *Future of Energy Security Summit hosted by the International Energy Agency (IEA) and the United Kingdom government in April 2025*, participants emphasised that *natural hazards and extreme weather events pose an escalating threat to global energy systems*⁵. The IEA's *State of Energy Innovation 2026* report⁶ emphasises the role of digital technologies, including proactive sensing and intelligent analytics, in seeing problems before they cascade.

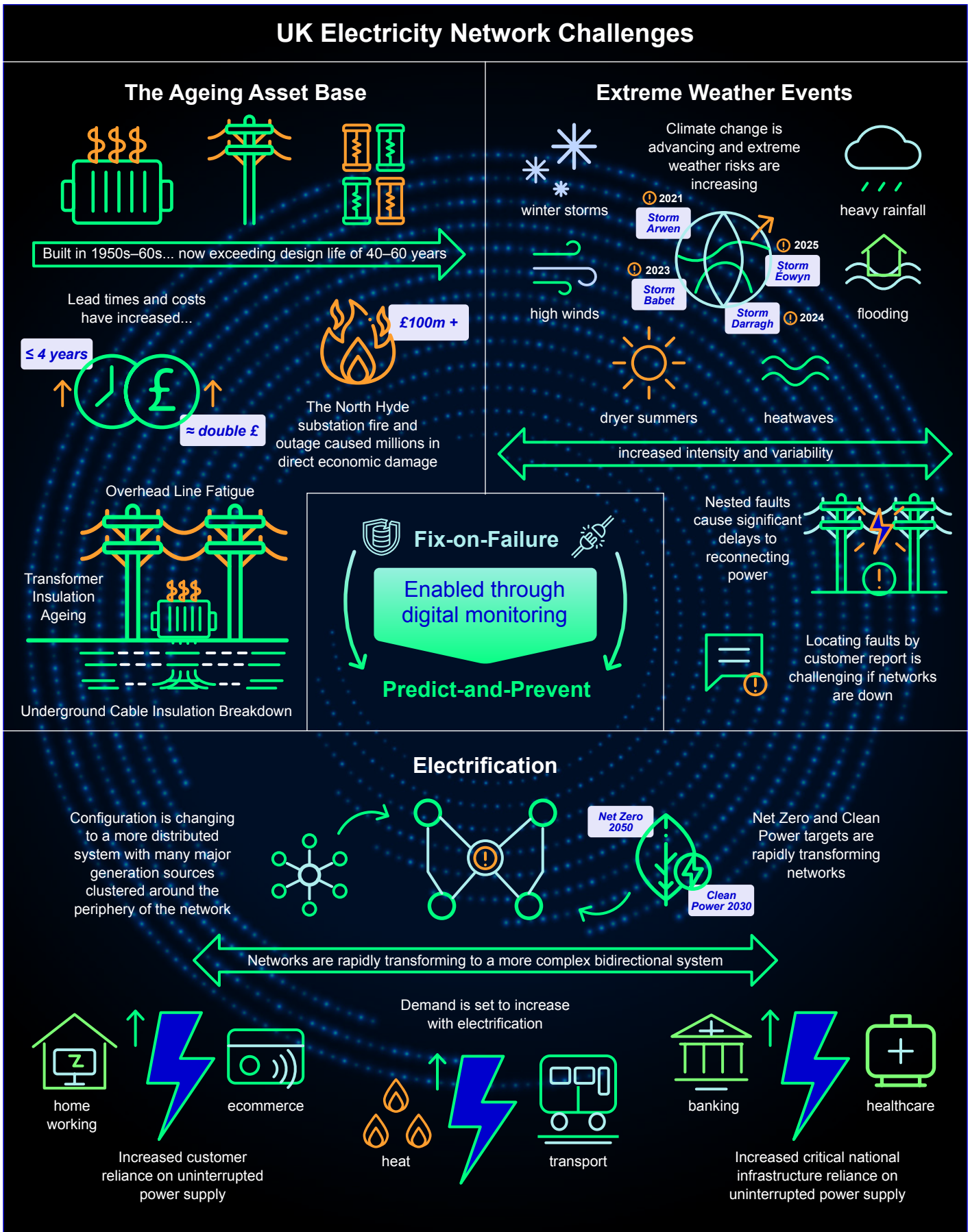
This report considers the context behind the changing resilience requirements of the UK's electricity distribution networks, presents an introduction to several categories of digital technology with the potential to enhance resilience, and conducts a short quantitative study on the effectiveness of continuous line-monitoring technology on fault location and rectification. It then reviews the resilience policy landscape in the UK, including current and proposed regulatory regimes, and offers recommendations to improve take-up and integration of digital technologies where appropriate.

Methodology

Research for this report was conducted utilising a mixture of desk-based qualitative research, quantitative modelling and expert stakeholder consultation. Qualitative literature reviews were carried out using the Rapid Evidence Assessment⁷ methodology. Stakeholder engagement was accomplished via a roundtable with participants from the DNO industry and government, held in March 2026. Insights from this event are incorporated into this report via Chatham House rules.



Section 1: The Changing Resilience Context



The Ageing Asset Base

The UK electricity networks were largely built out during the post-war period of nationalisation and expansion during the 1950-60s, and are rapidly ageing. Today, this translates to over 800,000 kilometres of overhead lines (OHL) and underground cables, along with hundreds of thousands of transformers and switchgear units.

Traditionally, electricity network assets are rated for 40 to 60 years of operational use – many of these assets are therefore nearing or at the end of their nominal operational design lifetimes. Replacement rates over the past few decades have been low, due to ‘sweating-the-assets’ practices post-privatisation as well as regulatory frameworks primarily focused on keeping customer bills down. This climate disincentivised investment into asset renewal.

The degradation mechanisms driving this accelerated failure rate are well-understood, with some examples given below:

- **Overhead Line Fatigue:** Conductors and wooden poles are subjected to cyclical mechanical stress from wind loading and thermal expansion/contraction cycles, along with slow corrosion of the steel-cored aluminium conductors from ambient humidity.
- **Underground Cable Insulation Breakdown:** In urban centres, particularly London and major metropolitan areas, the network relies heavily on cables installed decades ago. These assets are suffering from thermal ageing of paper insulation, exacerbated by the heavier loading patterns of modern cities. Joint failures are also a common failure mode, representing 80% of underground cable failures.
- **Transformer Insulation Ageing:** The life of a transformer is dictated by the life of its solid insulation. Thermal stress causes the depolymerisation of the cellulose paper insulation, a process which is progressive with age and irreversible.

In recent years, inflation and interest rate rises have made investment in new assets more expensive, compounded by significant delays in supply chains caused by unprecedented global demand, both in the transition to low-carbon energy systems and to cope with increased demand from electrification and datacentres. Large, high-voltage transformers have seen an almost doubling in price. Lead times have also drastically increased, with average times to delivery rising from 12-24 weeks to 1.5-4 years. High-voltage cable costs have increased due to spikes in raw material costs (copper and aluminium). Cables represent 80% of the DNO asset base on a current cost replacement basis.

This combination of ageing assets and costly, lengthy replacements alters the calculus around network resilience. Operating a ‘replacement-on-failure’ strategy has become more expensive, with the possibility of leaving communities underserved for long periods of time following an asset failure. In recent years digital monitoring technologies for such large power transformers, overhead lines and LV cable networks have progressed to offer effective real-time condition monitoring. These technologies can effectively detect developing pre-fault conditions in network assets, offering operators the capability to intervene ahead of failure, repairing equipment before customers are placed at risk of no supply, and substantially reducing costs. Without these systems, operators are only able to respond post-failure, creating increased costs and disruption for the DNO as well as customers who may be cut off.

These vulnerabilities were illustrated by the North Hyde substation fire on the 20 March 2025. Caused by a catastrophic failure on a high-voltage bushing due to moisture ingress, the fire led to thousands of local residents as well as Heathrow Airport to lose power for several hours. A NESO report stated⁸ that National Grid had detected elevated moisture levels in 2018 via oil samples taken during maintenance but had not undertaken mitigating actions. No advanced condition monitoring systems, which may have detected accelerating fault conditions before the catastrophic event, were installed at North Hyde, despite its importance in maintaining the critical national infrastructure asset of Heathrow Airport. Airlines estimated the economic damage of the outage to be £80-100 million, with National Grid spending tens of millions of pounds in clean-up costs⁹.



£100m +

direct economic damage
caused by the North Hyde
substation fire and outage

Extreme Weather Events

Extreme weather events and low-probability occurrences drastically impact the network, causing significant economic damage and protracted loss of supply to customers. These events include flooding, heatwaves, snowfall and high winds. Heatwaves can cause line sagging and conductor derating, as well as the potential for fires where sagging lines contact vegetation, and flooding can inundate substations. In the UK, the most common and drastic of these events are winter storms. These cause significant disruption through high winds and heavy rainfall, which damage electricity cables both directly and through treefall, and can flood transformers and other ground mounted assets.

The majority consensus expects storms to become more intense with heavier rainfall in the future, as the UK climate shifts towards hotter, drier summers and rainier winters^{10,11}. Changing patterns of rainfall and wind direction may introduce vulnerabilities and require the siting of assets, management of vegetation and orientation of electricity lines to be reconsidered. Changing rainfall and climate patterns have seen a consistent increase in vegetation growth rates, increasing the risk of tree damage from storms. Increasing electricity dependency due to the Net Zero transition will also increase customer vulnerability to power cuts.

The period from 2021 to 2025 has seen an increasing frequency and severity of storms testing the resilience of the distribution network:

- *Storm Arwen (Nov 2021)*: Left 1 million homes without power, some for over a week. It exposed the inability of DNOs to identify “nested faults”, secondary damage on lines that had already tripped.
- *Storm Babet (Oct 2023)*: Unlike the wind-driven Arwen, Babet brought exceptional rainfall, causing extensive flooding in the Midlands and Scotland. Substations were inundated, and physical access for repair crews was blocked for days, highlighting the vulnerability of ground-mounted assets to sudden flooding.
- *Storm Darragh (Dec 2024)*: Impacting 2.3 million customers and causing widespread damage across Wales and the West, this storm demonstrated the compounding effect of high winds on sodden ground, leading to higher rates of tree fall.
- *Storm Éowyn (Jan 2025)*: The first Red Warning storm for Northern Ireland in years, leaving over 1 million customers without power across Northern Ireland and Scotland. It reinforced the “long tail” of restoration, where complex, nested faults delay the final 1-2% of reconnections.

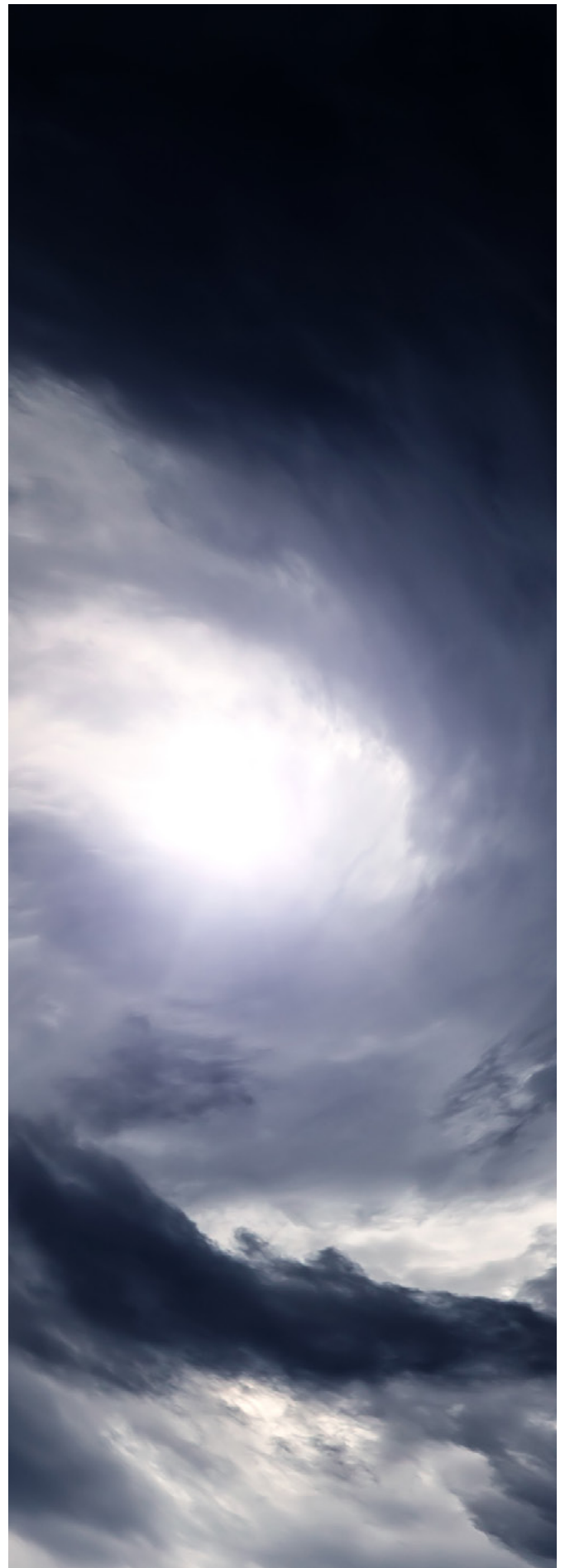


Table 1: Major UK Storm Events and Electricity Network Impacts (2020–2026)

Storm	Date	Max Wind	Worst-Affected Areas	Customers Disconnected	Max Duration
Arwen	Nov 2021	~100 mph (NE Scotland)	NE England, Scotland (esp. Aberdeenshire, Northumberland)	~1,000,000	Up to 13 days (worst cases)
Eunice	Feb 2022	122 mph (IoW — England record)	S. England, Wales, SE England	~1,400,000 (record)	Up to ~5 days (some SE England)
Dudley / Franklin	Feb 2022	~75 mph (Dudley); ~80 mph (Franklin)	N. England, Scotland, W. Scotland	~200,000 (combined)	Up to ~24 hrs
Darragh	Dec 2024	~93 mph	Wales, SW England, Midlands	~2.3 million (cumulative events in 24 hrs); ~260,000 at peak	Up to 4 days (mid-Wales rural)
Eowyn	Jan 2025	~100 mph (NI/Scotland)	N. Ireland (~283,000 peak), Scotland (~22,000+), N. England	~621,000 GB; +283,000 N. Ireland = ~904,000 total	Up to 10 days (N. Ireland rural)
Goretti	Jan 2026	~99 mph (SW England)	SW England, S. Wales, W. Midlands (also heavy snow)	~247,000 (National Grid ESO area); ~65,000 at 8am 9 Jan	Several days in worst-affected rural areas

Key vulnerabilities exposed by reviews into the impact of storms such as Arwen included the difficulty of detecting and fixing ‘nested faults’ - several faults in sequence on the same line - in the lower-voltage levels. These faults often are not picked up until the first breakage on a line is fixed and the line is attempted to be re-energised. Traditionally, these faults would require inspection of the entire affected line, a time- and resource- consuming process. Communications failures caused by disruption of mobile network coverage and overwhelmed DNO call centres also meant that many customers could not report a lack of supply, a key source of information for DNOs attempting to fix faults¹².

Digital line-monitoring technologies can detect nested faults and other advanced fault conditions, as well as providing information on line health and tree proximity in remote and difficult-to-access locations. This can provide a much more effective alternative method to relying on customer reports to track power outages and cable faults, as well as potentially reducing repair times by allowing teams to see the location of all faults including difficult to locate nested faults with greater precision as well as providing information on nested faults.

Case Study: Storm Arwen

Storm Arwen is widely regarded as the most consequential windstorm to affect UK electricity networks in at least fifteen years. The storm tracked unusually from the north, bringing sustained northerly gales, peaking at over 100mph, and snow across east Scotland and North-East England. This northerly wind direction was critically important: UK distribution network overhead lines are designed and orientated primarily for westerly and south-westerly storm loading conditions, meaning that line spans were loaded at their weakest orientation and vegetation was inadequately cleared on the windward (northern) side.

Storm Arwen resulted in approximately one million customers losing supply, with approximately 40,000 losing supply for over three days. Northern Powergrid described Arwen as the largest storm to impact their network since 2005. The Energy Networks Association characterised the event as at least three times as damaging as the ‘Beast from the East’ winter storm of 2018.





75,000

of customers remained off supply beyond 48 hours

4,000

customers experienced outages lasting more than one week

DNOs paid

£29.6m

in mandatory and voluntary compensation

While 82–83% of disconnected customers had their supply restored within 24 hours, approximately 75,000 remained off supply beyond 48 hours and nearly 4,000 customers, predominantly in remote rural areas of Scotland and Northumberland, endured disconnections of more than one week. Hundreds of distinct faults were recorded across the DNO networks, many requiring the complete replacement rather than repair of overhead line sections. Limited remote monitoring on lower-voltage networks (11 kV and LV) initially prevented DNOs from accurately assessing the scale and geographic distribution of damage by failing to pick up ‘nested faults’, causing delays in recovery and resource deployment.

The severity and prolonged nature of the Arwen outages prompted a formal review from The Energy Emergencies Executive Committee (E3C)¹³. Concurrently, Ofgem conducted a six-month regulatory review¹⁴. The E3C final report contained 45 recommended actions across five categories: network resilience, planning and preparation, incident management, communications and customer support, and post-incident support. Key actions included reviewing overhead line design standards and vegetation management corridors for atypical wind directions; introducing outcomes-based physical resilience standards; improving remote fault-detection capability; reforming GSOP compensation arrangements; and stress-testing DNO websites and call centres. Ofgem’s review concluded that staff had worked hard in challenging conditions but that thousands of customers received an unacceptable level of service, particularly regarding restoration timescales and communications. The three worst affected DNOs, Northern Powergrid, SSEN, and Electricity North West, agreed to pay £10.3 million into consumer resilience funds in addition to £29.6 million in mandatory and voluntary compensation. This event clearly illustrates both the challenges faced by DNOs attempting to rely on historic storm management techniques, and the increasing performance expectations of customers and the regulator.

Electrification

The Clean Power 2030 target and the UK’s transition pathway to net-zero emissions by 2050 necessitate considerable investment and system change. The UK’s electricity networks were built originally to transfer electricity from a relatively small quantity of large conventional power stations, often located in the centre of the country, to demand centres. A system with a large penetration of renewable energy sources will drastically change this configuration to a more distributed system with many major generation sources clustered around the periphery of the network, from large offshore wind farms in the North Sea to solar farms clustered in the South West. More of this distributed generation is now connected directly to the distribution network, altering the network from a system of purely unidirectional flows from generation to demand to a more complex bidirectional system. This reconfiguration of the network alters the load and stress profiles on network assets, a problem exacerbated by the low real-time visibility DNOs possess of their lower-voltage (LV) networks.

In conjunction with the rapidly changing generation profile, demand in the UK is changing rapidly. The transition to Net Zero implies a shift of major demand loads such as heating and transportation from fossil fuels to electricity. This will dramatically increase demand load on the system as heat pumps and EV chargers are installed throughout the country. As well as increasing total electricity demand, these new loads will increase peak demand, especially during cold winter mornings and evenings. There is also the possibility of significant ‘clustering’ of these loads as different neighbourhoods and regions adopt the technologies at different rates. These two factors together have the potential to put significant added stress on the distribution networks, a problem heightened by the lack of visibility at the LV level.

Both customer expectations of and reliance on an uninterrupted electricity supply have also increased over the past few decades. Over the past twenty years, the reliability of distribution networks has increased substantially. In 1995, the national average Customer Minutes Lost (CML) sat at approximately 140 minutes per customer, with around 100 interruptions per 100 customers. In 2025, the average CML was between 28-30 minutes per customer, with 36 interruptions per 100 customers¹⁵. This increase in reliability is welcome but comes with high customer expectations as well as greater economic reliance on uninterrupted electricity. There is an increased lack of redundancy, with major critical national infrastructure (CNI), such as rail networks, airports and water supplies connected directly to the distribution networks with little or no backup capability. The 2025 North Hyde substation fire, which cut electricity supplies to Heathrow Airport for several hours, exposed this lack of redundancy as well as the fact that network operators are often not aware of CNI connected to their networks and are not allowed to prioritise these sites in restoration efforts¹⁶. The post-Covid shift to greater levels of home working has also led to greater reliance. Whereas before, the vast majority of jobs were carried out in town and city centres where electricity supplies are extremely reliable, a lot of work is now more distributed, including in more rural areas where supplies may be less dependable.

These shifts in network usage and electricity flows have the potential to cause unforeseen issues and stresses, especially in areas of low network visibility. Smart meter data can assist DNOs in both network planning and loss-of-supply detection (in areas of high housing density) but is limited by privacy regulations and data aggregation constraints. A lack of visibility forces conservative planning assumptions such as the After Diversity Maximum Demand (ADMD)¹⁷, which can lead to inefficient and over-engineered reinforcement. Digital monitoring technologies therefore could contribute to both day-to-day stability of the distribution networks as well as longer-term planning, understanding areas of constraint and clustering on the networks as well as areas where excess capacity is available and potentially underutilised.

Conclusions

The UK's distribution networks face the modern challenges of ageing assets coupled with more expensive replacements due to a congested supply chain, an ambitious electrification and net-zero programme which leads to greater network loads and bi-directional flows, high customer expectations of stable supplies and substantial economic damages in the case of outages, and frequent extreme weather events increasing in both intensity and variability – with downed lines also causing potentially deadly public safety hazards.

The challenge for DNOs is to ensure the highest level of supply availability possible at an affordable cost to the consumer. This may entail a reconsideration of the current resilience paradigm – potentially from a “fix-on-fail” approach to a “predict-and-prevent” strategy underpinned by pervasive sensor deployment and real-time data analytics.

Digital technologies to enable this will be explored in the next section.

Key takeaways:

Ambitious policy targets requiring a step change in pace and scale of network investment: Government is four years away from its Clean Power 2030 targets and 25 years (or five RIIO price control periods) away from legally enshrined Net Zero targets. The primary Clean Power target is that by 2030, 95% of the UK's generation comes from clean sources¹⁸. In 2023, Ofgem was accordingly given duties related to sustainable economic growth and Net Zero.

Transformation of the energy system: System-wide electrification, decarbonisation and electricity demand growth putting pressure on the grid. Higher risk of cascading and compounding impacts through increased interdependencies between sectors. Challenges around the actual rate and pace of electricity demand growth. According to NIC, £37-50 billion of investment in the distribution network (a doubling of current annual allowances) could be needed to support additional demand and generation between today and 2050¹⁹.

Transformation of social and economic energy-use patterns: More people are working from home, running businesses from home, shopping from home etc. Heat, light and power are increasingly reliant on electricity.

Anticipated increase in climate-change related risks and challenges such as extreme weather events: Previous years' extreme weather events (e.g. Storm Eowyn, Storm Arwen) expose vulnerabilities in outage emergency response, particularly where Critical National Infrastructure (CNI) is concerned.

The interconnectedness of networks presents increased vulnerability due to cyberattacks and power grid blackouts as seen in April 2025 in Spain and Portugal with cascading impacts on critical infrastructure such as mobile and internet services and the broader economy.

Section 2: Resilience policy and regulatory context in 2026

This section outlines the UK’s network resilience landscape, focusing on the regulatory frameworks shaping investment decisions. It summarises the key stakeholders and assesses RIIO ED2 and RIIO ED3 through the lens of their resilience-related incentives.

It draws on insights from industry and policy stakeholders who took part in a ‘Networks for the Future’ roundtable coorganised by Imperial College London and PLMR under Chatham House rules.

Overview of key stakeholder roles and responsibilities

Responsibility for maintaining distribution network reliability and resilience in the UK is shared across government, Ofgem, the National Energy Systems Operator (NESO) and Distribution Network Operators (DNOs). At a very high level, government is responsible for setting the strategic direction for energy policy, including establishing the overarching policy framework, targets and resilience standards. Ofgem, as the independent economic regulator, makes decisions on business and investment plans, while NESO acts as the whole-system planner, operator of the electricity system and advisor to Ofgem and government. DNOs, as the regional monopolies that own, operate and upgrade the networks, are responsible for delivering front-line network resilience and reliability.

Ofgem note that the involvement of multiple actors when it comes to setting and implementing standards for resilience (particularly with regards to climate resilience) has created a ‘fragmented landscape’ that makes it challenging to clearly identify priorities for action.²⁰

Table 2: Overview of key stakeholder roles and responsibilities

Government (DESNZ)	<ul style="list-style-type: none"> ■ Sets the strategic direction for resilience: establishes the policy framework, long-term targets and resilience standards ■ Strategic energy targets include Clean Power 2030 and Net Zero 2050 ■ Currently developing the Energy Resilience Strategy (due late 2026) in response to NESO’s recommendations after North Hyde substation fire
National Energy Systems Operator (NESO)	<ul style="list-style-type: none"> ■ Publicly owned energy system operator with a whole-system remit, focused on coordination of energy flows ■ Provides national strategic oversight of resilience, ensuring that planning by Transmission Network Owners (TNOs) and DNOs is aligned with system needs, government ambitions and future risks ■ Cross-sector responsibilities include (1) conducting energy resilience assessments; (2) collecting and analysing data after events (e.g. North Hyde substation fire); (3) conducting strategic whole-system planning and (4) supporting distribution-level planning through development of transitional Regional Energy Strategy Plans (tRESPs)
Ofgem	<ul style="list-style-type: none"> ■ Provides the regulatory framework and incentives that guide DNOs to invest in resilience and reliability ■ Sets price controls and performance standards, including standards related to reliability, customer service, network safety and environmental performance through RIIO framework
Distribution Network Operators (DNOs)	<ul style="list-style-type: none"> ■ Regional companies that own, operate and upgrade distribution networks ■ Deliver front-line network resilience and reliability, from operating, maintaining and upgrading network assets, restoring during outages and preparing for long-term climate resilience to improving customer service

Stakeholder roles in network resilience: North Hyde Substation fire example

The post-incident response to the North Hyde substation fire illustrates how key stakeholders involved in resilience assume distinct but coordinated roles to develop better standards and network recovery approaches.

In the weeks following the fire, NESO was commissioned by the Department of Energy Security and Net Zero (DESNZ) to conduct a review into the outage, including assessing the root cause of the incident and developing outcome-focused recommendations for improving resilience of essential services to energy disruption in future. The report highlighted two key areas where liaison with energy network operators should improve: local responders and other critical network infrastructure (CNI) sector operators.

DESNZ' role has since been to respond to these recommendations through a new Energy Resilience Strategy (ERS), due for publication end 2026. NESO, Ofgem and Cabinet office are also involved in this process. The ERS will take a whole system, long-term approach to assessing and improving design standards, to ensure the future energy system is 'designed to be resilient to the evolving risk and threat landscape'.

Network resilience regulatory context in 2026

As the UK resilience context changes – driven by ambitious policy targets, increasing risks from climate change and a growing system-wide dependence on electricity – the regulatory and policy frameworks governing distribution network resilience must also change.

Since 2013, RIIO (Revenue = Incentives + Innovation + Outputs) has been Ofgem's regulatory framework for driving improvements in the UK's energy networks. For each five-year RIIO price control period, network companies submit business plans with agreed targets to Ofgem and can be financially rewarded for meeting and exceeding them.

Ofgem sets separate price control periods for electricity distribution networks and electricity transmission networks. RIIO 2 (2021-2026) is the current framework for electricity transmission, gas transmission and gas distribution networks, while RIIO ED2 (2023-2028) is the current framework for electricity distribution networks. While there are numerous reasons for separating transmission and distribution regulatory cycles, one of the key distinctions comes down to upgrades – upgrading the transmission network involves delivery of a small number of very large upgrades, whereas upgrading the distribution network involves delivery of hundreds of thousands of individual interventions and investments²¹. This requires close coordination between DNOs and a range of stakeholders, including local authorities, customers and businesses, and supply chain partners.

“The role of network operators is becoming increasingly challenging, technical and consequential.”

- Roundtable participant

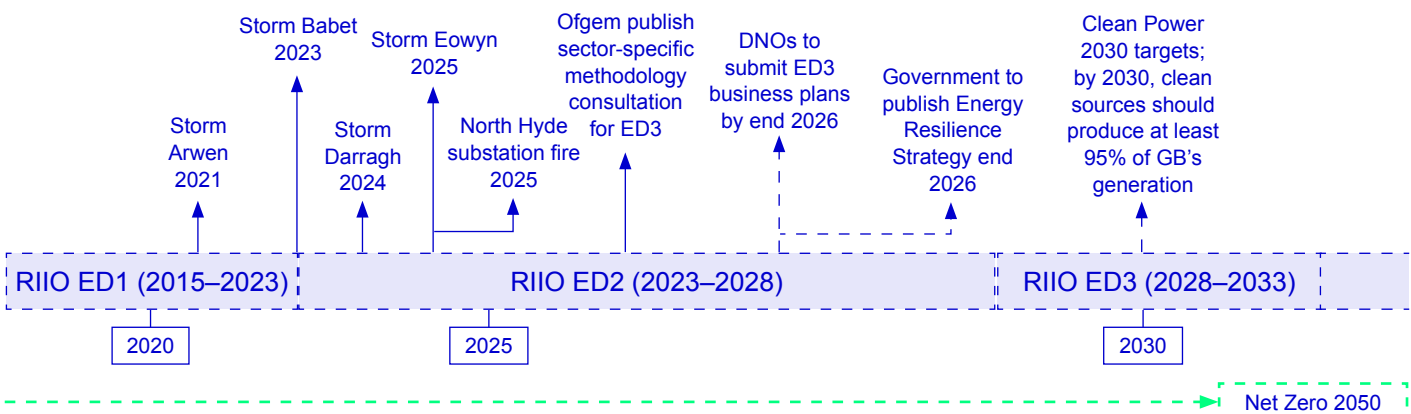


Figure 1: RIIO timelines, resilience drivers and milestones

RIIO-ED2: resilience in the current regulatory framework

Network resilience mechanisms and incentives ED2

RIIO ED2 includes a range of incentives to promote stronger network resilience and reliability. These span incentives to reduce consumer interruptions, improve asset health, improve day-to-day network reliability, as well as incentives to increase resilience against extreme weather events. RIIO ED2 is also the first price control period to formally introduce climate resilience as a targeted funding area by requiring DNOs to submit Climate Resilience Strategies (CRS).

Below is a summary of some of the key resilience- and reliability-related incentives and standards in ED2. Note that most incentives, such as Engineering Technical Report 138 (ETR 138), Interruptions Incentives Scheme (IIS) and Network Asset Risk Metric (NARM), pre-date the RIIO ED2 period.

Table 3: ED2 resilience incentives and standards

Mechanism	Regulation type	Description
Climate Resilience Strategies (CRS)	Reputational incentive	From ED2 onwards, network companies are required to submit a CRS as part of their Business Plan submissions. CRS include measures required to adapt to changes in climate and assess the impact on assets to improve network resilience.
Interruptions Incentives Scheme (IIS)	Financial incentive	IIS is a regulatory mechanism that sets financial rewards or penalties for DNOs based on frequency and duration of power cuts. Allowed revenue through IIS is measured by the number of Customer Interruptions (CI) and Customer Minutes Lost (CML).
Guaranteed Standards of Performance (GSOP)	Financial incentive/ Standard	GSOP sets out guaranteed standards of service levels which must be met by DNOs. If levels of service required are not met, DNOs must make a payment to the customer to compensate for the inconvenience caused by loss of supply.
Network Asset Risk Metric (NARM)	Financial incentive	NARM was developed in RIIO 2 to allow Ofgem to quantify the benefit of network companies' asset management activities to consumers. NARM considers the probability and impact of an asset failing and provides information on reliability. It is focused on chronic risk (e.g. asset deterioration) rather than climate-related risk.
Broad Measure of Customer Service (BMCS)	Financial incentive	BMCS is a financial incentive that rewards or penalises DNOs based on overall customer service outcomes, including reliability, communication and customer satisfaction. While BMCS is about delivering quality customer service to all customers, it also includes incentives focused on most-vulnerable customers.
Customer Vulnerability Incentive (CVI)	Financial incentive	CVI is a financial incentive that rewards DNOs for delivering enhanced outcomes for customers in vulnerable situations. It encourages DNOs to go beyond minimum requirements by implementing initiatives that improve accessibility, communication, and resilience for those customers.
Engineering Technical Report 138	Standard	ETR 138 is the floor resilience standard established in 2009. It is widely accepted as good practice for providing resilience against flooding of grid and primary substations. There are differing opinions on whether ETR 138 counts as a resilience metric, technical specification or level of service ²² .

Impacts of ED2 on network resilience to date

In this bridging period between ED2 and ED3, it is important that the successes and shortcomings of ED2's resilience-related incentives are clearly recognised, so that ED3 can build on what has worked and send the right signals to continue driving investment.

Regulatory incentives in ED2 and previous price controls have driven measurable improvements in overall distribution network resilience and DNO customer service. The Interruptions Incentive Scheme (IIS), for example, is considered to have been a demonstrably effective mechanism for catalysing improvements in network reliability. The IIS rewards or penalises DNOs based on their annual performance in reducing customers interrupted (CI) and customer minutes lost (CML), applying to both planned and unplanned outages, with the exception of extreme weather events. Since its introduction, CIs have more than halved – falling from 86.60 to 39.71 customers interrupted per 100 connected customers – while average minutes of supply lost per connected customer have fallen from 81.66 to 35²³. Other examples of where regulatory mechanisms have proven effective include customer satisfaction, where average scores have increased to more than 9 out of 10, and complaints, where average scores have also improved significantly over the period in which the incentive has operated²⁴.

Reception of RIIO ED2's resilience strategy, however, has been mixed. Under ED2, interventions that serve the long-term interests of consumers are challenging to justify, particularly in the context of measures to enhance resilience. In such cases, value is frequently associated with consumer outcomes that occur within the short-term regulatory cycle rather than those that deliver longer-term enduring value. Specifically, it has been suggested that ED2 does not include adequate enough financial incentives to 'galvanise investment in resilience'²⁵. Early indications, for instance, suggest that DNOs have not significantly increased load-related expenditure to prepare for higher future peak demand. This could be related to the turbulence around the beginning and end of points of price periods, but it may also reflect the fact that DNOs have not been sufficiently incentivised by current regulatory signals to invest with a view to future needs. Similarly, while ED2 does represent a first attempt to embed longer-term, integrated resilience planning within network business plans (e.g. through the introduction of Climate Resilience Strategies), Ofgem recognise that there has not been enough join-up between longer-term risk assessments and investment decisions within the price control period²⁶.

There have been certain unintended distortions. Despite its strong historic track record, the IIS contains a design feature that, from a climate resilience perspective, inadvertently weakens incentives: severe weather events are excluded from the scheme. DNOs therefore have limited financial incentives to invest in resilience against the kinds of outages that are expected to become more frequent as a result of climate change²⁷.

Additionally, while climate resilience strategies were introduced under ED2, there is little demonstration that these strategies have had an impact on DNO investment decisions. While this is not necessarily a problem for initial plans, going forward, climate resilience objectives will need to be better integrated to have an impact. This challenge is also compounded by another regulatory gap; in ED2, there are no metrics or standards in place for measuring climate resilience, making it challenging to monitor, measure and appropriately value progress or delays. Without a defined goal or consistent metrics, it is also difficult to justify and direct investment effectively (Ofgem, 2025c).

While it is complicated to turn 'resilience' into a set of metrics by virtue of its complex, multidimensional nature, current methodologies for asset and network level resilience in ED2 do not provide a comprehensive foundation for valuing resilience: while CMLs and CIs do provide metrics on historic impact from weather events, the fact that they exclude disruptions from severe events means they can distort 'the true picture of disruption' (Ofgem, 2025). The IIS also does not adequately account for long-term or systemic climate risks, contributing to a risk of underinvestment in resilience measures. Similarly, NARM does not explicitly capture climate change, which can make it challenging to identify if changes to asset health and/or the need for asset replacements are primarily driven by climate change or not. National Grid suggest to this end that while NARM has historically been a useful mechanism, it potentially 'drives decisions which prioritise risk reduction at lowest unit cost using like for like or cheaper alternatives which may not factor in future need'²⁸.



A note on assessing progress in ED2

When it comes to assessing the strengths and shortcomings of ED2, there are challenges related to the lack of regular, transparent updates on DNO performance. While Ofgem does publish annual reports, these only cover a (largely financial) subset of incentives, which limits how well stakeholders and other involved institutions are able to assess (a) whether DNOs are investing in a way which aligns with broader strategic resilience objectives and (b) how they are performing against one another. This is a barrier to carrying over learnings from one price period into the next.

One area where this is particularly relevant is data and digitalisation. By the end of ED2, DNOs are expected to have made significant progress integrating real-time data analytics and establishing open data platforms – with the expectation that this would lay the foundation for more resilient digital infrastructure by ED3 – yet it is unclear whether progress is on track. This lack of transparent reporting is also highlighted by several stakeholders in response to Ofgem’s ED3 consultations^{29,30}.

Citizens Advice recommend that Ofgem take to publishing performance monitoring for non-financial incentives, as well as publishing annual comparative performance monitoring, showing how network companies are performing relative to one another³¹.

Resilience in the upcoming regulatory framework: RIIO ED3

While the determinations for RIIO ED3 have not yet been finalised, the ED3 Framework proposal and ED3 Sector Specific Methodology Consultation, both published in 2025, demonstrate a shift in how network resilience will be integrated within the next price control period. Resilience outcomes in the proposed framework are more strongly aligned with longer-term strategic goals, including Clean Power 2030 and Net Zero 2050, reflecting clearer government positioning on policy priorities. This longer-term approach is supported by a more coherent and consistent view of what it means for UK networks to be resilient. The more substantive changes proposed in ED3, for instance, centre on developing grid-wide resilience which is more regionally specific, consumer-centric and underpinned by proactive investment practices.

To build towards a network which is fit for purpose on the longer term, ED3 introduces four new consumer outcomes: (1) net zero networks; (2) smarter networks; (3) resilient networks and (4) sustainable business. The explicit inclusion of ‘resilient networks’ illustrates the growing relevance of resilience in the UK energy transition – particularly in a context of accelerating system electrification, decarbonisation and climate-related risks.

Key changes from ED2 to ED3 resilience strategy

- Stronger focus on aligning investment in the price control period with short and long-term resilience needs and broader government strategic ambitions. Emphasis on “touching the network once”, enabled by transitional Regional Energy Strategic Plans (tRESPs) – long-term, regionally-tailored plans mapping DNO optimal cost and risk profiles through to 2050.
- Stronger focus on making resilience investments more tailored to regional specificities, requirements and ambitions, also enabled by tRESPs.
- Stronger focus on climate resilience and preparing the network to be resistant to extreme weather events. Existing incentives from ED2, including IIS, Network Asset Risk Metric (NARM) and Guaranteed Standards of Performance (GSOP), will be adapted to more actively incorporate climate resilience.
- Stronger focus on ensuring security of supply for all consumers, particularly Worst Served Customers (WSC). DNOs will be expected to publish more detailed data on customers and regions experiencing persistent unplanned interruptions. DNOs will also be expected to minimise the impact of even very short (<3 minutes) power cuts.



Resilience strategy in ED3

In the consultation documents for ED3, Ofgem acknowledge the limitations of a five-year regulatory framework when it comes to incentivising operators to invest in measures where the benefit is realised over a longer time period. Futureproofing for system resilience requires oversight, investment and a long-term view of how the network system will need to adapt in response to both predictable and unpredictable systemic and environmental changes. At the policy roundtable, one participant pointed to the challenges now facing the transmission network as a direct result of delayed investment in grid asset upgrades, emphasising the need to make sure the same thing does not happen to the distribution network: “A long-term view is very important – we can’t end up in the same situation the transmission network is in now – but there are issues with political cycles and priorities changing.”

ED3 therefore sets out to strike a better balance between short and long-term investment in the interests of consumers. The proposed framework emphasises the concept “touching the network once” – getting operators to invest in assets which achieve lower whole-life cost in the long-run and do not need to be replaced within successive price control periods.

How does Ofgem propose to overcome the limitations of the short-term regulation cycle and ensure that investments are made with a stronger view to future resilience requirements?

1. Introducing Transitional Regional Energy Strategic Plans (tRESPs)

Ofgem’s primary enabler is the transitional Regional Energy Strategic Plans (tRESPs), developed by NESO to be used as an input to DNO planning processes for ED3. Through tRESPs, DNOs will be expected to produce regionally-specific, long-term plans mapping their optimal cost and risk profiles through to 2050. The introduction of tRESPs reflects the recognition that networks in different regions will need to develop at different paces, and that DNOs will need to prioritise solutions to Ofgem’s customer outcomes based on local ambitions, challenges and characteristics.

Ofgem note that tRESPs should help ensure decisions are taken in consumers’ long-term interests, present a clearer long-term vision of investment needed in ED3 and successive price control periods, and provide the supply chain with better clarity and direction. It is worth noting, however, that while tRESPs are at the centre of Ofgem’s proposed shift towards more future-proof and integrated resilience planning, they are not mandatory.

2. Adapting incentives to improve climate resilience

ED3 also presents a renewed focus on climate resilience. While Climate Resilience Strategies are already a feature of ED2, Ofgem acknowledges that their influence on short-term investment planning to date has been limited. A key objective for ED3 is therefore to more actively embed climate within incentives and the overall resilience strategy. Proposals to enable this include more detailed guidance on CRS, as well as the introduction of Climate Resilience Metrics and Indicators (CRMI).

Existing incentives from ED2 will also be adapted to more actively incorporate climate resilience. Ofgem proposes that NARM, IIS and GSOP may be maintained but adapted to more strongly reflect climate risks and modern electricity usage. Specifically, Ofgem is proposing to (1) review IIS Severe Weather Exceptional Event (SWEE) thresholds; (2) review GSOP payments; (3) review standards and their enforcement; and (4) incorporate climate considerations into NARM.

“A long-term view is very important – we can’t end up in the same situation the transmission network is in now – but there are issues with political cycles and priorities changing.”

- Roundtable participant

The proposed framework emphasises the concept “touching the network once” – getting operators to invest in assets which achieve lower whole-life cost in the long-run and do not need to be replaced within successive price control periods.

3. Adapting incentives to improve resilience for all consumers

A further feature of ED3 is its consumer-centric focus. While the UK has a very high network-wide performance average (above 99.9%), Ofgem emphasise the importance of network reliability and resilience for all consumers because this figure obscures persistent underperformance in specific areas and for specific groups. Rural and remote areas, for instance, tend to experience much higher rates of network failure and outages. Given that rural areas are also more likely to host low carbon generation, it has been suggested that there is a risk communities feel the energy transition is 'extractive', with the benefits being carried out while local reliability issues go unaddressed³². Previous price controls, including ED2, sought to address this largely through Independent Stakeholder Groups (ISG), which have improved customer engagement but have historically not been particularly representative of Worst Served customers (WSC) – customers experiencing four or more unplanned outages per year. Additionally, it has been noted that DNOs have historically underspent on their WSC allowances. "DNOs talk about CIs and CMLs across the network, but there are some customers that go off more than three times a year [...] there's a lot of variety in how success is quantified."

ED3 sets out to redress this challenge and ensure benefits are not just concentrated among the majority. Specifically, Ofgem expect DNOs to publish more detailed data on customers and regions experiencing persistent unplanned interruptions, and to create targeted plans to address these. Other interventions in discussion include improved fault detection and response and stronger community engagement with frequently affected customers. Ofgem also signals it will be expecting more of DNOs when it comes to minimising the impact of even very short (<3 minutes) power cuts. This is a notable shift from ED2, where short-duration interruptions are not incentivised under IIS – a gap that poses particular risks for certain vulnerable consumers (i.e. with medical needs), who can be adversely affected by even very brief supply interruptions.

Does the proposed ED3 framework do enough to meet network resilience needs?

Through the ED3 proposed framework, Ofgem vocalise an intention to centre resilience more comprehensively within network planning. Various dimensions of what it means for the network to be genuinely resilient are taken into account; ED3 is notably more considerate than ED2 of long-term regional, climate and consumer-specific resilience needs. The question now is how effectively that intention translates into incentives which provide network operators with a clear direction of travel from here through to 2050.

When asked whether the proposed regulatory framework was sufficient to incentivise investment in long-term network resilience, one participant replied: "It's very hard to give an easy answer since there are so many competing requirements, but the bottom line [as a DNO] is affordability."

The regulatory framework proposed in ED3 will therefore only be successful in driving resilience if DNOs consider that the investments bring good value for money. Equally, DNOs will need to be encouraged to assess their investments across multiple directorates within their businesses, rather than siloed approaches.

Ofgem do outline concrete steps being taken to adapt certain incentives – IIS thresholds, for instance, are likely to be adapted so there aren't perverse incentives for DNOs not to act during severe weather events. NARM and GSOP are to be similarly adapted to more strongly reflect climate risks and modern electricity usage. The specifics of how these mechanisms will be adapted to more fully account for and incentivise resilience, however, remains unclear.

"DNOs talk about CIs and CMLs across the network, but there are some customers that go off more than three times a year [...] there's a lot of variety in how success is quantified."

- Roundtable participant

"It's very hard to give an easy answer since there are so many competing requirements, but the bottom line [as a DNO] is affordability."

- Roundtable participant

A review of documents published to date suggests that while ED3 showcases a stronger narrative focus on resilience, how this is practically turned into incentives sending the right investment signals is less obvious. Noting that Clean Power 2030 targets are due to be met two years into the period, there are several risks to long-term network resilience planning in ED3: (1) a gap between the strength of narrative and the strength and scope of the proposed incentives; (2) the continued tension between short-term funding cycles and long-term resilience investment needs; (3) the absence of metrics, standards or indicators to measure progress against resilience goals; and (4) missed opportunities to reward investments that deliver co-benefits.

Gaps between the strength of the narrative and the strength and scope of the proposed incentives

Incentives in RIIO are designed to improve performance across different consumer outcomes, and to date, these have been largely successful mechanisms. Incentives have improved reliability, customer satisfaction, average time to connect, and reduced complaints³³. Equally, in areas where there have not been incentives, DNOs have been visibly slower to make progress. In ED2, there were weaker performance improvements related to customers off supply for more than 12 hours in normal weather, repeated long outages, and short interruptions, on account of the lack of incentives.

However, not all incentives have been equally successful at directing DNOs to engage in best-practice. In particular, while financial incentives like the IIS have proven effective, reputational incentives like Climate Resilience Strategies and Consumer Vulnerability Incentives have been less so. The success of reputational incentives primarily hinges on DNOs being publicly held to account for (under) performance, but with Ofgem not publishing detailed, comparative data reports on DNO performance, the influence of reputational incentives is limited. Given the monopoly status of DNOs, there is also a more fundamental question here about the efficacy of reputational incentives as a mechanism for motivating DNOs to invest in resilience.

There are also risks in the minutiae of how incentives in ED3 are interpreted. In ED2, there has been a lot of variation in DNO approaches to vegetation and storm resilience, with some spending heavily on resilience and backlog clearance, and others focusing on technology and targeted methods. While this flexibility is key, particularly given regional differences, there is a risk that if incentives are not 'tightened' to more strongly reflect long-term resilience-related outcomes and expectations, then those outcomes may not be met. For instance, in ED2, several DNOs are projecting significant overspend on resilience-related tree-cutting, while others, adopting a more risk-based, data-informed strategy, are predicted to underspend. Ofgem should learn from this outcome to be more prescriptive about incentivising uptake of hard and soft resilience measures in ED3. For now, there is a lot relying on the good will of shareholder-owned DNOs to respond to incentives in the most strategically-aligned and consumer-centric way, when there may be gaps in detail which allow for shortcuts to be taken.

Tension between short-term funding cycles and long-term system resilience investment needs

During the policy roundtable, it was noted that there was a continued tension between the short-term regulatory cycles and medium- to long-term resilience investment needs. While ED3 presents a more ambitious attempt at drawing short- and longer-term planning together, there are persistent challenges. Ofgem has to strike a balance between driving investment in line with long-term strategic priorities, while recognising that priorities often change in line

A review of documents published to date suggests that while ED3 showcases a stronger narrative focus on resilience, how this is practically turned into incentives sending the right investment signals is less obvious.

with political cycles. One area this is a particular challenge is balancing the goal to reduce unit cost (i.e. delivering outputs as cheaply as possible within the regulatory cycle) and the goal to maximise whole system value (i.e. delivering outputs with the greatest system-wide benefits over the long-term).

One roundtable participant suggested that incentives in ED3 are still largely set around minimising unit costs within period as opposed to “touching the network once” to deliver optimum value for customers. This creates a real risk that investments will continue to be made to the detriment of long-term consumer interests. As another participant noted, historically, DNOs are less willing to pay for assets with a high upfront capital expenditure, even if the cost is recovered over the longer term, is cheaper overall, and brings more cross-cutting value. A key question going into the final stages of ED3 preparation is therefore how the regulator can more directly incentivise DNOs to value and consider the longer-term, system-wide benefits of an investment.

The absence of metrics, standards or indicators to measure progress against resilience goals

It was established during ED2 that ED3 would introduce a range of standards and metrics for measuring resilience. For instance, Ofgem planned to set a long-term climate resilience goal, defining an ‘acceptable level of climate resilience’ at the ED3 consultation stage. During ED2, the Energy Networks Association (ENA) and DNOs also established a climate resilience working group to develop Climate Resilience Metrics and Indicators (CRMIs), under the expectation that they would be ready to be incorporated into DNO business planning and tRESPs for ED3. To date, neither of these expectations have been met. Several stakeholders have already flagged that the development of CRMIs is lagging behind and unlikely to be complete ahead of ED3³⁴. More broadly, Citizen’s Advice also point out that in ED3, there is still no minimum standard of reliability that customers can expect regardless of location³⁵.


This is a real risk to resilience-related ambitions in ED3. Specifically, investment to enhance climate resilience is likely to be diluted for as long as there are no overarching strategies or appropriate metrics for measuring (and subsequently rewarding or punishing) performance. CRMIs were intended to be key metrics for measuring progress against overarching goals, comparing DNO performance, and, in turn, holding them to account for their climate pathways. Without them, ED3 risks being an extension of ED2 in this sense – with climate resilience strategies falling to the wayside, or being measured so differently across different network operators that comparison is difficult.

Missed opportunities to reward investments that deliver co-benefits

While new customer outcomes built on resilient, smart and net zero networks show closer alignment with policy ambitions, the associated incentives do not look to more strongly reward investment which delivers value across several outcomes. For instance, in ED3 there is a discrepancy between the narrative recognition that digitalisation has a role to play in supporting the development of a smart *and* resilient grid, and the resilience-related incentives, which do not actively guide DNOs to invest in ways that prioritise technologies with wider system value i.e. monitoring technologies which support better forecasting, fault prevention and fault recovery. This is explored in further detail in the box on the next page.

“Incentives in ED3 are still largely set around minimising unit costs within period as opposed to “touching the network once” to deliver optimum value for customers.”

- Roundtable participant



Digitalisation for resilience – missed co-benefits in ED3

The role of digitalisation for improved network resilience

ED3 recognises digitalisation as an important enabler of current and future network resilience. Through advanced monitoring, analytics and forecasting tools, network operators are better able to assess the health and performance of assets before committing to major reinforcements. This allows investment to be prioritised where it delivers the greatest whole-system benefit and helps ensure that interventions are made with long-term resilience and capacity in mind. These tools can also enable fast and pre-emptive fault detection, allowing operators to respond to potential risks – both on blue sky days and in response to more severe weather events – more efficiently. Digitalisation of the network also builds the groundwork for future applications such as AI-driven data analytics, which aligns with government's intention to position itself as an 'AI Superpower'.

The digitalisation-for-resilience funding gap

There is a discrepancy between the recognition that digitalisation has a significant role to play in supporting the development of a smart, futureproof grid, and the incentives available to persuade DNOs to act. While there are digitalisation-specific plans which DNOs are expected to submit, the incentives outlined in the 'resilient networks' customer outcome do not stress the value of digital tools for resilience.

Additionally, there is a digitalisation funding gap. Funding for digitalisation projects has primarily been available through innovation funding pots such as the Networks Innovation Allowance (NIA), which has successfully allowed DNOs to trial early-stage innovation projects. It was noted at the policy roundtable, however, that for more established, mature technologies, DNOs are largely expected to self-fund projects. For network operators, whose primary considerations tend to be affordability and value for money, this therefore creates a gap between the policy narrative – that investment in digitalisation matters – and the practical incentives and funding opportunities to invest in mature technologies which contribute to overall system goals.

Designing improved incentives

Ofgem has to strike a balance between setting incentives which guide DNOs to invest in resilience, but without being too prescriptive about what those investments should look like. Resilience investment will require a combination of hard measures (e.g. such as safety and resilience cutting, particularly in the context of severe weather) and softer, digital measures that monitor, inform, and optimise those hard interventions. Ofgem should be actively encouraging this integration. The question is less about mandating use of specific technologies and more about designing incentives which clearly highlight the value of digitalisation and reward 'best in class' investments which mutually improve the smartness, resilience and sustainability of the network.

Key takeaways – Resilience policy and regulatory context

Incentives in Ofgem’s RIIO framework are designed to improve performance across different consumer outcomes, and to date, these have been largely successful mechanisms. In a context of accelerating system electrification, decarbonisation and climate-related risks, however, these incentives will have to adapt to become more considerate of future consumer needs. In ED2, for instance, interventions that serve the long-term interests of consumers are challenging to justify, particularly in the context of measures to enhance resilience.

ED3 proposals have sought to address this challenge, demonstrating a stronger focus on planning for long-term system resilience. However, while this is clearly articulated through the narrative, how this is to be practically enacted through incentives is less clear. We highlight four potential risks to network resilience planning in ED3:

Gaps between the strength of the narrative and the strength and scope of the proposed incentives: While financial incentives like the IIS have proven effective, reputational incentives to improve resilience (e.g. Climate Resilience Strategies) have been less so. ED3 does not propose to materially change this approach; particularly in relation to IIS storm exemptions. Given the monopoly status of DNOs, we would also question the efficacy of reputational incentives as a mechanism for motivating DNOs to invest in resilience.

The absence of metrics, standards or indicators to measure progress against resilience goals: It was established that a set of Climate Resilience Metrics and Indicators (CRMIs) would be ready to be incorporated into DNO business plans and tRESPs by ED3. However, stakeholders have flagged that the development of CRMIs is lagging behind and unlikely to be complete in time³⁶. ED3 risks being an extension of ED2 in this sense – with climate resilience strategies falling by the wayside or being measured so differently across different network operators that comparison is challenging.

Tension between short-term funding cycles and long-term system resilience investment needs: Regulation has to balance the goal to reduce unit cost (i.e. delivering outputs as efficiently as possible within the regulatory cycle) and the goal to maximise whole system value (i.e. delivering outputs with the greatest system-wide customer benefits over the long-term). Incentives in ED3 are still largely set around minimising unit costs within period as opposed to touching the network once to deliver optimum value for customers.

Missed opportunities to reward investments that deliver co-benefits: While new customer outcomes built on resilient, smart and net zero networks show closer alignment with policy ambitions, the associated incentives do not look to appropriately reward investments which deliver value across several outcomes. For instance, in ED3 there is a discrepancy between the narrative recognition that digitalisation has a role to play in supporting the development of a smart and resilient grid, and the resilience-related incentives, which do not actively guide DNOs to invest in ways that prioritise technologies with wider system value.



Section 3: Digital Technologies for Resilience

Introduction

The rapid evolution of digital technologies is fundamentally transforming the operation of modern power systems. Traditionally, distribution networks mainly relied on manual inspections and reactive maintenance practices, resulting in constrained visibility and slower fault response. However, the increasing penetration of large-scale distributed energy resources (DER) such as wind and solar, as well as the heightened exposure to extreme weather events, have significantly increased the complexity and operational requirements of distribution networks. In response, a new generation of digital solutions, including drone-based inspections, continuous monitoring technologies, and advanced analytics has emerged to enhance situational awareness, enable proactive asset management, and improve system resilience. These advances have the potential to assist and augment physical hardening and traditional resilience efforts by providing real-time visibility over the networks, allowing operators to both monitor the health of assets under standard operating conditions and responding quickly to mitigate the effects of extreme events. As well as improving fault-response times, these technologies can assist in proactive resilience – detecting pre-fault conditions such as transformer insulation degradation, cable joint failure and intermittent vegetation contact to power lines, allowing operators to act on these before failure. As such, they are reshaping how network operators detect, respond to, and even prevent faults, forming a critical foundation for the transition towards more intelligent, adaptive, and resilient power systems.

Technology Comparisons

Mobile Storage

Mobile storage units are transportable battery energy storage systems that can be connected at different buses on the distribution network. Their primary function is to transport and supply energy where it is needed most, supporting resilience during outages or maintenance. In addition, when deployed on site, mobile storage units can also do local ground-level inspection and assessment of the assets and connection points where they are installed. Operators can evaluate equipment condition, verify connections, and conduct targeted diagnostics at these specific locations. Unlike drones or fixed sensors, however, this inspection capability is only limited to the immediate area where the storage unit is physically connected. In practice the scale of supply needed to restore power meaningfully far exceeds the capacity of mobile storage units except for the most vulnerable of customers.

Distributed Energy Resources

DERs such as rooftop solar, small-scale battery energy storage systems, and local conventional generation can contribute to resilience by supporting islanded operation and reducing load shedding during extreme weather events. In general, DERs do not directly feedback condition information; nevertheless, they can assist in maintaining supply and provide operational data to system operators. Their effectiveness depends on integration and coordination, and therefore they can offer medium-to-fast fault-response speeds when properly managed.

Repair Crews

Traditional repair crews remain a core component of outage response. They provide physical inspection, troubleshooting, and repair of damaged components rather than directly supporting demand-supply balance. Capital expenditure is relatively low, as the main costs are operational rather than upfront. However, their response speeds are inherently slower than automated technologies, and flexibility is limited by crew availability, travel time, and safety constraints.

Aerial-Based Inspections

Drone-based inspection refers to the use of unmanned aerial vehicles to conduct periodic visual assessments of network assets such as overhead lines, poles, and substations. Drones are typically deployed on a scheduled basis or following fault events to capture high-resolution imagery, thermal data, whereas LiDAR scans are mostly aircraft based and periodic. These methods replace or supplement traditional manual inspections and allows rapid surveying of difficult-to-access infrastructure. However, aerial inspections are inherently intermittent: visibility is only available when flights take place, and performance can be limited by weather and operational constraints, including line-of-sight regulations.

Line Sensors/Continuous Monitoring

Line sensors and related continuous monitoring technologies are permanently installed devices that provide real-time data on network conditions. These systems can continuously detect faults, monitor conductor temperature, identify abnormal loading, and provide precise fault location information. By transmitting data continuously to control centres, they enable proactive asset management and automated fault detection. Unlike drone inspections, continuous monitoring does not depend on human mobilisation and operates regardless of weather conditions. The function of continuous monitoring technology is highly dependent on a stable and reliable communication system. Once communication is interrupted, the stability of the real-time monitoring network may be compromised, though mobile communications usually remain operational for 5-30 minutes following interruption of supply. Line sensors also typically contain some level of battery backup – allowing transmission of data if communication networks are restored in time.

Digital Twins

Digital twins are detailed virtual representations of the network that combine real-time data (e.g., the data collected from continuous monitoring technologies), models, and simulations. They can cover a wide range of tacks to support network operation. However, they require substantial initial investment in data connection, integration and modelling, leading to medium-to-high capital expenditure and slower adoption. Once implemented, however, digital twins provide powerful analytical capabilities, enabling rapid scenario assessment and optimised fault-response strategies.

Cost–Benefit Comparisons of Digital Technologies

The following table highlights the distinct operational characteristics of the technologies when assessed solely against the four required metrics. The metrics are discussed in more detail below.

Table 4: Cost-benefit analysis of technologies

	Capital Expenditure	Speed of Adoption	Operational Flexibility	Fault-response Speeds
Mobile Storage	High	Slow	Low	Medium
DER	High	Slow	Medium	Medium
Repair Crews	Low	Fast	Low	Slow-Medium
Drone-based inspections	Low	Fast	Medium	Medium
Line sensors	Low - Medium	Moderate	High	Fast
Digital Twins	Medium	Slow-Moderate	High	Fast

Capital Expenditure

Physical hardware-based solutions such as mobile storage, DER installations, and digital twins generally require the highest capital investment³⁷. In contrast, software-oriented approaches like machine learning analytics and the mobilisation of repair crews involve relatively low upfront costs. Drone-based inspection has the lowest overall capital requirement, as a small number of drones can cover wide areas³⁸, though their coverage is still limited by LOS restrictions, meaning they cannot operate³⁹, widespread deployment across many locations (along with the necessary communication infrastructure) which could lead to a medium investment cost, depending on the scale of implementation.

Speed of Adoption

Drones can be adopted very quickly; they require little fixed infrastructure and can be deployed soon after procurement. Continuous monitoring technologies involve a more moderate adoption speed because planning, installation, and integration with control systems are required. Mobile storage generally has a slow adoption speed: units have limited capacity,

need to be moved between locations via the transport network, and procurement and site preparation also create longer lead times than for drones⁴⁰. Technologies that rely primarily on software or existing human resources, such as ML analytics and repair crews, can be adopted rapidly. By contrast, digital twins and DER integration require significant planning, data integration, and system upgrades, resulting in slower implementation timelines.

Operational Flexibility

The highest flexibility is provided by digital twins, machine learning tools, and continuous monitoring systems. These technologies can adapt to different operational needs and support multiple decision-making processes. Drones offer medium operational flexibility because they can be redeployed to different parts of the network as inspection needs change. In comparison, mobile storage and repair crews can be considered as low flexibility: while units are transportable, they are constrained by logistics, connection requirements, and the need to be physically present at a location to perform either energy support or local inspection.

Fault-Response Speeds

Continuous monitoring technologies deliver the fastest fault-response speeds, as they detect and communicate problems automatically in real time. Digital twins with advanced AI techniques can also enable rapid response by interpreting data and recommending actions. Drone inspections provide moderate response speeds, since faults can only be identified after a flyover has been arranged and completed. Repair crews are comparatively slow due to mobilisation and travel times. Similarly, mobile storage and DERs also offers moderate response speeds: once on site, operators can inspect connection points and support local restoration, but it cannot provide system-wide or immediate fault detection.

Conclusions

This comparison demonstrates that the effectiveness of each technology varies depending on the task at hand, i.e., pre-fault detection, fault detection, and repair. For pre-fault detection, line sensors and continuous monitoring offer the core real-time visibility needed to identify deteriorating components before failure. While digital twins can enhance the value of this data by improving analysis and decision-making, drones and manual inspections can also play a role, but only in specific areas of the network, and they are less efficient compared to sensors in providing continuous coverage. Fault detection becomes crucial when external damage, such as fallen trees during storms, causes the majority of faults. In this stage, line sensors are highly effective because they cover the entire distribution network, even in challenging weather conditions, whereas drones and personnel are more limited in their ability to operate in adverse environments and can only inspect small parts of the network at a time. Repair is the final stage, and human intervention is necessary to physically fix faults; alternatives, such as network duplication, are cost-prohibitive for large distribution networks. Drones and repair crews are essential for inspecting and fixing specific issues, particularly in high-voltage infrastructure, but their role in day-to-day operations is limited. Digital twins and AI techniques complement continuous monitoring by using sensor data to predict potential faults and guide intervention priorities. These technologies do not directly interact with drones or personnel but enhance the overall effectiveness of the monitoring system by transforming raw data into actionable insights. Together, these technologies contribute to improved decision-making and faster fault resolution.

Each of these technologies provides a specific subset of functional capabilities, and none alone can address all operational requirements. From an investment perspective, continuous monitoring should be prioritised as the foundational capability, since it provides the real-time visibility required to enable faster fault detection, improve decision-making, and enhance the effectiveness of all other technologies. To realise the maximum benefits, continuous monitoring technologies should deliver accurate pre-fault, low-line fault and nested fault location, as well as integration with a digital insights platform to manage asset health.

Building on this baseline, DNOs can then deploy complementary solutions, such as drones for targeted inspections, analytics for decision support, and DER or mobile storage for resilience, according to specific asset classes and operational needs. More detailed techno-economic analysis is needed to guide coordinated investment across a portfolio of complementing technologies.

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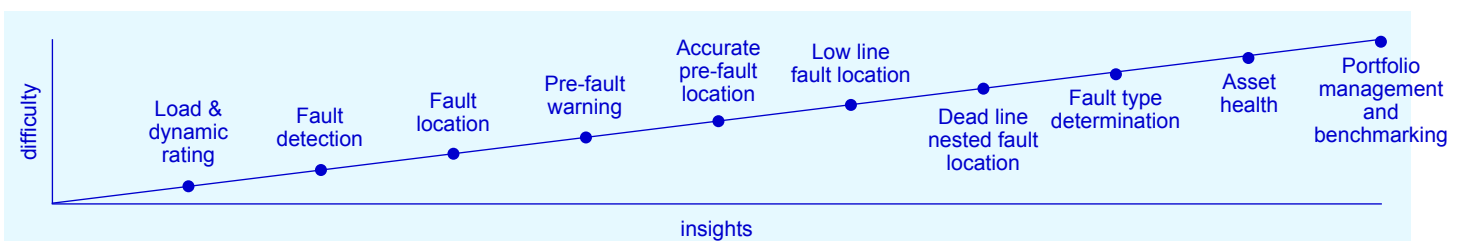


Figure 2: Escalating capabilities of continuous monitoring⁴¹

Quantitative Analysis of the Advantages of Continuous Monitoring

The below quantitative analysis focuses on continuous monitoring, as it is the key enabler of improved network visibility, directly impacting fault detection, response speed, and outage prevention. It also provides the data foundation for repair crews (RCs), making it a critical baseline capability for enhancing network resilience.

Outline of the Proposed Analysis Strategy

The utilised mathematical model for quantitative analysis is based on a coupled power-transport network, as illustrated in Figure 3, which involves three modules: RCs, the power distribution network, and the transportation network. There is a central monitor that can communicate with each RC and broadcast to individuals the system outage information (e.g., damaged component, status, and location) via

a communication layer, in order to help RCs make more informed decisions. Specifically, the potential destinations of RCs include their initial depots and the locations of damaged components (e.g., distribution lines). When an extreme event happens, RCs are sent out to sequentially repair the damaged components, which constitutes two kinds of alternative decisions: 1) routing to destinations in the transportation network and 2) repairing the targeted components in the power distribution network.

The objective of the proposed strategy is to maximise the weighted sum of restored loads for resilience enhancement, which can be realised as the resilience index shown in Figure 3. The resilience index (RI) is defined as the ratio of weighted supplied loads and total weighted loads. It is expected that the higher value of RI indicates more restoration of the weighted loads and consequently better performance of the overall resilience enhancement.

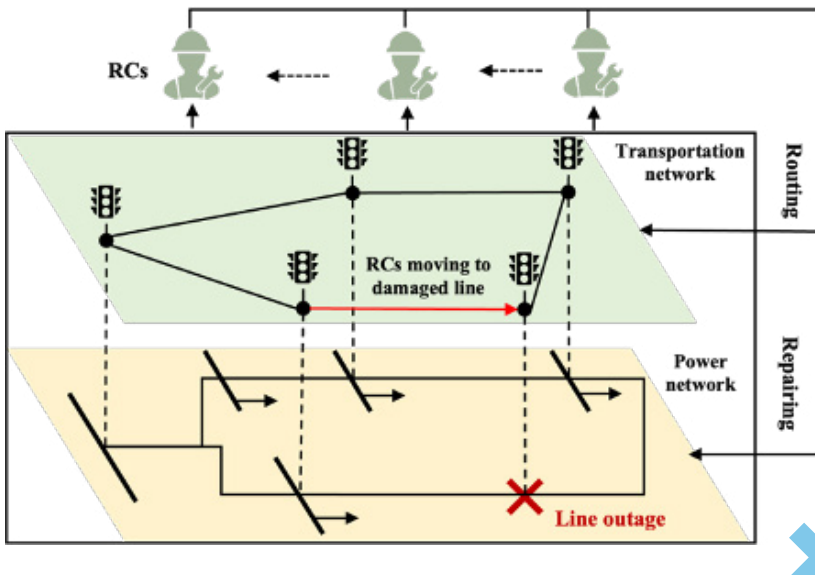
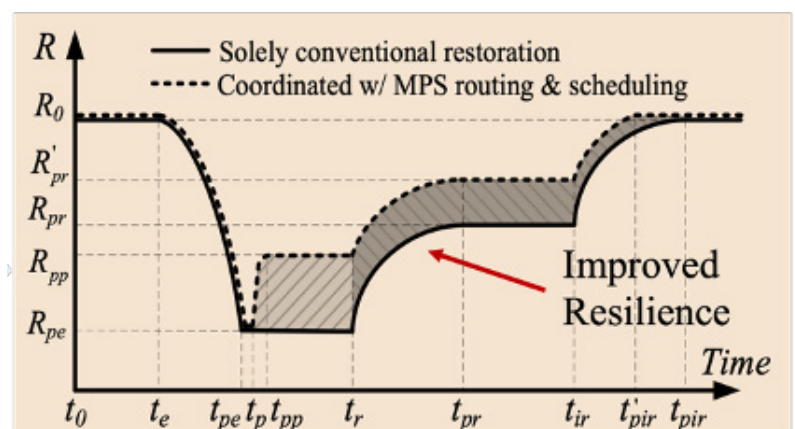


Figure 3: Illustration of a coupled power-transport network and corresponding resilience index for resilience assessment. Repair crews (RCs) are navigated through transportation networks to arrive at the fault locations and repair the faults (e.g. line outage). D_c and D_n refer to critical demand and non-critical demand, while w_c and w_n are the shedding costs of critical loads and non-critical loads, respectively.



$$RI = 1 - \frac{w_c \Delta D_c + w_n \Delta D_n}{w_c D_c + w_n D_n}$$

Experimental Setup

The power network used for analysis is constructed by replicating the IEEE 69-bus standard distribution system 25 times, resulting in a large-scale network comprising a total of 1,725 buses, as exhibited in Figure 4. This assumption is based on three factors: a) the network features a radial topology and overhead distribution lines, which are common characteristics of distribution systems in Great Britain; b) the network is publicly available, allowing for transparency and accessibility in testing and research; c) the network size and structure allow the modelling of multiple line failures and islanded operation, which are critical aspects of resilience-oriented power system operation.

Within this network, 25 RCs are strategically deployed to carry out maintenance and restoration activities, particularly during extreme weather events. Under normal operating conditions, the average repair time

for a damaged component is approximately four hours. However, based on engineering practice, this could be reduced to around two hours with the deployment of continuous monitoring technologies, which enable faster fault detection and localisation.

The system is assumed to experience one extreme weather event per year, with the remaining period characterised by normal, or 'blue-sky' conditions. During extreme events, the network is subject to a high volume of disruptions, with approximately 300-500 faults occurring across the system. In contrast, under blue-sky conditions, the network experiences a much lower failure rate, typically around one or two faults per day. To reflect the ageing effect of the equipment in the future system, a high failure rate case is also developed with the assumption that one fault happens per day in each sub-network, resulting in a total of 25 faults per day across the entire network.

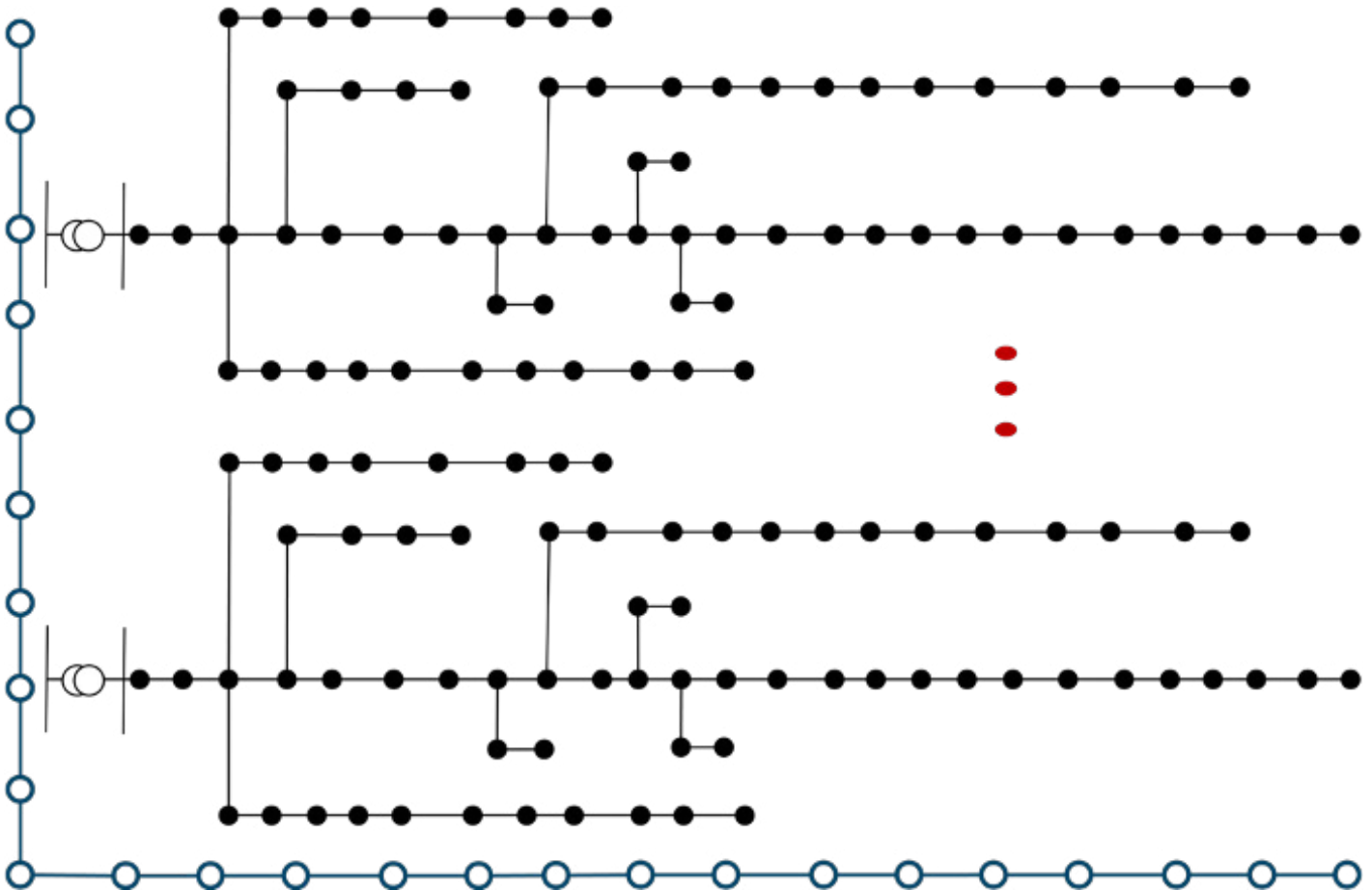


Figure 4: Network structure of the studied large-scale distribution system with 1,725 buses.

Comparison Case Design

Based on the above experiment settings, the following four scenarios are defined to evaluate the impact of continuous monitoring technologies on system resilience and restoration performance:

Case 1: Baseline (Without Continuous Monitoring)

This scenario represents current operational conditions without advanced monitoring technologies. A response delay of 1 hour is assumed before RCs are dispatched following an event, while the fault detection requires 2 hours. Once the fault is located, the repair process takes a further 2 hours. This scenario serves as the reference case for further comparison.

Case 3: Enhanced Detection Accuracy

This scenario assumes that continuous monitoring technologies provide precise and immediate fault localisation. As a result, fault detection time is reduced to zero, allowing RCs to proceed directly to the fault location. The repair time remains at 2 hours. This scenario highlights the value of accurate, real-time visibility in facilitating fast load restoration.

Case 2: No Response Delay

In this scenario, continuous monitoring enables immediate awareness of the event, eliminating the initial response delay. Therefore, RCs are dispatched without delay (0 hours) once a fault occurs. However, fault detection and repair durations remain unchanged. This scenario highlights the benefit of improved situational awareness in accelerating restoration actions and enhancing resilience.

Case 4: Reduced Outage Frequency

In addition to faster response and detection, continuous monitoring can enable proactive intervention and preventive maintenance, thereby avoiding a proportion of potential faults. In this scenario, the total number of line outages is reduced, reflecting the ability of monitoring systems to identify and mitigate emerging issues before they lead to failures. This scenario captures the preventive benefits of continuous monitoring in enhancing overall grid resilience.

Analysis of Results

The comparison result is illustrated in Figure 5. It can be found that the deployment of continuous monitoring technologies lead to a notable improvement in grid resilience, due to the enhanced reaction speed and fault detection accuracy of RCs. In detail, when response delays are eliminated and detection accuracy is enhanced, the system can restore service more quickly, particularly during extreme weather events. The RI improves substantially, with the system reaching 75.33% resilience during storms, compared to only 56.14% in the baseline scenario. The faster fault detection and the ability to dispatch crews immediately lead to a much more efficient fault restoration process, which is crucial in resilience enhancement.

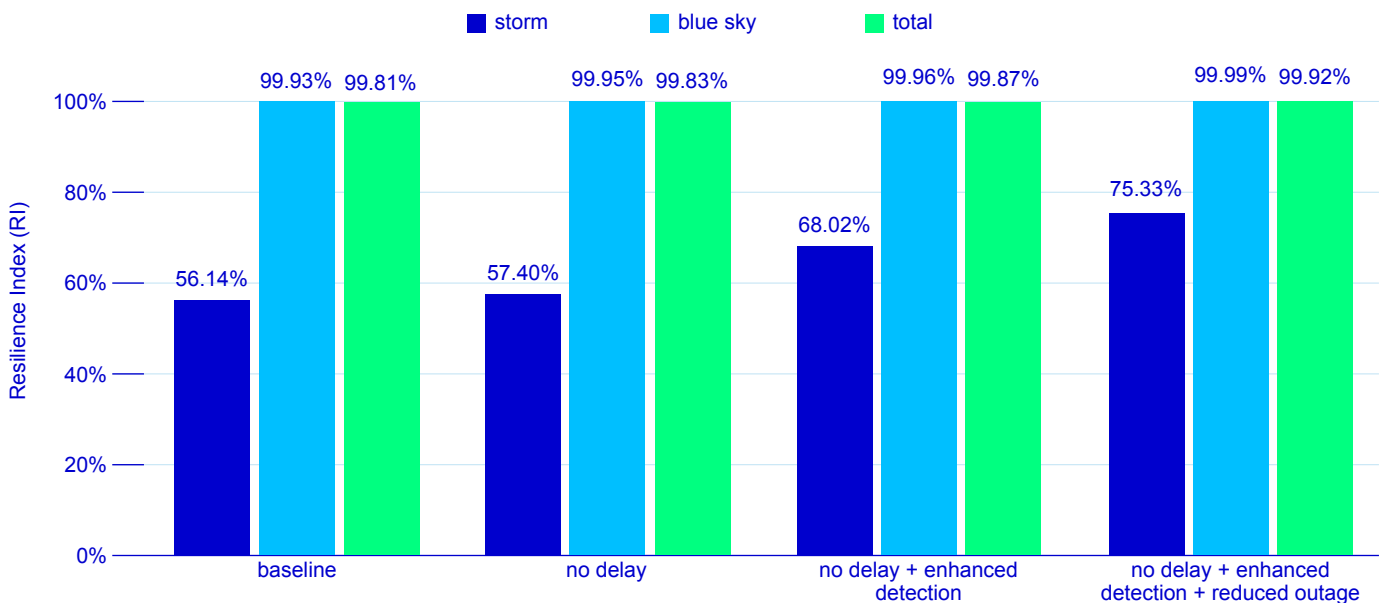


Figure 5: Resilience index comparison across four different cases.

In addition to faster reaction times, continuous monitoring can proactively identify potential line outages before they occur. This proactive approach helps avoid a significant number of outages, further enhancing resilience. As the results show, incorporating both enhanced detection and reduced outage frequency leads to an even greater improvement in resilience, with the system achieving 99.92% total resilience, a reduction in customer minutes lost by 58% compared to the baseline case. In particular, during storm conditions, incorporating both enhanced detection and reduced outage frequency increases system resilience from 57.40% to 75.33%, representing an improvement of approximately 31%. This scenario highlights the full potential of continuous monitoring in not just improving fault response times, but also in preventing faults from occurring in the first place, ultimately ensuring a more reliable and resilient distribution network.

Where there are ageing assets, the benefits of continuous monitoring are even more significant, with reduction in customer minutes lost of 80% compared to the baseline case.

These results suggest that DNOs should prioritise investment in continuous monitoring as a foundational capability to enhance network visibility and resilience.

By leveraging improved fault detection and proactive outage prevention, DNOs can significantly reduce restoration time and strengthen system performance, particularly under extreme weather conditions.

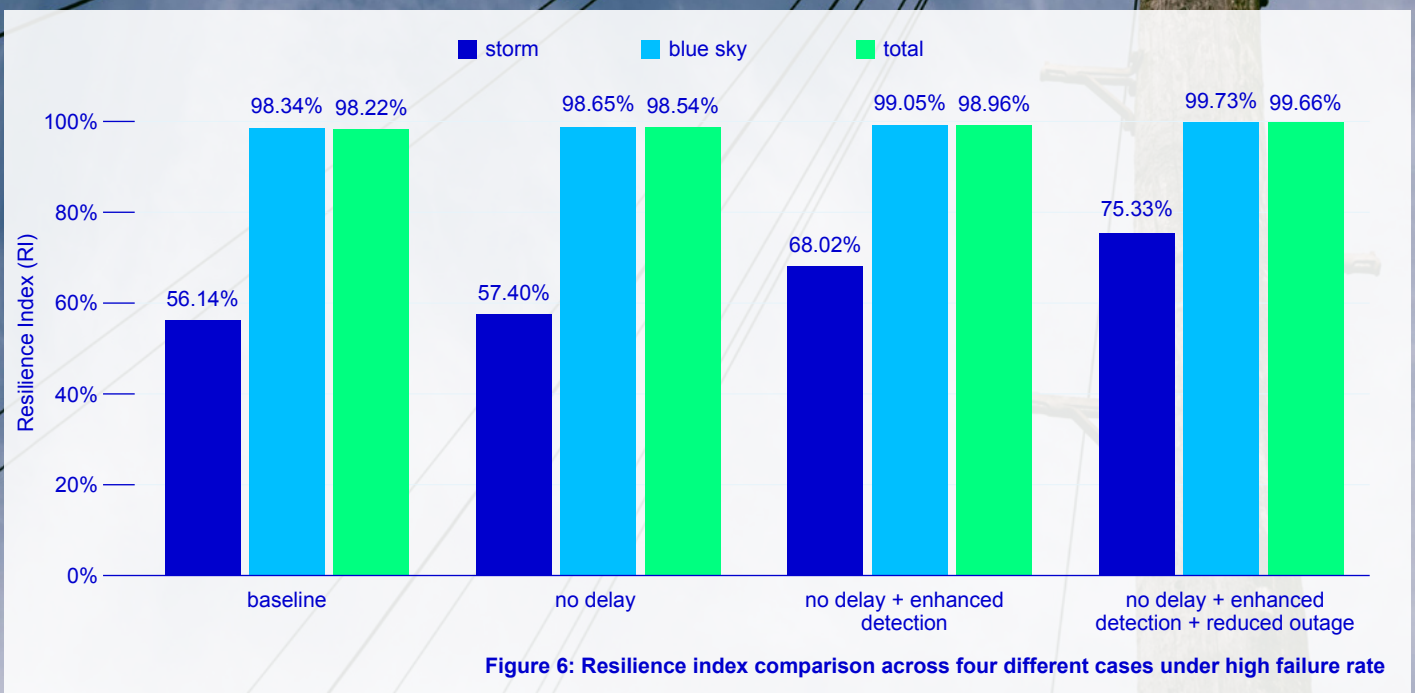


Figure 6: Resilience index comparison across four different cases under high failure rate

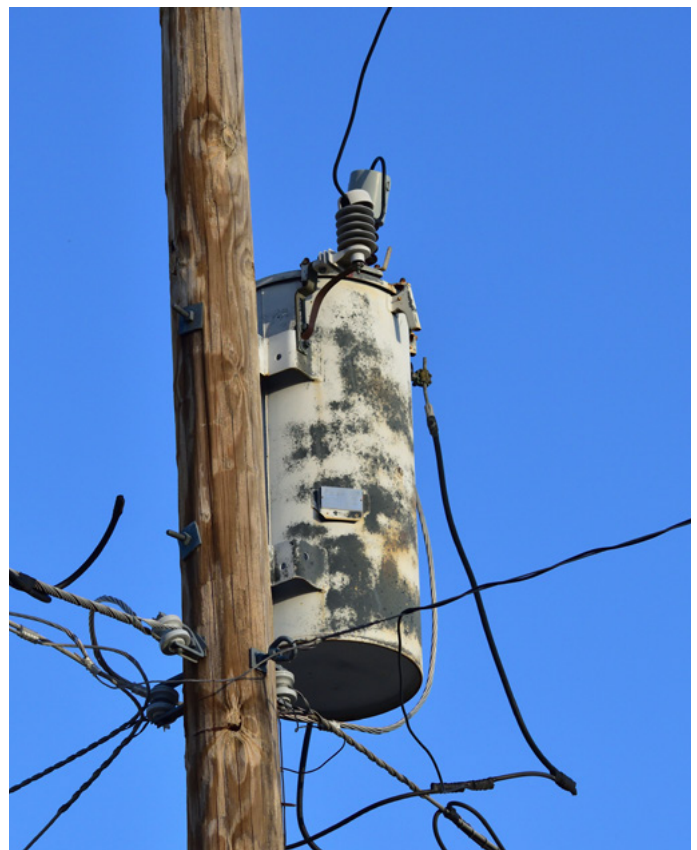
Policy recommendations

1. Strengthen incentives to drive long-term resilience

- a. Reputational incentives have not driven sufficient investment in resilience. **Ofgem should move more decisively toward financial incentives for resilience measures**, including through strengthening or replacing existing reputational mechanisms for climate resilience.
- b. In parallel, **incentives must better reflect long-term value**. The principle of “touching the network once” will not be realised without actively rewarding whole-life cost efficiency and resilience benefits.
- c. **Incentives should go further to reward outcomes delivered, rather than just the presence of resilience technologies** – so as to encourage genuine performance enhancement and unlock long-term benefits, rather than short term lowest-cost compliance. Linking incentives to measurable improvements such as faster fault detection, reduced restoration time and avoided outages would help align investment decisions with Ofgem’s stated objectives.
- d. Incentive distortions should be amended for ED3. While Ofgem has stated that the IIS, GSOP and NARM will be adapted to more strongly reflect climate risks and modern electricity usage, final details on adaptations have not been confirmed. To address perverse incentives in the IIS, **storm-related exemptions on CI and CML should be progressively scaled back to drive improvements**. Ofgem could consider exposing DNOs to a proportion of storm-related CI and CML impacts. NARM must also be adapted to account for increased asset deterioration and for future asset health linked to changing climate conditions. Additional factors and assumptions should be developed as recommended by NIC and the NARM Electricity Distribution Working Group (NEDWG)⁴²
- e. **Ofgem should also enhance existing mechanisms and introduce new incentives on leading delivery indicators**, such as contract placement timescales and forward order volumes, to cultivate the cultural and operational urgency needed to assure delivery, mitigate risks for customers and therefore reduce the need for Ofgem to retrospectively adjust allowances.

2. Support investment in high-impact technologies

- a. The current framework does not sufficiently incentivise technologies that materially improve resilience. While regional flexibility remains important, **Ofgem should provide stronger and more prescriptive guidance on what constitutes effective resilience investment**, including actively promoting the adoption of both hard and smart resilience measures.
- b. **Ofgem should more clearly prioritise investments that deliver multiple system benefits**, including resilience, net zero and smart network outcomes – overcoming the current lack of cohesion. Technologies that improve forecasting, fault prevention, restoration time and overall network resilience should be incentivised in their own right, but especially where these also contribute to smart network and net zero objectives.
- c. **The Innovation Roll-out Mechanism (IRM) should be adapted to support high impact scale-up technologies which can materially improve customer outcomes**, and not only less-established technologies with less immediate or narrower market impact.



3. Improve transparency and accountability

- a. Reduced visibility of DNO performance and investment plans is a growing barrier to effective regulation. **Ofgem should mandate centralised, standardised and comparable reporting across all DNOs**, including data on resilience, reliability, investment activity and performance during severe weather events.
- b. The lack of defined resilience metrics remains a critical gap. **Clear metrics, indicators and standards (e.g. CRMIs) should be developed, implemented, and enforced as part of ED3 to guide investment, with comparative assessments published to measure performance and ensure accountability.** This is essential to ensure that previously committed reforms are delivered and that resilience objectives are embedded in regulatory decision-making.
- c. While quantitative methods (e.g. stress testing and CRMIs) are developed, other actions should be taken to facilitate investment. **A standardised qualitative framework for DNOs to justify climate resilience investments in business plans should be adopted with a mechanism to ensure accountability for delivery.** Beyond the quantitative and qualitative data required to justify climate resilience investments, immediate “no regrets” options should focus on areas such as wind and flooding hazards, where the understanding of the investment need is at a higher level of maturity.

4. Provide clearer strategic direction from government

- a. **The Department for Energy Security and Net Zero should ensure the forthcoming Energy Resilience Strategy provides clear direction to Ofgem and DNOs to prioritise long-term resilience, security of supply and public safety.** The Strategy should consider the role of digital technologies in supporting early fault detection, faster restoration, improved operational safety and reduced consumer costs. This will assist a shift from reactive fault response toward proactive, embedded resilience enabled by real-time network visibility, ensuring that strategic policy intent is translated into regulatory frameworks and investment decisions.
- b. Resilience, energy security and critical national infrastructure (CNI) will require closer coordination between NESO, DESNZ and Ofgem. Systemic resilience needs a holistic approach that accounts for interdependencies and cascading failures across energy, water, and transport networks. **NESO and DESNZ should improve understanding of critical connections to the energy system, mapping of dependencies between energy and other CNI and accelerating the development of shared data products and analytical tools. As part of the Energy Resilience Strategy, DESNZ and the Cabinet Office should work across government departments considering options for embedding power resilience across all CNI sectors.**



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