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*Switching up the smart system:  
How the smart system can  
transform energy resilience*

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25 JUNE 2026

# Foreword



*The time is now for Great Britain to harness the full potential of its smart metering system. Our smart meters can do so much more than just track our energy use. This important report from LCP Delta shows just how powerful a fully realised smart meter system could be: strengthening Great Britain's energy grid resilience, better identifying vulnerable consumers and – crucially – saving money for households and businesses.*

*The report opens up a range of possibilities for smarter use of our smart energy system. We at Calisen are committed to playing our part in maximising this potential through ever-improving data and analytics, and building stronger connections across the system to drive innovation, efficiency and progress.*

**Catherine O'Kelly, CEO, Calisen**



*As we become increasingly dependent on electricity to meet our energy needs, we need to transition to a more modern, resilient and affordable energy system.*

*But without accurate and timely data, we often end up paying more than necessary for our energy - this imposes unnecessary burdens on our aging energy system and wastes valuable resources.*

*Smart meters are a key technology in providing that data, capturing and communicating energy flows. In this report we look at some of the potential use cases where smart meters can ensure a more resilient energy system and at the same time deliver more affordable energy to consumers.*

**Tom Veli, Partner, LCP Delta**



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*Executive Summary*

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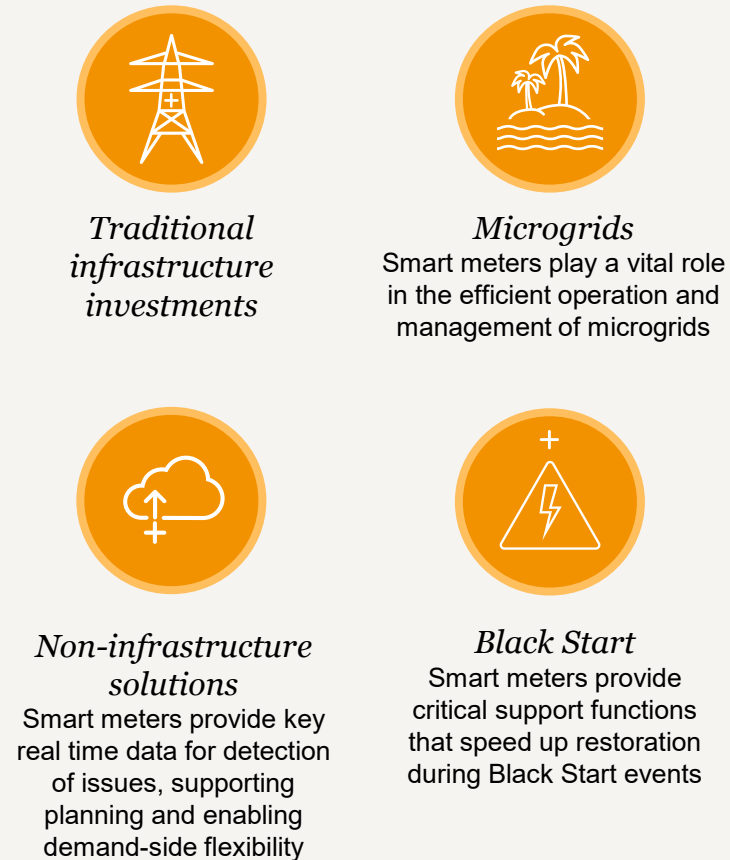
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# A taxonomy of grid resilience

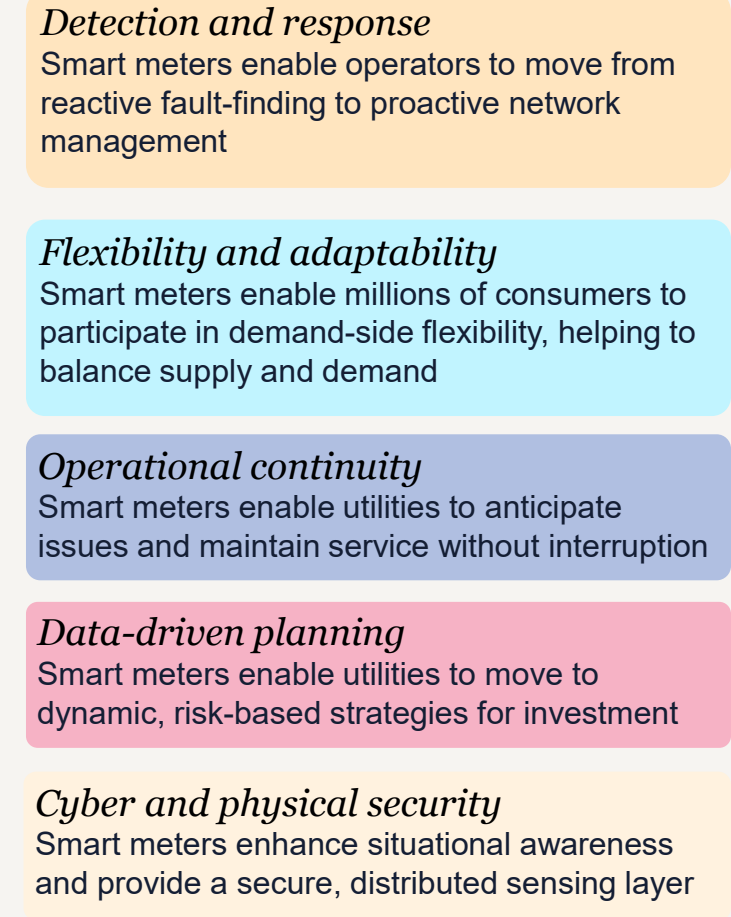
## Resilience definition



## Current approaches for delivering resilience



## Components of Resilience



# Summary

Our research identifies specific use cases where smart meters can deliver more benefits for Great Britain. The report analyses these opportunities using evidence from real-world trials and modelling to demonstrate the benefits and associated policy requirements. It highlights the role smart meters can play in enhancing grid resilience, optimising the energy system, and delivering operational savings.



## Voltage Control

The management of voltage levels across the low voltage (LV) electricity network to keep them within statutory limits



## System Optimisation

Via flexibility; the ability to dynamically balance fluctuations in supply and demand under varying conditions



## Operational Savings

Reduce the time, cost, and resources needed to manage the electricity system and consumer accounts, including social returns

Use case

Smart meter-enabled voltage control improves energy efficiency and grid resilience by providing visibility of voltage levels beyond substations. Trials show that optimising voltage using smart meter data can reduce consumption, lower bills, and cut carbon.

Smart meters enable consumer-led flexibility by providing near real-time data, allowing consumers to shift usage and support grid stability. Smart meters enable services such as the Demand Flexibility Service (DFS) which can reward households for reducing demand.

Smart meters replace manual readings with automated, half-hourly data, reducing costs, potential errors, and enabling more accurate settlement and billing. They also help identify and support vulnerable customers more effectively.

Potential gross benefit across GB consumers

The research models base case and best case scenarios e.g. current rollout versus 100% rollout

**£572-770m**  
from Conservation Voltage Reduction (CVR) voltage control

**£103-139m**  
from avoided overvoltage

**£1-1.5m**  
from Winter DFS

**£415-560m**  
from excess energy to customers enabled by smart meters

**£312-420m**  
from operational savings of the full smart meter rollout

**£185-250m**  
of social return from using smart meters to identify vulnerable households

Total annual gross benefits of £1.9bn at 100% rollout

Lifetime benefit

# Next steps for industry



## Voltage Control

*The management of voltage levels across the low voltage (LV) electricity network to keep them within statutory limits*



## System Optimisation

*Via flexibility; the ability to dynamically balance fluctuations in supply and demand under varying conditions.*



## Operational Savings

*Reduce the time, cost, and resources needed to manage the electricity system and consumer accounts, including social benefits*

**Opportunity for industry**

Develop new hardware or services to supply networks with accurate, near real-time voltage measurement data.

Enable automated flexibility by supporting the rollout of smart meter features like Auxiliary Proportional Controller (APC) to allow devices to be controlled remotely.

Industry needs to collaborate to complete the rollout by addressing hard to reach consumers and complex metering arrangements

**Policy asks**

1. Real-time voltage measurement data at grid-edge for DNOs.
2. Timely access for network operators to smart meter voltage data.

1. Improve smart meter operation to ensure half-hourly data is available for all installed meters.
2. Expanding access to the DCC-controlled smart meter signals beyond just suppliers.

1. Streamline and improve data access to individual household smart meter data in the use case of identifying Priority Service Register eligible customers.
2. Mandate the installation of smart meters in all newbuilds to accelerate rollout and futureproof new housing developments.



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*Part 1: Analysing resilience in the  
UK and around the world*

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Resilience isn't optional - it's worth billions and protects every home.

# 1. *Defining resilience*

As Great Britain transitions toward a sustainable, futureproof energy system, resilience is the backbone of our electrified future. A second energy crisis, triggered by international conflict, has increased the pressure to reduce oil and gas dependence. The stakes are enormous: the UK is investing an estimated **£1.4 trillion** in modernising an ageing system that embraces clean sources of power, yet around 25% of homes still lack a smart meter and over 7% of smart meters are non-communicating, leaving critical blind spots in our energy system. The number of non-communicating meters has been tracking down as the industry identifies issues.

Resilience means more than keeping the lights on. It safeguards health, prevents economic shocks, and ensures fairness for vulnerable consumers. Every outage avoided saves money and stress: Ofgem's latest figures show compensation for prolonged outages can reach **£2,165 per household**, while the Value of Lost Load for businesses can exceed **£250 per kWh**.

Smart meters are the foundation of this resilience. They provide near real-time visibility, enable rapid fault detection, and unlock flexibility, turning a reactive grid into a proactive one. Without them, we risk slower recovery, higher costs, and greater vulnerability as electrification accelerates. This section provides a broad definition of grid resilience, the different ways to quantify resilience and to monetise it.



# Introduction

**The futureproofing of GB’s energy system leans heavily on electrification. As petrol cars give way to EVs and gas boilers are replaced by heat pumps, more of the economy runs on electrons rather than molecules.**

While reducing exposure to international oil and gas price shocks is essential, the shift to electrify increases the need for a strong and resilient electricity distribution grid. Ageing assets and historic under-investment in local networks heighten the risk of constraints and outages just as dependence on electricity grows. Events have shown what can happen when resilience is stretched.



A frequency event on 9 August 2019 caused automatic disconnections affecting around a million consumers. Official reports traced this to the loss of two large generators and the speed of the frequency fall.



More recently, a 2025 substation fire linked to maintenance failings triggered major disruption at Heathrow, prompting an Ofgem investigation\*.

These incidents demonstrate why grid resilience matters ever more in an electrified economy. At the same time, the electricity generation mix is changing. Wind and solar are intermittent by nature and not fully dispatchable (i.e., the output depends on weather and time of day rather than operator instruction) and are unable to provide system inertia.

The transition to cleaner energy systems is recognised as a massive structural undertaking.

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**+ £1.4 trillion** Estimated investment cost of achieving the UK’s net zero carbon emissions target. From a 2021 report by the Office for Budget Responsibility\*\*

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From a public-policy perspective, investing in resilience is not optional. It is integral to delivering the transition in a way that is just and sustainable. A resilient system supports the shift to low carbon technologies, by enabling them to be integrated reliably, by buffering shocks from intermittent supply, and by assuring consumers that their energy remains secure.

- This resilience supports health outcomes: a household that cannot afford heating or suffers repeated outages faces direct risks to health (cold-homes, inability to run medical devices, food spoilage) and indirect risks (stress, financial strain).

## Consumer expectations

From a recent Ofgem commissioned consumer outcomes research study\*\*\*:

- Resilience, largely defined as uninterrupted supply, is viewed as a bare minimum. So, **consumers expect resilience** in their energy networks.
- There is strong resistance overall to passing on the cost of investment to consumers and consumers expect energy suppliers to reinvest profits and be held accountable for reaching their goals. So, **consumers are generally unwilling to pay for this resilience**.

\*Source: [Ofgem opens investigation into NGET](#)

\*\*Source: [2021 report by the Office for Budget Responsibility](#)

\*\*\*Source: [Ofgem Energy consumer outcomes: research](#)

# Why do we need resilience?

## The need for resilience in the GB system is driven by its growing dependence on electricity

### Why the growing system need?

Western Europe, including GB, has generally enjoyed a highly resilient grid compared with other regions. As the energy system evolves, we are increasingly tapping into abundant domestic renewable resources that offer long-term cost stability, improved energy security, and lower environmental impact. At the same time, this shift brings with it new technical considerations for a grid historically designed around centralised thermal generation, including intermittent renewable generation from wind and solar, as well as less dispatchable thermal plant and inertia:

- Traditional thermal units use large synchronous machines that naturally provide rotational inertia, the kinetic “buffer” that slows frequency changes after a disturbance.
- Most modern wind and solar plants connect through power electronics and, without specific controls, contribute little or no inherent inertia.

### Why the growing consumer need?

Just as the supply side is facing challenges, so the **demand side** is becoming increasingly dependent on electrification both to serve new demands and to replace conventional energy sources in:



**Mobility:** The shift to EVs is accelerating, from private cars and public transport to commercial fleets. This increases overall electricity demand and creates local peak-load pressures.



**Heating:** Electrification of heat through technologies such as heat pumps, electric boilers, and district heating networks. This not only increases overall electricity consumption but also changes demand patterns, particularly in colder seasons.



**Home working:** The widespread adoption of remote working and digital technologies has made households small hubs of energy use. This has shifted electricity use from offices to homes throughout the day. Combined with household electrification this increases pressure on local distribution networks.

### Natural disasters

The growing need is compounded by the increased frequency and intensity of extreme weather events caused by human-caused rise in greenhouse gases\*; microgrids have historically provided a degree of resilience against these.

In addition to natural disasters, the increasing development of marginal sites (such as flood plains and beachfronts) has certainly resulted in increasing losses, the so-called “growing bullseye” effect of:



Wildfires



Tsunamis



Hurricanes



Floods



Earthquakes

In California, pre-emptive measures intended to prevent wildfires have resulted in significant economic losses from grid outages.

Driven by wildfire risks, public safety power shutoff events affected more than 1 million consumers in California in 2019, with an estimated economic loss of ~\$2 billion.

\* The Intergovernmental Panel on Climate Change (IPCC)'s [Sixth Assessment Report](#) explores the causes of the increased frequency in extreme weather events.

# The definition of resilience

**We have taken a broader definition of resilience, to include reliability (& operational performance), societal resilience and economic resilience, as well as technical resilience.**

The conventional definition for grid resilience is narrower, referring to the ability of the system to withstand shocks and stresses and quickly recover from disruptive events. Traditionally, resilience is defined in purely technical terms, for example as *“the ability of assets, networks and systems to anticipate, absorb, adapt to and/or rapidly recover from a disruptive event”*.

For this report, we have broadened the concept for grid resilience to include operational resilience, societal resilience and economic resilience. This gives a more comprehensive view of the types of resilience challenges faced by the energy system today.

As society becomes more dependent on electricity, resilience becomes more important to daily lives and the overall economy.

In parallel the energy system is becoming more complex with an increasing share of intermittent generation and consequently less conventional thermal generation, increasing the vulnerability of the system and the need for resilience.

## Components of grid resilience

### Technical resilience

The ability of assets, networks and systems to anticipate, absorb, adapt to and/or rapidly recover from a disruptive event. The emphasis is on high-impact, low frequency events



### Societal resilience

The protection of consumers and communities, particularly vulnerable groups, ensuring equitable outcomes during disruptions



### Operational resilience

Maintaining and avoiding failure of supply of the system under normal operating conditions. This includes reliability, operational performance such as power quality, and performance optimisation.



### Economic resilience

Strategic planning of the energy system to deliver energy economically despite financial shocks (e.g., fuel price spikes, infrastructure failures).



# The definition of resilience

## Technical resilience



**Technical resilience is the ability of the system to prepare for, operate through, recover as quickly as possible, and adapt from high-impact, low frequency events**

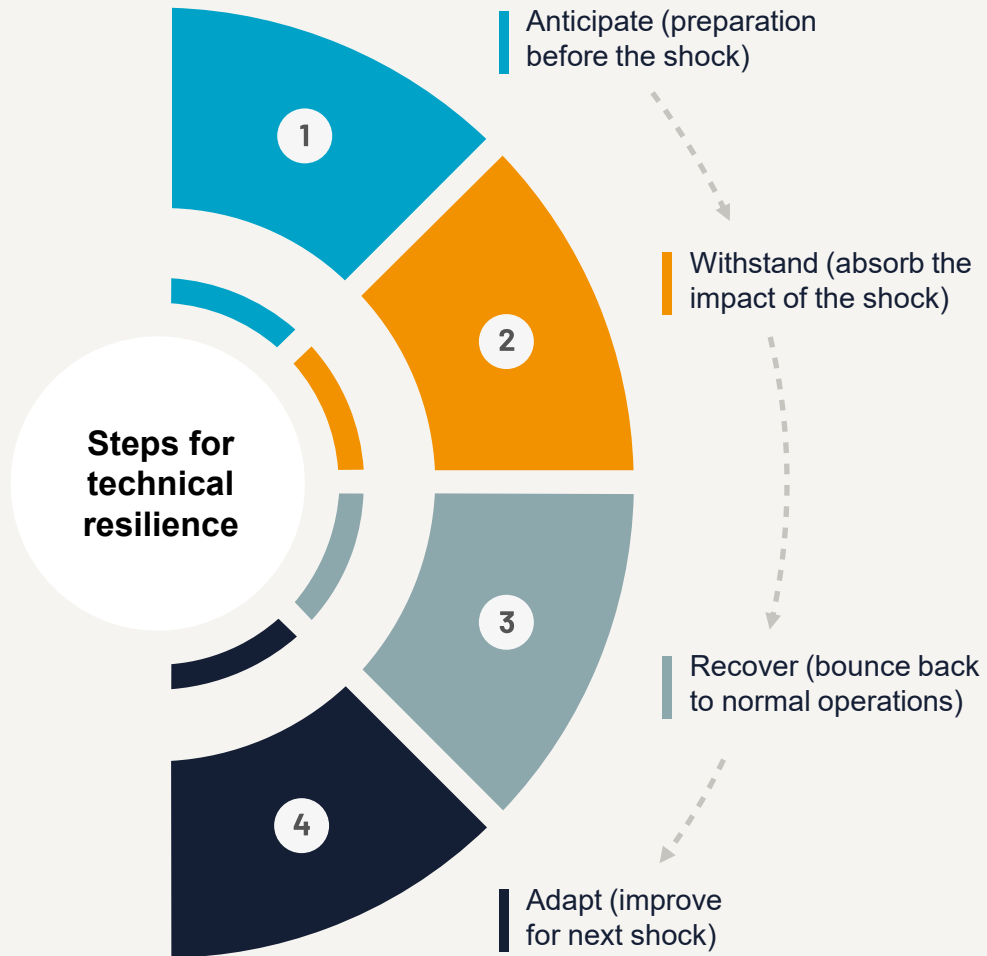
**Technical resilience** has been defined by various organisations in closely related ways focusing on high-impact disturbances. For example, the U.S. Federal Energy Regulatory Commission proposed defining resilience as *“the ability to withstand and reduce the magnitude and/or duration of disruptive events, including the capability to anticipate, absorb, adapt to, and/or rapidly recover from such events”*.

Core to all definitions is the idea of absorbing shocks and bouncing back quickly. The emphasis is often on high-impact, low-frequency events, including extreme weather events, cyber attacks or blackouts that are infrequent but lead to major consequences.

In the GB context, the Cabinet Office defines resilience as:

*“The ability of assets, networks and systems to anticipate, absorb, adapt to and/or rapidly recover from a disruptive event”*

**Cabinet office definition of resilience**



# The definition of resilience

## Technical resilience - examples

### Earthquakes



Both direct impact of earthquakes and the secondary effect of tsunami can be devastating. In the case of the Great Eastern Japan earthquake in March 2011, the most severe effects were caused by the tsunami on coastal areas.

However, the indirect effect of the failure of the Fukushima nuclear power station had catastrophic effects on the environment. The precautionary shut down of Japan's entire nuclear fleet subsequently had a severe and long-lasting impact on the entire country.

### Ukraine cyber attack



In December 2015, three electricity distribution companies in Ukraine were the target of a coordinated cyber-attack that led to power cuts for around 225,000 consumers. It is widely considered the first confirmed case where a cyber-attack directly caused a power outage.

The series of events for the attack were:

- Attackers entered through simple phishing emails sent to staff.
- They spent months inside the IT network without being detected, eventually reaching the systems that remotely control substations.
- On the day of the attack, they used stolen credentials to open circuit breakers and switch off power.
- They also wiped computers, disabled communications equipment, and disrupted call centres to slow the response.
- Engineers restored supply manually within hours, but digital systems took longer to rebuild.

### Hurricanes



Superstorm Sandy made landfall near Atlantic City, New Jersey as a post-tropical cyclone on October 29, 2012 .

A storm surge of 12.65 feet hit New York City causing flooding across the state. In all, the storm damaged 650,000 homes and knocked out power for 8.5 million consumers.

The storm caused an estimated \$65 billion in damages and 159 deaths, where 50 of those were attributed to power outages alone.

# The definition of resilience

## Operational resilience



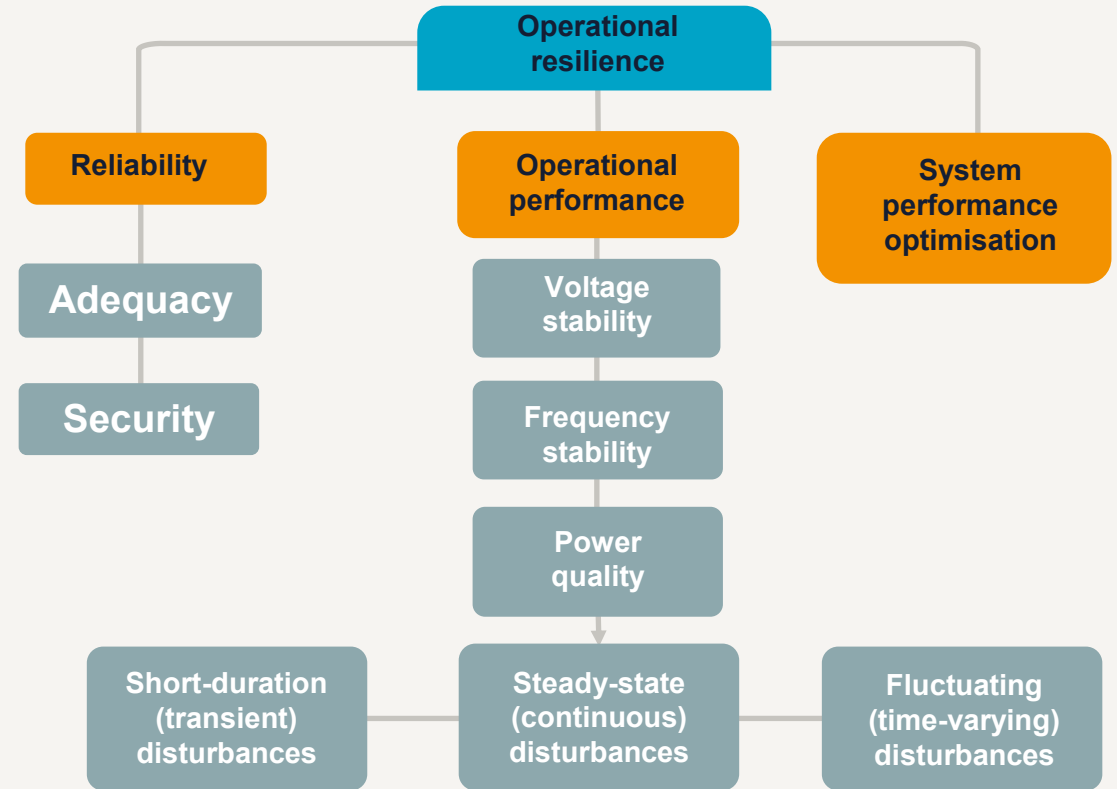
**Operational resilience is defined as the ability to maintain supply of the system under normal operating conditions**

Traditional **reliability** typically covers two aspects: adequacy (having sufficient resources to meet demand) and security (the ability to handle contingencies without uncontrolled outages).

For the purposes of this report, the definition of operational resilience also includes operational performance and system performance optimisation in addition to traditional reliability.

- **System adequacy** ensures there are sufficient resources to meet demand. Without sufficient generation and network capacity, even a mild stress can lead to outages.
- **Operational performance** is about how clean and stable the supply is even under load changes or disturbances. This includes frequency stability, voltage stability and the handling of power quality issues such as harmonic distortion or transient surges.
  - Power quality issues can be split into three types: steady state (including voltage deviations, unbalance and harmonics), short duration (transients, interruptions) and fluctuating (flicker).
- **Performance optimisation** means that resilience (avoidance of outages) is not achieved solely by brute-force redundancy, but also by smart operation and efficient use of resources. Modern grids use advanced monitoring, automation, and analytics to optimise their performance.

### Components of operational resilience



#### Reliability vs resilience


**Reliability** is how well the network performs during *normal* conditions.  
**Resilience** is how well the network copes with *unexpected or extreme* events.  
 In this report, reliability is treated as part of operational resilience, and reliability metrics are often used to benchmark overall resilience


# The definition of resilience

## Operational resilience - examples


### Reliability


Two metrics are frequently used to measure reliability, System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI). Based on these, **Singapore's** power system is the most reliable in the world.

 + SAIDI 0.13 – 0.26 minutes per year over 2021 to 2025

 + SAIFI 0.006 – 0.008 per year over 2021 to 2025

By contrast, many African countries do not consistently enforce SAIDI / SAIFI limits. In **Kenya**, the reliability is much lower with SAIDI reported in hours rather than minutes. Both SAIDI and SAIFI do not meet the target set by the Energy & Petroleum Regulatory Authority.

 + SAIDI 9.42 hours for year ended June 2025

 + SAIFI 3.67 for year ended June 2025

### Operational performance



The recent blackout in the Iberian Peninsula (**Spain** and **Portugal**) demonstrates an operational performance failure.






The blackout was *triggered* by a short circuit on a 400 kV transmission line in the Basque region.

The main issue was an **overvoltage** event (a deviation from normal voltage levels, a power quality issue) that created a positive feedback loop, worsened by weak grid stability and limited fast-response flexibility.

At the time of the event, wind generation had already been curtailed, and gas plants were running near full capacity, limiting the system's ability to react quickly.

### System performance optimisation

In **Great Britain**, the Demand Flexibility Service (DFS) is a notable example of system performance optimisation aiming to keep demand peaks lower in winter 2022/23 and 2023/24. National Grid ESO paid homes and businesses to shift or reduce demand during peak consumption periods.

-  In winter 2022/23, 1.6 million homes and businesses actively participated. By winter 2023/24, this grew to 2.6 million subscribed meters.
-  Total demand reduction increased from 3.3 GWh across all events in winter 2022/23 to 3.7 GWh in winter 2023/24.
-  Payments for delivery rose from approximately £11.1 million in winter 2022/23 to about £11.9 million in winter 2023/24.

# The definition of resilience

## Societal resilience



**Societal resilience addresses fairness so that the most at-risk consumers are not disproportionately harmed by disruptions**

Societal resilience is aimed at protecting people and communities, especially those who are most vulnerable, during energy system shocks.

- It goes beyond conventional resilience to consider the impact on people ensuring that critical services and vulnerable consumers are protected during outages.
- It also ensures that all consumer groups can participate in and benefit from resilience measures.

Vulnerable consumers can include definitions with both socio-economic and energy-specific criteria. This can include, but is not limited to groups such as:

- Consumers who are medically dependent on electricity.
- Elderly consumers.
- Consumers living with a disability.
- Low-income households and those in fuel poverty.

Societal resilience is just as important: if disruptions disproportionately impact vulnerable consumers, resilience goes beyond a technical issue and becomes a social issue.

### Expanding on vulnerable groups

- Vulnerable consumers often have fewer buffers (economic, social, technological). For example, if a consumer is already struggling with heating costs, a prolonged outage may push them into serious difficulties. Safeguarding against this reduces systematic risks like health impacts and community disruption
- Households relying on electricity for medical equipment, life support or those who face higher risk during outages are recognised, and resilience would ensure networks prioritise support for these consumers.
- If the energy system disproportionately affects the vulnerable, public confidence will erode, making further engagement in the energy transition more challenging.

### Societal resilience in Great Britain

In Great Britain, societal resilience is seen as a critical issue and network companies regulated by Ofgem have obligations for vulnerable consumers. This includes keeping a Priority Services Register (PSR) of those who are classed as vulnerable.

The ENA Energy Networks Innovation Strategy explicitly lists supporting consumers in vulnerable situations as one of six key themes.

- This led to coordinated efforts including data-sharing improvements. For example, when a vulnerable consumer moves home or their situation changes, all relevant utilities will be notified.
- The ENA and DNOs collaborate with health services to identify consumers who are reliant on medical equipment.

# The definition of resilience

## Societal resilience - example

### Prepayment meters

Between 2022 and 2023, energy suppliers in **Great Britain** failed to meet regulations when they installed prepayment meters to recover debt without receiving household permission. This was especially harmful for vulnerable consumers.

Prepayment meters can expose vulnerable households to self-disconnection if they cannot afford top ups meaning they may lose heating and power.

This was a **fairness breach** as vulnerable consumers were disproportionately impacted.

#### Actions taken by Ofgem

- +£5.6M** Paid by energy suppliers in compensation to 40,000 affected consumers
- +£13M** Debt written off by energy suppliers for affected consumers in this period
- +£55M** Financial support provided directly to affected consumers by energy suppliers prior to Ofgem's review

### Fuel vouchers

In **Great Britain**, since 2018, the Energy Redress Scheme is operated and managed by the Energy Saving Trust on behalf of Ofgem.

The scheme was set up to collect voluntary redress payments from energy companies who have breached their licence conditions or other regulatory obligations.

- These payments are redistributed to benefit consumers, especially vulnerable consumers.

The Energy Redress Scheme includes a Fuel Voucher Fund, distributing vouchers to vulnerable consumers on pre-payment meters and at risk of self-disconnection across Great Britain.

- +£7.8M** Distributed in fuel vouchers up to September 2024.
- +134K** Distinct households received fuel -vouchers up to September 2024.

This scheme recognises some households are disproportionately at risk and provides societal resilience.

### Breached obligations

In **Australia**, one of the largest energy suppliers breached obligations designed to protect vulnerable consumers on multiple occasions.



In 2024, the Federal Court ordered penalties of AUD \$12 million for breaches to its life-support obligations on more than 5,000 occasions.



In 2025, the company was ordered to pay AUD \$17.6 million after breaches to energy rules. This included failing to provide adequate support to 6,806 consumers experiencing payment difficulty.

When consumers who rely on life-support equipment are disconnected or not properly registered, the risk of serious harm increases.

# The definition of resilience

## Economic resilience



**Economic resilience refers to the strategic planning of the energy system to withstand financial shocks or stresses**

Economic resilience includes maintaining affordability for consumers in the face of volatile fuel prices or unforeseen costs, ensuring network companies remain financially healthy (so they can invest in infrastructure), and having robust supply chains and workforce arrangements to deliver projects on time and on budget.

- It also covers how the market and regulatory mechanisms handle extreme events. For example, whether a global gas price spike or failure of a major contractor develops into unrecoverable costs, extreme delays or critical service failures.

Economic resilience is avoiding scenarios where a lack of financial resilience would undermine the physical resistance of the system. If companies are bankrupted or cannot fund necessary repairs, or if consumers face excessively high energy bills leading to a crisis, the grid's resilience would be at risk.

RIIO is a regulatory price-control framework used by the regulator Ofgem to set how much network companies (electricity transmission, distribution, gas distribution, etc) in Great Britain can earn from customers. Its name stands for *Revenue = Incentives + Innovation + Outputs*.

## Ofgem's RIIO framework

Lessons learnt from recent energy supplier collapses (such as Tomato Energy and Rebel Energy) in the retail market led regulators wanting to ensure monopoly networks stay afloat and do not require bailouts.

- Energy networks are natural monopolies: they are regulated, non-competitive, and their income is set by Ofgem through price controls.
- However, even though networks were not in financial trouble, the supplier crisis made regulators, government, and investors aware of how expensive a large-scale failure can be.
- As a result, under the RIIO-ED2 and RIIO-T2 price control, Ofgem brought in more explicit requirements to maintain strong financial resilience (e.g., maintaining healthy debt levels to be able to absorb shocks without taxpayer help) and deliver investment for energy networks.

The RIIO-ED3 framework in Great Britain has explicitly discussed financial resilience of network companies, taking account of tight ring-fenced conditions and restrictions on dividend payments if credit metrics fall.

- ED3 highlights the importance of applying a consistent financial resilience requirement across sectors, particularly given the larger investment required for the transformation of the energy system.

Ofgem's monitoring of network operational and capital expenditure also feeds into resilience.

- Under/overspend against allowances can signal efficiency or inefficiency in delivering reliability

# The definition of resilience

## Economic resilience - example

### CfDs and Interconnectors

#### Contracts for Difference (CfD)

During the gas price shock in 2022-23, Contracts for Difference (CfD)\* cushioned bill payers.



When wholesale prices surged above the CfD strike prices, generators paid money back into the scheme, which led to the below

**+  
£18 per  
household**

Reduction in government funding required under the Energy Price Guarantee in winter 2022-23

#### Interconnectors

Interconnectors under Ofgem's cap-and-floor regime stabilise revenues and share upside with consumers.

- Great Britain's regulated model sets a minimum ("floor") and maximum ("cap") revenue level over 25 years.
- **Excess revenues above the cap are returned to consumers**, while the floor limits downside in stressed markets. This supports continued operation and investment through financial shocks

### Energy supplier failure

In 2021-22, the GB market suffered a wave of energy supplier failures due to weak financial resilience.



29 suppliers failed



The cost for these failures were ultimately socialised by bill-payers



Parliamentary committees and the National Audit Office attributed this to inadequate capitalisation and poor risk management in the energy retail market

#### Outcome of the energy supplier failures

As a result of the energy supplier failures, retail market reforms were brought in by Ofgem.

- Minimum capital requirements were introduced.
- Powers to ring-fence consumer credit balances and Renewables Obligations receipts were also introduced so that capital could not be diverted to other business uses.

### Over-reliance on Russia

Prior to 2022, Germany was heavily reliant on the Russian pipeline gas for its energy. When supplies were disrupted following the invasion of Ukraine, the country faced a major supply shock risk.

- The government responded by rapidly contracting for Liquid Natural Gas (LNG) terminals (including Wilhelmshaven and Lubmin) and pivoting their supply chains.
- German policy documents emphasise that LNG import capacity, storage, and diversification of supply routes are critical for resilience.

*\*CfDs apply to specific types of renewable generation and were implemented to encourage the deployment of renewable generation.*

# Quantitative and qualitative value of resilience

Quantifying, valuing and monetising resilience



# Quantifying resilience

## Quantifying resilience – metrics used

### SAIDI and SAIFI are the most widely used indices for resilience

For the benchmarking of resilience, several different performance-based metrics are used to incentivise network investment on an annual basis:

- Customer outage time
  - Average duration
  - Peak duration
  - Cumulative duration
- Load not served (kWh)
- Number of customers affected
- Time to recovery
- Cost of recovery
- Reliability standards (part of system adequacy): Loss of Load Probability (LOLP) / Loss of Load Expectation (LOLE).
  - NESO publishes their LOLE in their winter outlook. Their base case for 2025/26 is less than 0.1 hours.

\*This can vary by country, but within Europe, it is typically three minutes. This includes Great Britain. \*\*based on a 2022 report from the Council of European Energy Regulators (CEER)

### SAIDI and SAIFI

System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) quantify how long consumers are without electricity during outages. These metrics are well-established and widely reported in industry today.

**+ SAIDI** The sum of the restoration time for each sustained interruption multiplied by the sum of the number of consumers interrupted, divided by the total number of consumers served for the area. This metric is expressed in average minutes per year.

**+ SAIFI** The sum of the number of interrupted consumers for each power outage (greater than three minutes) during a given period, divided by the total number of consumers served for the area. This metric is expressed in the average number of outages per year.

**Lower SAIDI and SAIFI values show greater reliability and therefore higher operational resilience**

### Great Britain

- SAIDI is reported as *Customer Minutes Lost (CML)*, which measures the average minutes lost per customer due to outages lasting more than three minutes.
- SAIFI is reported as *Customer interruptions (CI)*, which measures the average number of interruptions per 100 customers longer than three minutes.

Compared to other European countries, Great Britain performs strongly, ranking in the top 10 for both planned and unplanned outages\*\*, including 2<sup>nd</sup> for planned SAIFI and 3<sup>rd</sup> for planned SAIDI.

### Perceived value metrics

- Willingness to Pay (WTP)
  - This is the maximum amount a consumer would be willing to pay to avoid an electricity outage.
- Willingness to Accept (WTA)
  - This is the minimum amount a consumer would require as compensation to accept an outage.

# Quantifying resilience

Resilience metrics – examples of consequence categories

<i>Direct consequence</i>	<i>Resilience metric</i>
Electrical service	<ul style="list-style-type: none"> <li>Cumulative customer-hours of outages</li> <li>Cumulative customer energy demand not served</li> <li>Average number (or percentage) of customers experiencing outage during a specified time period</li> </ul>
Critical electrical service	<ul style="list-style-type: none"> <li>Cumulative critical customer-hours of outages</li> <li>Critical customer energy demand not served</li> <li>Average number (or percentage) of critical loads that experience an outage</li> </ul>
Restoration	<ul style="list-style-type: none"> <li>Time to recovery</li> <li>Cost of recovery</li> </ul>
Monetary	<ul style="list-style-type: none"> <li>Loss of utility revenue</li> <li>Cost of grid damages (e.g. repair or replace lines, transformers)</li> <li>Cost of recovery</li> <li>Avoided outage cost</li> </ul>
<i>Indirect consequence</i>	<i>Resilience metric</i>
Community function	<ul style="list-style-type: none"> <li>Critical services without power (e.g., hospitals, fire stations, police stations)</li> <li>Critical services without power for more than N hours (e.g., N &gt; hours of back up fuel requirement)</li> </ul>
Monetary	<ul style="list-style-type: none"> <li>Loss of assets and perishables</li> <li>Business interruption costs</li> <li>Impact on Gross Municipal Product (GMP) or Gross Regional Product (GRP)</li> </ul>
Other critical assets	<ul style="list-style-type: none"> <li>Key production facilities without power</li> <li>Key military facilities without power</li> </ul>

# The value of resilience

Economic value is attributed to resilience split between DNO and consumer perspective

## DNO investment decisions regarding resilience must consider both the costs and respective values of the technological solution

There is a growing need for resilience and a growing value in providing it. However, it is challenging to attribute a precise value to resilience per se as it varies on the application:

- Some values are tangible, others perceived
- Different applications have different values
- Different countries perceive value differently

But investment decisions require an understanding of both the costs of implementing a solution and the resulting benefits. Benefits may include the avoidance of penalties as well as rewards and improved operational value:

- Regulatory penalties
- Symmetrical regulatory rewards
- Compensation payments to consumers
- Reduced OPEX

\*Source: [https://www.ofgem.gov.uk/sites/default/files/2025-04/Consumer\\_Standards\\_24-7\\_Metering\\_Support\\_Impact\\_Assessment.pdf](https://www.ofgem.gov.uk/sites/default/files/2025-04/Consumer_Standards_24-7_Metering_Support_Impact_Assessment.pdf)

## Residential Value of Lost Load (VoLL)

Residential consumers attribute a perceived value to lost load, and sometimes tangible values:

- Critical consumers on vulnerable connection
- Remote consumers on vulnerable connection
- Perceived value, Willingness-to-accept (WTA) or Willingness-to-pay (WTP).
  - In Great Britain, the most recent WTA value used by Ofgem in 2025 is £26.47 / kWh\*
- The value of VoLL varies significantly depending on the consumer groupings, outage attributes such as duration, frequency, time and season, societal / regional factors, valuation method

## Non-residential values

Industry and critical infrastructure deliver financial value in many ways, for example by avoiding production losses, equipment damage, safety risks, and reputational harm.

- Business critical functions: data centres, industrial process, food storage
- Life critical infrastructure: operating theatre, intensive care
- Other critical infrastructure: military, transport, emergency services
- Literature reviews by Electricity North West in GB (2016) and Energiforsk in Sweden (2021) find that VoLL range from a few €/kWh to as much as €250/kWh

# The value of resilience

## The Value of Loss Load (VoLL)

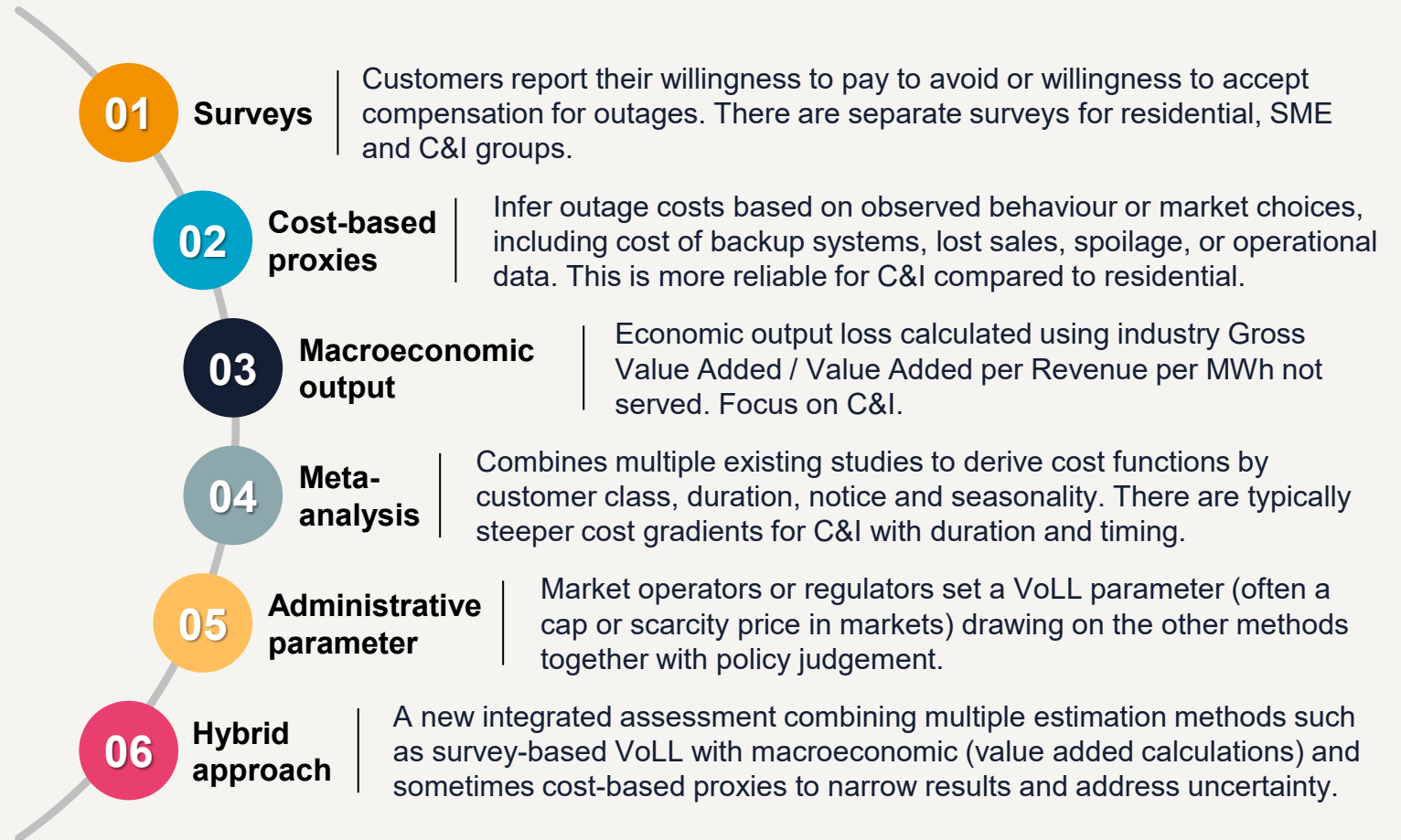
### VoLL depends heavily on the methodology used to calculate it

Reported VoLL figures often include:

- Customer category
- Outage duration (e.g., 1 hour)
- Season (e.g., winter)
- Peak or off-peak (or morning, afternoon, evening).
- Whether there was prior warning of the outage
- Region specific

As dependence on a single vector (e.g., electricity) grows then so will its perceived VoLL. There are also a range of methods for calculating the VoLL that consider different aspects.

- VoLL heavily depends on methodology used.
- Capturing all costs from industrial outages (including lost product, spoilage, restart costs, etc), VoLL for industry tends to be higher than for households.
- The true outage cost in industry is often underestimated.



# The value of resilience

Valuing resilience from the perspective of industrial customers

**The impact of outages varies by application and perceived value by region; avoiding outages can be worth more than €250/kWh to select commercial customers**

There are multiple ways to examine the VoLL for industrial and commercial customers. Typically, cost-based proxies and macroeconomic output are used to calculate a willingness-to-accept that is framed for businesses.

For industrial and commercial sectors, the value of resilience typically ranges from a few €/kWh to as much as €250/kWh.

- The values shown on the right are for the peak values, although in some cases the value can be relatively low or even zero, depending on the criticality of the process affected.

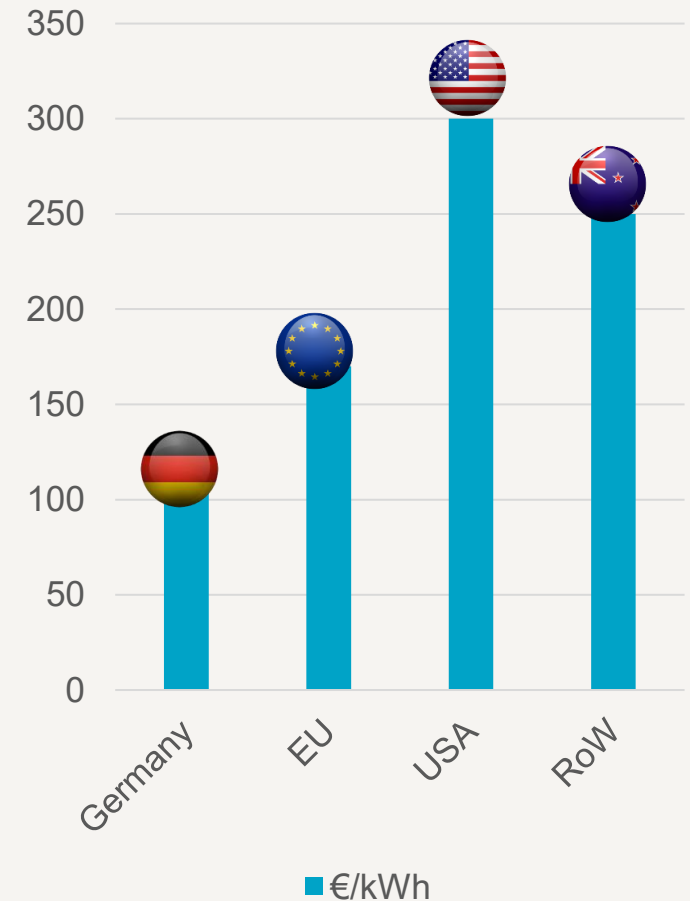
Studies in the US (2009) and New Zealand (2013), found VoLL could even exceed €250/kWh for outage-sensitive sectors like continuous process manufacturing, food processing, and finance, where downtime quickly leads to major economic losses

Industrial VoLL varies across countries, sectors and analyses because of many factors.

- **Real industrial costs differ.** Different processes, shutdown costs etc
- **Outage scenarios differ.** Studies use different assumptions for duration timing, notice, frequency of outages.
- **Customer segmentation differs.** Industrial can mean anything from heavy chemicals to small workshops.
- **Methods and assumptions differ.** This includes different treatments of non-market costs.
- **Country specific context and regulation.** National income, industrial structure and regulatory preferences.

**Value of Lost Load (VoLL) for industrial customers is attributable to quantifiable business costs and is typically significantly higher than for residential.**

C&I VoLL in different regions



# The value of resilience

## Data centres

### Business disruption, lost revenue and end-user productivity are major economic impacts of an outage for data centres

Data centres' operation underpins essential digital services (the cloud, payments, logistics, public services, etc) and increasingly, AI training and inference, which run 24/7 and have very low tolerance for interruptions.

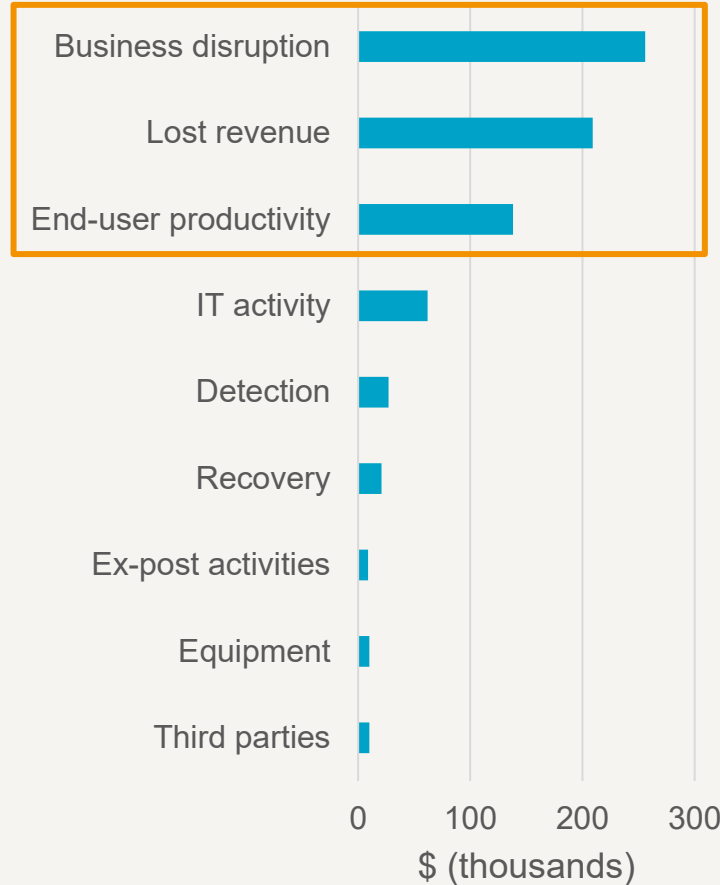
In GB, NESO's "Ten Year Forecasts" in the Future Energy Scenarios 2025 predict that demand from data centres will grow from 7.7 TWh in 2024 to 20.1 TWh in 2030, representing a ~2.5x increase.

While published in 2016, analysis of U.S. data centres\* indicates a break down of the outage costs:

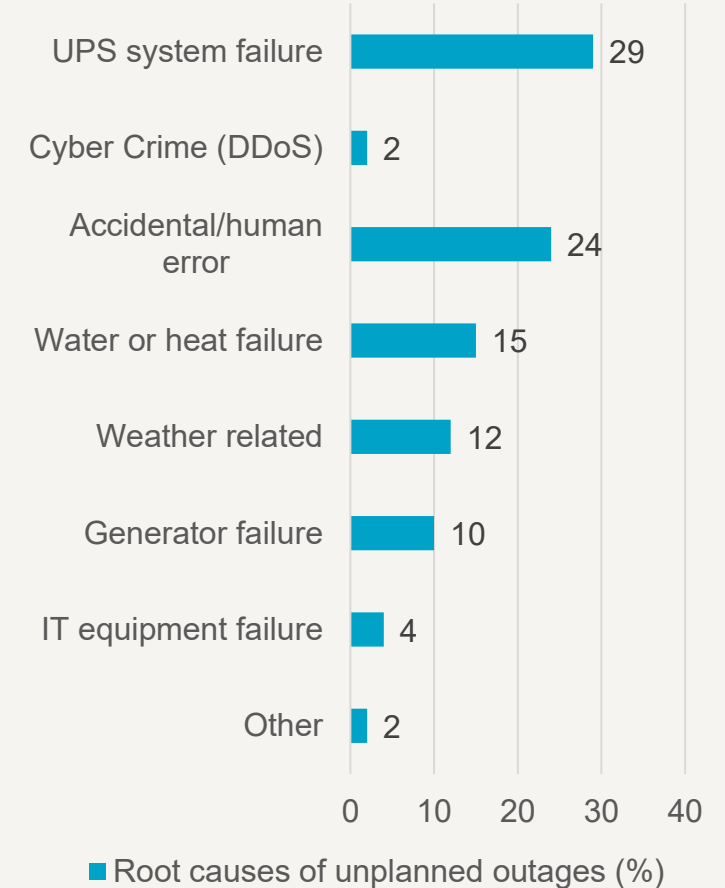
- Direct costs (cash expenses for recovery): 36%
- Indirect costs (time, effort, and internal resources): 51%
- Opportunity costs (lost business from reputational damage): 13%

More recent [analysis from 2024](#) shows that while outage frequency has declined, costs per incident have increased, with over half of outages exceeding \$100k, and over 16% exceed \$1 million. The cost structure remains unchanged.

Breakdown of unplanned outage costs by category\*



Root causes of unplanned outages\*



\*from Ponemon Institute. (2016, January). Cost of Data Center Outages. Sponsored by Emerson Network Power.

# The value of resilience

Valuing resilience from the perspective of residential consumers

**The value of resilience to residential consumers depends on their perception of value. There is little tangible value or loss.**

For residential consumers, there are two main ways that consumers perceive value:

- Willingness to pay (WTP): the maximum amount a consumer would be willing to pay to avoid an electricity outage.
- Willingness to accept (WTA): the minimum amount a consumer would require as compensation to accept an outage.

In practice, WTA is often higher than WTP. In Ofgem research from 2013, a WTA estimate for domestic users during winter peak at the weekend is £11.82/kWh compared to a WTP estimate of ~£1.65/kWh. This is roughly a seven-fold difference.

- When it comes to energy supply, consumers expect the grid to be resilient and therefore believe they should be compensated for outages (WTA) but are unwilling to pay as much for it (WTP).

For residential consumers, the values range from a few £/kWh up to about £40/kWh. Structural differences, such as country-specific, time of year, differences in income, may provide an explanation. The residential Value of Lost Load (VoLL) tends to be lower than for industrial and commercial VoLL, although this varies based on the I&C segment.

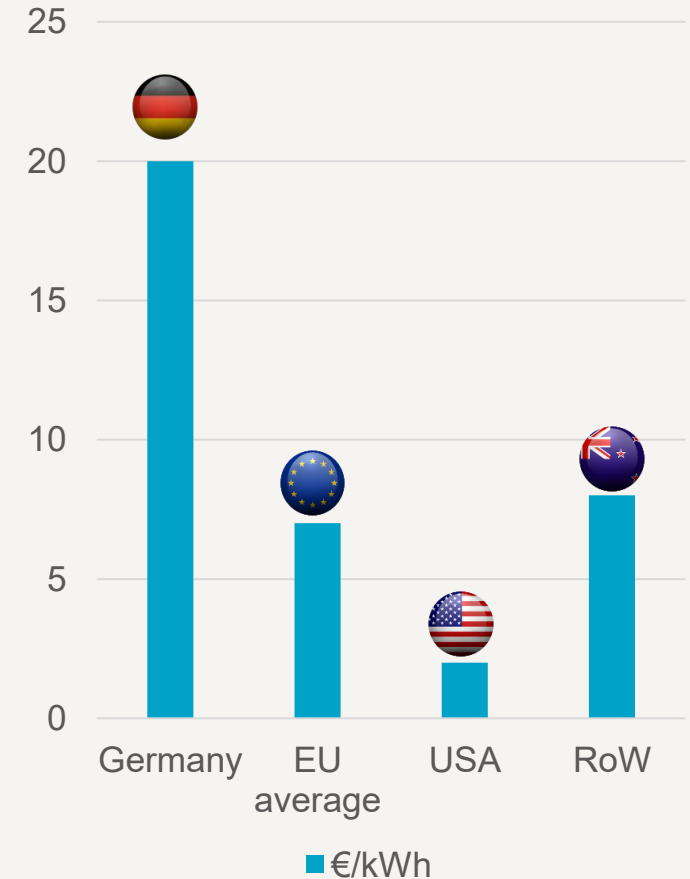
The value of VoLL also has a cultural element with different values even between EU states.

+ £17 / kWh Headline load-weighted average VoLL value (WTA) from Ofgem's 2013 research for domestic and small-to-medium business consumers during peak winter workdays

+ £21 / kWh Value of VoLL in current price control period RII0-ED2 (April 2023 to March 2028). This is Ofgem's 2013 research adjusted by inflation.

+ £26.47 / kWh Value of VoLL in a 2025 impact assessment study from Ofgem, also based on Ofgem's 2013 research and a **65% increase** over the original £17/kWh.

Average VoLL in different regions



# The value of resilience

Reasons for the difference between Willingness-to-accept (WTA) and Willingness-to-pay (WTP)

## Income / budget constraints

Willingness-to-pay (WTP) is limited by what consumers can afford or expect to pay. On the other hand, Willingness-to-accept (WTA) is a hypothetical compensation number, less bounded by immediate budget constraints. This tends to widen the gap between WTP and WTA.

## Loss aversion

Consumers fear losing something, such as their electricity service, more than they value gaining the same service. So, WTA, which asks consumers about “giving up” a service, tends to be higher than WTP, which asks about “paying to avoid losing”.

## Substitutability

If there are few good substitutes for the good, for example having uninterrupted electricity supply during a peak winter period, then the compensation required for loss might be high because the consumer anticipates higher cost or difficulty of replacement.

## Survey framing

Estimated the VoLL through stated preference methods is sensitive to how questions are asked, to the respondents’ perception of the scenario, the compensation, and consumers sense of ownership or entitlement. WTP estimates have a well-documented downward bias due to “entitlement”.

When consumers are asked how much they might pay to avoid an outage, they may think about income, budget and say a more modest number. Whereas when asked how much compensation they would require in the event of an outage, they inflate the number, thinking about how bad it would be.

In studies such as Ofgem’s VoLL research, the results are used to inform security of supply policy including feeding into how much capacity they should hold to avoid outages. In this case consumers may not be willing to pay more to improve a service but when an outage occurs, they may feel that the involuntary disruption is worth some form of payment for the service they provide.



# Monetising resilience

## DNO perspective

Just as the value of resilience varies depending on the user, there are also a range of economic mechanisms imposed to incentivise appropriate service standards in different markets

### Australia

In Australia, the Australian Energy Regulator has a scheme called the Service Target Performance Incentive Scheme (STPIS) for DNOs.

- The scheme is primarily aimed at maintaining and improving service performance and incorporates the reliability metrics SAIDI and SAIFI.
- This is a symmetrical scheme that rewards DNOs for exceeding targets and penalises DNOs for missing targets.

### Finland

Finland has a penalty for non-delivered energy.

- The utility pays between 10% and 200% of the annual grid fee as consumer compensation for between 12 and 288 hours of interruption

Duration of outage	% compensation
12 – 24 hours	10%
24 – 48 hours	25%
48 – 72 hours	50%
72 – 120 hours	100%
120 – 288 hours	150%
>288 hours (12 days)	200%, (max €2,000)

- Consumers may also claim for damages for other events.
- There are exceptions for exceptional circumstances, such as storms.

### Great Britain

Great Britain operates on a compensation basis for power outages. Ofgem monitors and enforces this. Under normal conditions, consumers receive automatic payments if outages exceed set thresholds:

- For example, £95 for each consumer if <5,000 households are without power for more than 12 hours
- For more than four power cuts in a year (each of more than three hours), consumers can claim an additional £95.

For severe weather condition outages, compensation is dependent on the category of storm and duration of the event.

- Initial payments are £85 with an additional £45 every 6 hours, up to a maximum £2,165.

Under the Interruptions Incentive Scheme as part of Ofgem’s RIIO-ED2, the performance of DNOs is measured against targets, including customer interruptions (equivalent to SAIFI) and customer minutes lost (equivalent to SAIDI).

- If they outperform, they can be rewarded and if they under-perform, they may be penalised.

Resilience today means combining hard assets with smart intelligence. Every smart meter installed strengthens the grid, reduces costs, and makes the UK's energy system more sustainable.

## 2. *Delivering resilience*

Delivering resilience has traditionally meant pouring concrete and laying cables, capital-intensive projects like Ofgem's **£9 billion upgrade** to Britain's high-voltage network, the largest since the 1960s. That investment will add £74 to consumer bills by 2031, but it's expected to save £80 per household by reducing curtailment costs and maximising renewable energy use.

Yet physical infrastructure alone can't keep pace with the demands of a decentralised, electrified grid. Non-infrastructure solutions such as smart meters, digital twins, and flexibility platforms are the game-changers. Smart meters act as a nationwide sensor network, enabling timely fault detection, demand-side flexibility, and predictive maintenance. Without them, we pay the price: in 2025, curtailment cost Great Britain **around £1.9 billion**, a stark reminder that data-driven resilience is cheaper than wasted clean energy.

This section reviews the current approaches to grid resilience and their respective merits and challenges



# Overview of current approaches for delivering resilience

In this section we explore 4 core current approaches to grid resilience and their respective merits and shortcomings



## Traditional infrastructure investments

**Building resilience through physical infrastructure is capital intensive, but essential for capacity growth and long asset life.**

Measures to increase resilience of the grid that are applied to **power lines, substations and transformers** include physical hardening of assets, integrating redundancy (alternative route) and fault isolation design, and upgrading or expanding capacity.

**Backup generation** supports resilience by providing reserve power but face high operating costs and under-utilisation.



## Microgrids

**Microgrids assist the integration of renewables and offer power resilience by interconnecting DERs which can be operated in isolation from the main grid.**

Microgrids can operate in **island-mode** from the wider grid, providing resilience both locally and to the system when the grid fails.

However, microgrids, as a **microcosm of the wider grid**, face the same challenges as the wider grid such as load balancing, managing voltage and frequency stability, managing faults, and cybersecurity.



## Non-infrastructure solutions

**Non-infrastructure solutions such as network software and digital solutions that provide resilience with near real-time data.**

However, Smart Meter Operations Center (SMOC) and Distributed Energy Resource Management System (DERMS) are expensive and data intensive systems.

**Operational and System processes that provide resilience include curtailment and flexibility services.** Curtailment cost GB almost £1 billion last year, a high price to pay for inadequate network capacity.



## Black Start

**Black Start is the ultimate disaster recovery mechanism when there is a total or partial system shutdown or “black out”.**

NESO ensures the system can be restored, by dispatching isolated power stations to start individually and gradually reconnect to each other to form an interconnected, restored system.

Large synchronous power plants have traditionally provided Black Start. However, with fewer thermal plants in operation, GB will become increasingly **dependent on inverter-connected assets** for Black Start.

# Delivering resilience: Traditional infrastructure investments

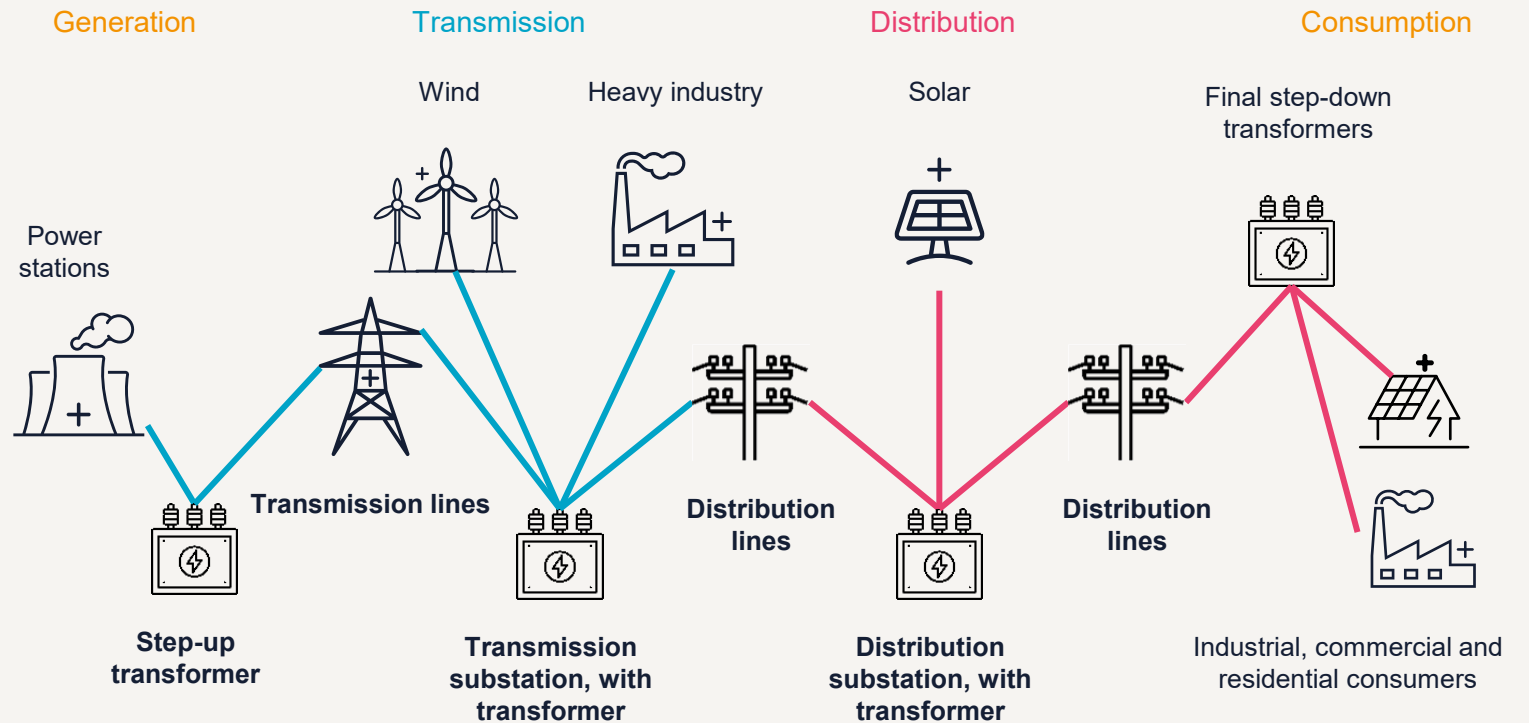
Building resilience through physical infrastructure is capital intensive, but essential for capacity growth and long asset life

**Traditional infrastructure investments for resilience are capital-intensive projects focused on physical assets that expand or reinforce the grid**

**Key components to physical grid infrastructure related to resilience:**

- Transmission and distribution Lines
- Substations and transformers
- Backup generation

Illustrative grid components (components in bold are the focus of this section)



# Delivering resilience: Traditional infrastructure investments

Building resilience through physical infrastructure is capital intensive, but essential for capacity growth and long asset life

## Great Britain



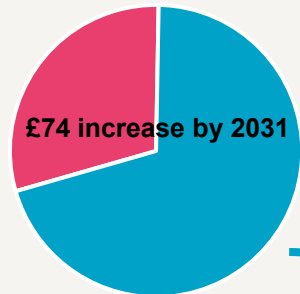
### Case study

In July 2025, [Ofgem](#) approved a **£9bn investment programme** to upgrade Britain's high-voltage network, **the largest grid expansion since the 1960s**. Ofgem estimate the investment will result in **increased electricity network charges on consumer bills of £74 by 2031**, but this cost is offset by savings.

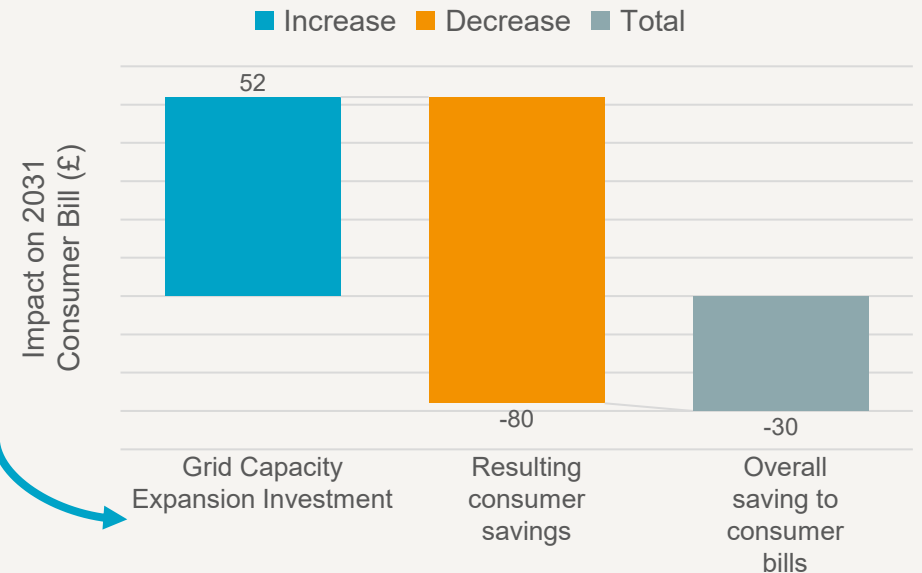
The grid capacity expansion investment is expected to result in **£80 of savings for consumers by 2031**, by:

- 1. Reducing constraint costs** – cutting payments to wind farms that are forced to curtail output because the grid cannot transmit their power.
- 2. Maximising renewable energy use** – ensuring clean generation meets demand, reducing reliance on expensive gas-fired plants.

Cost of maintaining grid safety, resilience and reliability, £22



Grid Capacity Expansion, £52



# Delivering resilience: Traditional infrastructure investments

Building resilience through physical infrastructure is capital intensive, but essential for capacity growth and long asset life

## Transmission and distribution lines

Transmission lines carry electricity from power plants to substations and distribution lines carry it onto homes and businesses. Upgrading lines to boost grid resilience requires significant capital with long permitting and construction timelines:

- **Line hardening** – materials or coatings to improve weather resistance against corrosion, extending asset life and reducing outages.
- **Redundancy lines** – alternative paths to reduce single points of failure. Measures include extra feeders (alternative paths), sectionalised switches (dividing feeders into sections to isolate faults) and reclosers (automatic response after fault detection).
- **Increasing line capacity** – eases congestion and thermal overload. Dynamic line rating sensors like “smart thermometers” allow lines to carry more capacity when safe to (e.g., in cool and windy conditions). Reconductoring is another method, where cables are replaced with advanced materials of higher-capacity.
- **Relocating lines** – undergrounding or elevating lines to protect against extreme weather or flooding.

## Substations and transformers

Transformers change voltage levels (steps up or steps down), for efficient power transmission and distribution. Substations house transformers and other equipment to support the same purpose. They form vital grid ‘nodes’ that manage voltage, direct power and isolate faults.

Infrastructure investments in these grid ‘nodes’ that deliver resilience include:

- **Equipment upgrades** – power transformers with on-load tap changers, voltage regulators, and capacitor banks are used to maintain voltage.
- **Fault isolation design** – circuit breakers and protective relays limit fault propagation.
- **Physical hardening** – elevating substations above flood levels, adding fire-resistant coatings, and adding seismic reinforcement.
- **Redundancy design** – multiple transformers and feeders exist for back-up, providing improved response during equipment failure.

**While expensive, these improvements help prevent outages, allow for faster repairs, and support the growing use of renewable energy.**

## Backup generation

Backup generation assets provide the reserve power when main generation or the grid fail but can have high operating costs and be under-utilised assets.

Relevant applications that can provide grid resilience include utility-scale generators at substations, front-of-the-meter generators (e.g., community-scale), and microgrid generators. This does not include small residential generators.

**Diesel or gas generators and battery storage**, are often located at critical facilities and support resilience by:

- **Ramping up in minutes** to stabilise the grid in sudden demand spikes or generation shortfalls.
- **Providing firm capacity** during extreme weather or renewable intermittency.
- **Supplying emergency power.**

# Delivering resilience: Microgrids

Microgrids are a microcosm of the wider grid

**Microgrids assist the integration of renewables and offer power resilience by interconnecting DERs which can be operated in isolation from the main grid**

## A microgrid provides resilience when the grid fails

A microgrid is a system of interconnected energy loads and at least two distributed energy resources (DERs) within a clearly defined boundary, and with a single point of coupling to the wider electricity distribution grid.

It can connect and disconnect from the grid to enable it to operate in grid-connected or island-mode. The speed of response to an outage and the duration of islanded operation depend on the intended application and the generation technologies connected to the microgrid.

There are various use cases for microgrids, including industrial and commercial microgrids, utility microgrids, community microgrids, critical infrastructure microgrids (e.g. for hospitals or military bases) and remote or weak grid applications.

While microgrids can operate in island-mode from the wider grid and operate with fewer resources, they face the same challenges as the wider grid such as load balancing, managing voltage and frequency stability, managing faults, and cybersecurity.

## Components of a microgrid

### POWER GRID

The wider electricity distribution grid



### SUBSTATION

A single point of coupling to the wider electricity distribution grid, to connect / disconnect from the grid



### DISTRIBUTED ENERGY RESOURCES

Generation sources such as renewables (solar PV, onshore wind), firm power sources (gas or diesel generators) or energy storage (Lithium-ion batteries)



### CONSUMER LOAD

Connecting the generation sources to the end-consumer



### MICROGRID CONTROL

Allows for optimisation of the system in response to supply and demand

# Delivering resilience: Microgrids

How do microgrids deliver resilience? What opportunities are there for smart meters?

## Microgrids deliver resilience both locally and to the system

### Local resilience

The ability of microgrids to operate in isolation from the main grid protects its users from loss of power and disruptive events that impact the main grid.

### System resilience

Microgrids also support the resilience of the wider electricity grid, by:

- **Helping reduce peak load** by locating generators close to point of consumption
- **Acting as a Black Start anchor** in case of an outage
- **Minimising reconnection peaks** via soft synchronisation, staggered load reconnection, energy storage buffering or generator ramp-up control.
- **Disconnecting** users from the main grid when it uses fossil generation and preserve carbon-free power supply for users, without destabilising the main grid.

## Smart meters play a vital role in the efficient operation and management of microgrids

### Smart meters can benefit microgrids through:

- **Near real-time monitoring and control** – by enabling operators to monitor power quality, detect islanding, and identify inefficiencies to optimise energy flows and control voltage within the microgrid.
- **Enabling demand response** – by receiving demand response (DR) instruction signals from operators (for end-users or automated assets to change demand) and providing accurate measurement of DR event participation for fair compensation
- **Detecting and diagnosing faults** – by enabling operators to identify and respond quickly to issues, preventing outages
- **Helping integrate distributed renewable energy resources** – by providing data on their intermittency and variability, which can contribute valuable data for forecasting
- **Enhancing billing accuracy** – by ensuring more accurate billing with detailed data on consumption.

## Great Britain

The **Isle of Skye** is connected to the national electricity grid but also uses microgrids to support communities during power outages.

The [SSEN resilience-as-a-Service \(RaaS\)](#) project on the Isle of Skye is trialling a new solution which uses a battery energy storage system with local distributed energy resources to quickly and automatically restore power when a fault occurs on the upstream network.

By temporarily **operating in island mode** during an outage, RaaS will maintain supply to the local community while the DNO repairs the fault or dispatches a diesel generator for a longer-term issue.

The battery can also provide **additional revenue streams** from the provision of flexibility services, **reducing the cost of resilience service**. As the battery is owned by the energy supplier, E.ON, this also avoids challenges around DNO energy storage asset ownership.

# Delivering resilience: Non-infrastructure resilience solutions

Network software and digital solutions can provide resilience, but are often complex, expensive and data intensive

## Smart Meter Operations Center (SMOC) acts as a command center for operational intelligence

**SMOC provides a centralised platform for managing smart meters**

- Providing real-time visibility of meter performance and the ability to detect anomalies.
- Aggregating data from Head-End Systems (HES), Meter Data Management Systems (MDMS), billing systems, and grid monitoring systems (SCADA).
- Automating incident response and predictive maintenance using machine learning.

**SMOC provides grid resilience by**

- Enabling operators to detect overloads and voltage issues, and respond quickly.
- Detecting outages and anomalies in near real-time and automating incident response.
- Supporting predictive maintenance by analysing voltage fluctuations and device health over asset life.

## Distributed Energy Resource Management System (DERMS) acts as a command center for DER

**DERMS is a digital platform designed to monitor, control, and optimise distributed energy resources (DER)**

- Providing near real-time visibility of DER assets across the network
- Helping coordinate DER dispatch to avoid overloads and voltage issues
- Enabling DER to provide ancillary services and supporting DER bidding into energy markets, where allowed

**DERMS provides grid stability, congestion management, and voltage control, which is critical during extreme weather or high DER penetration.**

**DERMS supports grid resilience by:**

- Sending commands to DER to adjust output or consumption based on grid needs.
- Using algorithms to predict DER availability and optimise their contribution to grid stability.

These technologies help energy companies spot problems faster, keep the lights on during unexpected events, and make better decisions about repairs and upgrades.

## Digital Twin can act as a virtual replica of physical network components

**A digital twin is a virtual model of the network built from data on cables, transformers, meters, and sensors.**

- It allows network operators to simulate scenarios without risking real infrastructure.
- It enables modelling of extreme weather, outage impact analysis, DER and load integration, and cybersecurity events.

**Digital twin development can support in providing grid resilience by**

- Predicting failure points of the physical asset, reducing asset downtime or failure.
- Improving planning for climate resilience and integration of renewables and DER.

# Delivering resilience: Non-infrastructure resilience solutions

Flexibility achieved through operational and system processes also provides resilience to the grid

## Curtailment is a flexibility solution that provides resilience, but also signals grid constraints

**Curtailment is where the output of a generator (usually renewable) is reduced to maintain system stability. It is a tool network operators use to manage imbalances.**

Curtailment supports grid resilience by:

- **Preventing overloading** – by reducing load on equipment during periods of high generation.
- **Maintaining grid stability** – helping balance frequency and voltage when renewables spike.

### Great Britain

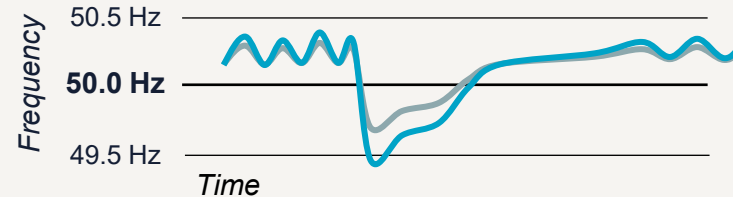


**Last year, GB lost close to £1 billion in curtailment compensation payments, a high price to pay for inadequate network capacity.**

Curtailment is a live issue in GB due to inadequate capacity at both distribution and transmission levels. This results in wasted clean energy, lost revenues for generators, and inefficient use of assets that sit idle.

## Flexibility can support short-term resilience

Flexibility is the ability to **dynamically balance fluctuations in supply and demand** under varying conditions. Frequency reflects the balance between supply and demand. Frequency falls if demand is greater than supply, and rises if supply is greater. NESO is responsible for keeping the frequency within  $\pm 1\%$  of 50Hz, illustrated below.



Grid **frequency is becoming more unstable** due to increased renewable generation, which risks damaging equipment or causing blackouts. There is a role for short-term flexibility to balance the grid in real-time to help with short-term issues (i.e., ancillary services, intraday market). Traditionally, flexibility has been sourced from supply side assets. However, **‘demand-side’ assets are increasingly relied on.** This means decentralised, distributed assets, like batteries or EVs, can respond to grid signals to provide flexibility.

## Flexibility can also prevent or delay the need for investment

Flexibility, whether in the form of **load shifting** or provision of **local grid services** by consumers, helps **avoid or defer capital-intensive network reinforcement** by:

- **Lowering peak demand** – by incentivising consumers with dynamic tariffs to shift the time at which they use energy away from peak hours. This reduces the peak load which minimises the need for network reinforcement.
- **Maximising use of existing infrastructure, reducing the cost of generation and grid-scale storage** – by using flexible assets to reduce curtailment of renewables and shifting loads to utilise grid assets outside peak hours.
- **Helping balance the grid and reduce network constraints** – by providing a specific flexibility service to a network operator via a market mechanism.

Based on modelling, the Clean Power 2030 Action Plan finds that flexibility could reduce system costs by up to £70 billion by 2050. ([UK GOV](#))

# Delivering Resilience: Black Start

Black Start is the ultimate disaster recovery mechanism when there is a total or partial system shutdown or “black out”

**Black Start is the procedure of recovering the National Electricity Transmission System (NETS) from a total or partial outage which has caused an extensive loss of supplies**

**Black Start, also known as Restoration, is where isolated power stations are started individually and gradually reconnected to each other to form an interconnected system again.**

While the event of total or partial shutdown of the NETS is unlikely, NESO is responsible for ensuring the system can be restored following such an event.

NESO contracts with generators and providers for Black Start capability. Providers need to meet three basic requirements for Black Start, including

1. start up independently from external supplies,
2. be able to energise the transmission network,
3. be able to provide block loading of local demand (i.e., gradual reconnection of groups of consumers to the grid).

**Black Start is a critical part of system resilience for restoration**

Traditionally, Black Start services have been provided by large synchronous power plants, connected at transmission level. As the UK moves away from thermal power plants to cleaner and more decentralised energy, new options for Black Start are being considered.

NESO’s modernisation strategy plans include integrating DER into Black Start, shifting to inverter-connected distribution network assets for Black Start services. However, there are complexities and technical challenges to be overcome.

**Smart meters can provide critical support functions that speed up restoration during Black Start.**

1. **Rapid fault detection and location** via power outage alert message.
2. **Controlled re-energisation** via randomised offset feature to allow controlled, delayed asset reconnection after an outage.

## Great Britain

**Distributed ReStart** is a £11.7m UK innovation project led by NESO in partnership with industry stakeholders. The goal of the project is to **develop processes and technology to restart the electricity system using distributed energy resources** after total or partial blackout.

Distributed ReStart explores how smaller, distributed assets like onshore wind, solar PV, batteries and demand-side resources can restore power, instead of traditional, large fossil-fuel generators. The project seeks to:

1. demonstrate the **technical feasibility** of DERs to support system restoration,
2. develop **new operational processes** for stakeholders (NESO, DNOs and DER owners),
3. establish **market arrangements and incentives** for DER participation in restoration services,
4. implement **advanced control systems** to manage DER participation safely and efficiently.

Smart meters act as the heartbeat monitor of the grid, turning blind spots into a resilient, data-driven grid.

## 3. *Dimensioning resilience*

Resilience isn't just about hardening infrastructure, it's about visibility, flexibility, and foresight. Today, network operators still fly partially blind at the low-voltage edge, relying on customer calls to detect faults. Without granular, real-time data, outages linger, vulnerable consumers face greater risk, and investment decisions lean on outdated assumptions.

Smart meters change that. They provide half-hourly consumption data, "last-gasp" outage alerts, and voltage monitoring, creating a nationwide sensing and control fabric. This enables faster fault detection (often 10-15 minutes quicker than traditional methods), targeted restoration, and predictive maintenance.

The opportunity is clear: with around 70% of homes equipped, nearly 30% of Britain remains outside this digital safety net. Closing that gap means moving from reactive fixes to proactive resilience, and thus anticipating risks, optimising investments, and protecting consumers. Every smart meter installed strengthens detection, flexibility, and planning, making resilience not just a concept but a reality.

This section identifies the gaps in current approaches to resilience and the potential role(s) for smart meters in delivering components or addressing gaps. This also notes aspects presenting challenges to smart meters to help in prioritisation of focus areas for further analysis and eventual investment.



# Dimensioning resilience

How and where can smart meters support the energy system?

## Smart meters in GB

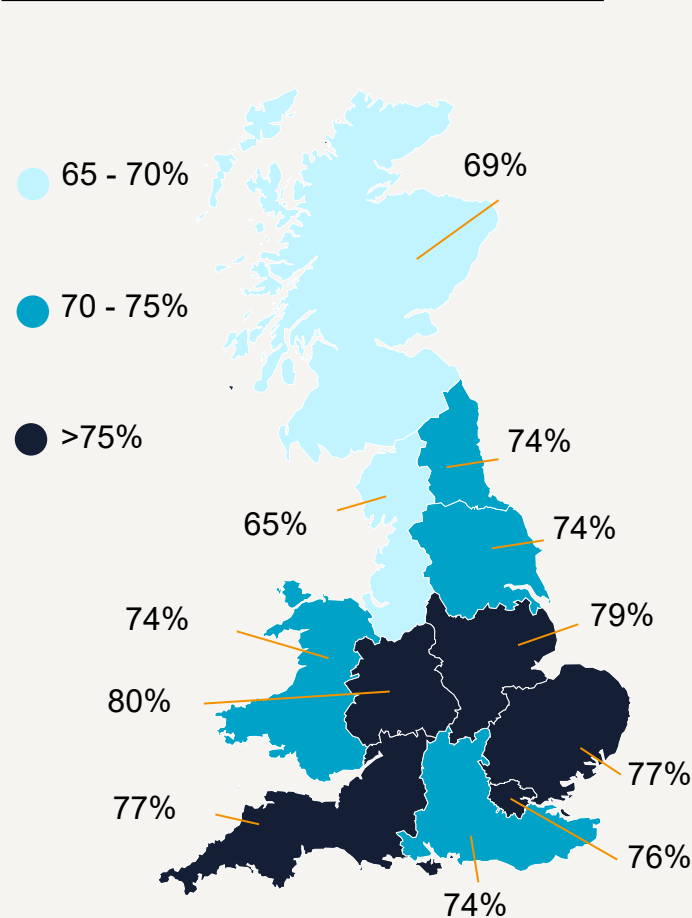


A secure, digital electricity or gas meter that automatically transmits half-hourly consumption data, supports two-way tariff & control commands, and provides near-real-time cost feedback to customers.

### Key use cases for smart meters

1. Replaces manual reads and estimated bills with more accurate, half-hourly settlement data
2. Creates a nationwide sensing and control fabric for flexible demand, outage detection and low-voltage network analytics.
3. Forms the data backbone for the UK's carbon-neutral, electrified energy system.

## Rollout of smart meters in GB



GB is behind most Western European countries on the roll-out of smart meters, with only about 70% of meters being smart-enabled. Other countries, including Spain, Italy or France, can leverage the considerably higher installed base of smart meters and the data they provide to operate their electricity grid more efficiently.

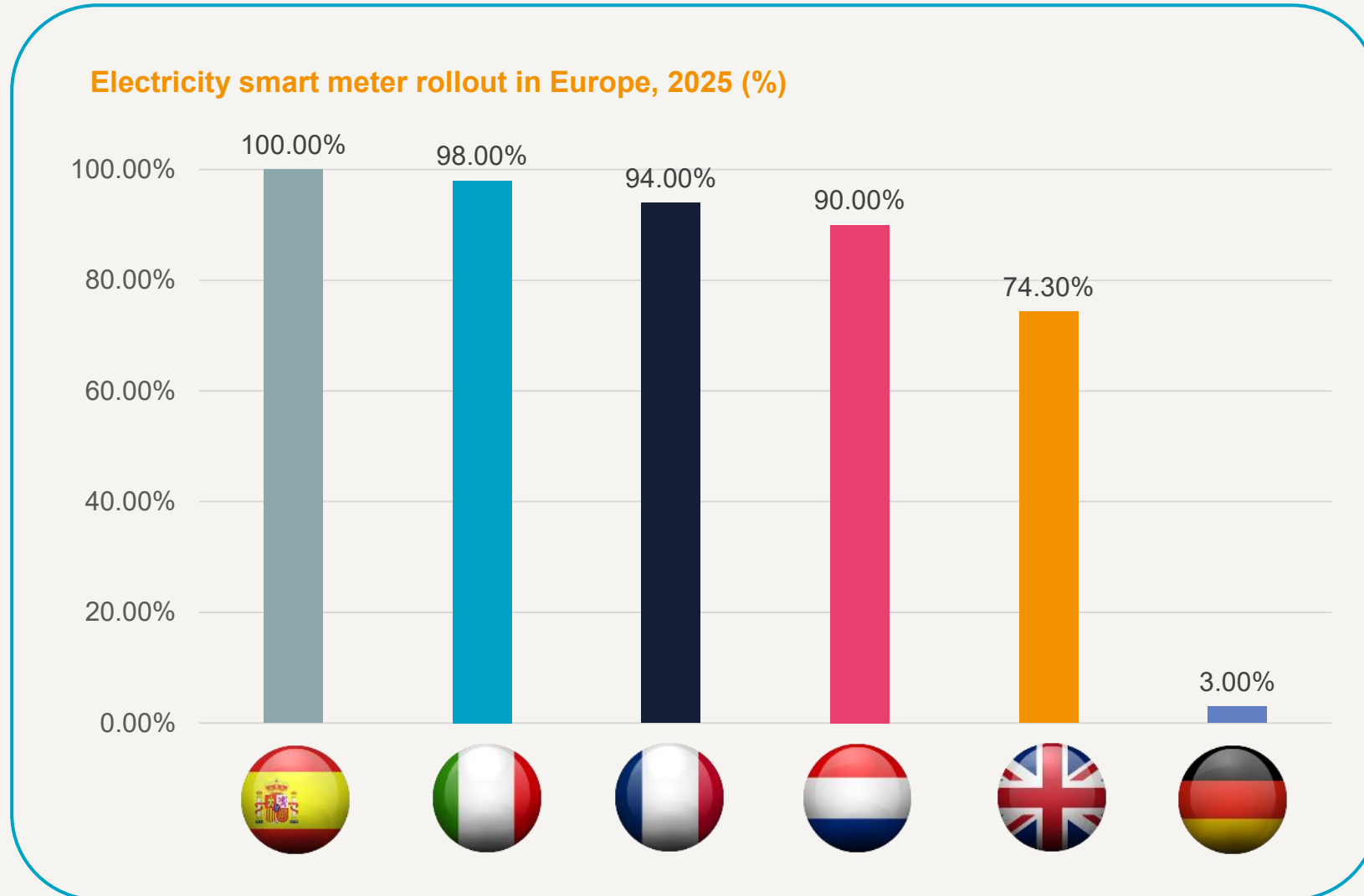
Smart meters have historically been installed at a steady pace across GB, with around 2 million added each year. However, there are disparities in the deployment within the country and installation rates are expected to slow as the remaining properties are harder to access or have barriers like landlord/tenant. Strengthening the importance of smart meters among all stakeholders is key to completing the roll-out as quickly as possible, paving the way for a more flexible, more sustainable and futureproof electricity system.

### Smart meter rollout in GB

Generally, higher smart meter penetration aligns with shorter outage durations (SAIDI).

# Dimensioning resilience

How and where can smart meters support the energy system?



# Dimensioning resilience

How and where can smart meters support the energy system?

## Grid resilience components

Over the previous sections, we showed that resilience is multidimensional: it is as much about **seeing** faults in real-time as it is about **adapting** the system, **keeping power flowing**, **planning** the network of tomorrow and **protecting** the data and assets that underpin it. For this section, we map those dimensions onto five components of grid resilience:

1. Detection and response
2. Flexibility and adaptability
3. Operational continuity
4. Data-driven planning
5. Cyber and physical security

## Summary of gaps in existing resilience approaches

### Detection and response

Network operators still fly partially blind at the low-voltage edge; faults are often inferred from customer calls rather than observed directly which slows down the first wave of corrective action.

### Flexibility and adaptability

While large-scale generation can be dispatched, most behind-the-meter flexibility remains untapped because the system can't see, value or coordinate millions of small assets in real time.

### Operational continuity

Outage management is reactive and manually prioritised. Without granular load and condition data, crews can't target the highest-impact fixes or pre-empt cascading failures.

### Data-driven planning

Investment decisions still lean on annual peak estimates and simple growth factors, leaving planners blind to emerging load shapes such as clustered EV charging or rooftop PV backfeed.

### Cyber and physical security

Legacy field devices and fragmented communication channels create weak points that are difficult to monitor continuously, exposing the grid to escalating cyber and tampering risks.

This section signposts new or existing (and under-utilised) smart-meter use-cases that can help close these gaps.

# Detection and response

Detection and response is the real-time awareness and contingency management of the energy system

As the energy system becomes more electrified and complex, rapid detection and response to faults is essential for maintaining resilience. Traditionally, network operators have relied on customer phone calls to identify low-voltage (LV) faults, which can delay corrective action and leave vulnerable customers at risk. While smart meters are now widespread, their advanced capabilities for near real-time fault detection and network monitoring remain under-utilised. Key gaps in grid resilience approaches on detection and response include:

- Most LV faults are still discovered reactively, after customers report outages, rather than through direct observation.
- “Last-gasp” outage alerts (i.e., high-priority messages sent by smart meters when power is lost) are not yet fully integrated into operational workflows, meaning valuable near real-time data is often missed.
- There is limited ability to triage and prioritise support for vulnerable customers during outages, which can lead to inequitable outcomes.

## Use cases for smart meters

Smart meters have the potential to transform detection and response by acting as a distributed network of sensors. Key use cases would include:

- **Outage detection:** When a smart meter loses supply for more than 3 minutes, it sends a “last-gasp” (AD-1) alert over the secure DCC network, time-stamped and geo-located to the premise. This allows operators to pinpoint faults within minutes, often **10-15 minutes faster** than waiting for customer calls.
- **Voltage and power quality monitoring:** Advanced meters continuously sample voltage and log power quality events such as frequency deviations and phase angle changes. Aggregating this data gives network operators a live, granular view of the LV network, enabling them to **anticipate and spot issues** like conductor faults or voltage sags before they escalate.
- **Supporting vulnerable consumers:** Smart meters can be used to help identify potential vulnerable customers based on consumption patterns to ensure sufficient support is provided.

- Smart meters monitoring energy usage could be used to help vulnerable consumers stay in their homes longer by providing an early detection of risk.

### The benefits of smart meters

Detection and response is the foundation for a resilient grid. By harnessing smart meter data, operators can move from reactive fault-finding to proactive network management. This not only speeds up recovery and reduces disruption, but it also lays the groundwork for other resilience components such as enabling flexibility, improving operational continuity, and supporting data-driven planning.

# Flexibility and adaptability

Flexibility and adaptability is the grid's ability to adjust in real-time to changing supply and demand

As the energy system evolves, the ability to flex and adapt in real-time is increasingly vital for grid resilience. Historically, flexibility has been provided by large, centralised generators, but the rise of DERs and smart technologies means that millions of small assets, such as EV chargers and heat pumps, can now play a role. However, much of this potential remains untapped due to siloed coordination and weak price signals. Key gaps in this resilience component include:

- Demand-side flexibility is still a niche offering, with most households and businesses unable to participate easily.
- Coordination between distributed assets is fragmented, with DSOs and NESO operating in silos, lacking a unified approach.
- Price signals for flexibility are inconsistent, making it difficult for consumers to respond effectively.

## Use cases for smart meters

Smart meters are central to orchestrating flexibility behind the meter, enabling new ways for consumers and suppliers to interact with the grid. Key use cases would include:

- **Half-hourly settlement data:** Every smart meter records energy usage in half-hour intervals, creating a robust audit trail. During a Demand Flexibility Service event, suppliers can identify exactly which premises delivered a reduction in consumption and settle rebates with confidence. This eliminates the need for statistical estimates and reduces risk for all parties.
- **Remote tariff switching:** Smart meters can store up to 48 different time-of-use tariffs. Suppliers can remotely activate special tariffs during periods of grid stress (a “red-alert” evening) and revert to standard rates automatically. This provides strong, targeted price signals without the need for manual intervention or costly upgrades.
- **Load control via HAN devices:** SMETS2 meters support command-and-control of paired devices using ZigBee technology.

Suppliers can issue curtailment commands that are enacted locally, even if the household's broadband connection is down, enabling reliable and responsive demand management.

- **Real-time usage feedback:** In-home displays connected to smart meters provide immediate feedback on energy use and cost. Studies show that simply visualising this information can reduce peak demand by 3-5%, delivering “organic” flexibility across the system.

## The benefits of smart meters

Flexibility and adaptability are the bridge between detection and response, and operational continuity. By enabling millions of consumers to participate in demand-side flexibility, smart meters help balance supply and demand, reduce the need for costly network reinforcement, and maximise the use of renewable energy. This strengthens technical resilience and empowers consumers to play an active role in the energy transition.

# Operational continuity

Operational continuity is ensuring electricity is kept flowing even when something goes wrong

Operational continuity is the ability to deliver electricity reliably under normal and foreseeable conditions. It remains critical to grid resilience and part of operational resilience discussed in [Section 1: Defining resilience](#). Traditionally, it has been achieved through centralised planning, robust transmission standards (e.g. N-1 security standards), and scheduled maintenance. However, the energy transition introduced new complexities. Key gaps in this resilience component include:

- Limited visibility at the grid edge. Traditional systems lack granular, real-time data for low-voltage networks where most distributed energy assets and consumer technologies connect.
- Slow fault detection and restoration. Manual processes and limited automation delay response during outages.
- Fragmented coordination. Transmission and distribution operators (NESO and DSOs) often operate in silos, with limited integration of operational data
- Static operational models that are designed for predictable, centralised generation, rather than dynamic bidirectional flows from distributed energy assets.

## Use cases for smart meters

Smart meters can improve operational continuity by providing near real-time, granular insights and enable proactive management. Key potential use cases include:

- **Automated outage restoration:** As mentioned in the detection and response dimension, smart meters in GB send a “last gasp” (AD-1) alert when the smart meter loses power for more than 3 minutes. Combined with the data on the smart meter’s location, these alerts enable faster switching and sectionalising of the network, reducing downtime.
- **Grid islanding support:** Smart meter data makes it possible to pre-define a set of LV “island candidates” with known load and asset characteristics, helping system operators determine know which zones are technically plausible microgrids in case of an outage.
- **Post-event diagnostics:** Voltage and power quality logs assist in root-cause analysis, improving restoration strategies for future events and the understanding of the system.

## The benefits of smart meters

Operational continuity ensures that electricity supply remains stable and reliable, even under stress. Smart meters play a pivotal role by providing near real-time visibility into consumption and grid conditions, enabling utilities to anticipate issues and maintain service without interruption. Through smart meters, operators can remotely monitor voltage, detect outages instantly, and execute rapid restoration strategies. This reduces outage duration, improves asset management, and lowers operational costs.

# Data-driven planning

Data-driven planning is using real data to plan ahead so the grid can cope with future changes

As the grid becomes more decentralised and dynamic, planning based on historical averages is no longer sufficient. Extreme weather, electrification and the integration of distributed energy assets require predictive, data-driven strategies to anticipate risks and optimise investments. Key gaps in the data-driven planning dimension include:

- Fragmented datasets and outdated models limiting visibility into real-time conditions on the grid.
- Limited integration of customer vulnerability and asset health data, leading to inequitable resilience outcomes.
- Reactive investment prioritisation makes it hard to justify and optimise resilience spending.

## Use cases for smart meters

Smart meters provide granular, time-stamped data that can transform planning. Key use cases would include:

- **Load forecasting:** Half-hourly consumption data from smart meters enables accurate demand projections at feeder level, supporting local energy planning. As there is not yet a full smart meter rollout in GB, NESO does not use smart meter data in their Distribution Future Energy Scenarios (D-FES) and instead rely on transmission metered data.
- **Asset health insights:** Voltage and power quality data from smart meters help identify stress points in LV networks, informing targeted reinforcement before failures occur. Ofgem's RIIO-ED2 framework encourages DNOs to use this data for predictive maintenance.
- **Distributed asset integration modelling:** Smart meter data reveals behind-the-meter generation and storage patterns, allowing planners to simulate grid behaviour under high penetration of distributed energy assets.

- **Societal resilience mapping:** Linking consumption data with vulnerability registers helps planners prioritise upgrades for critical services and vulnerable communities.

## The benefits of smart meters

By leveraging smart meter data, utilities can move from static, compliance-driven planning to dynamic, risk-based strategies. This improves investment efficiency, enhances equity, and enables proactive reinforcement of weak points which ultimately reduces outage risk and supports long-term resilience.

# Cyber and physical security

Cyber and physical security protects the grid from hackers, keeping the grid safe and reliable

Digitalisation expands the grid's attack surface, making cyber and physical security inseparable. Threats range from ransomware targeting operational technology systems (including, for example, SCADA systems, sensors, and controllers in power grids) to physical sabotage of substations. A layered, integrated approach to cyber and physical security is essential to maintain operational continuity. Key gaps in this dimension include:

- Legacy SCADA systems and remote assets often lack modern security controls.
- Millions of connected devices create multiple entry points for potential attackers.
- Hybrid threats can disable monitoring systems and damage physical infrastructure simultaneously.

## Use cases for smart meters

Smart meters can play a critical role in strengthening cyber-physical security dimension of resilience. Key use cases include:

- **Tamper detection:** Smart meters log and report physical tampering attempts, alerting operators to potential sabotage. This helps detect energy theft or interference quickly.
- **Anomaly detection:** Consumption and voltage anomalies can indicate cyber intrusions. Abnormal events could reflect meter tampering, data manipulation, meter malfunction or other irregularities.
- **Secure communications:** Smart meters in GB operate on a closed, dedicated communication network with security by design. They do this via encrypted channels (through the DCC network) reducing the risk of data interception. The DCC also has 24/7 monitoring of the network for anomalies.
- **Network segmentation:** Acting as secure endpoints, smart meters help maintain integrity between consumer premises and core grid systems.

## The benefits of smart meters

Smart meters enhance situational awareness and provide a secure, distributed sensing layer. By detecting tampering and anomalies early, they reduce the likelihood of cascading failures and support rapid incident response. Their encrypted communication protocols also strengthen the grid's cyber defence posture.



+ LCPDelta

*Part 2: Three themes to better utilise  
the British smart meter system*

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A project for  CALISEN

# Summary

Our research identifies specific use cases where smart meters can deliver more benefits for Great Britain. The report analyses these opportunities using evidence from real-world trials and modelling to demonstrate the benefits and associated policy requirements. It highlights the role smart meters can play in enhancing grid resilience, optimising the energy system, and delivering operational savings.



**Voltage Control**  
*The management of voltage levels across the low voltage (LV) electricity network to keep them within statutory limits*



**System Optimisation**  
*Via flexibility; the ability to dynamically balance fluctuations in supply and demand under varying conditions*



**Operational Savings**  
*Reduce the time, cost, and resources needed to manage the electricity system and consumer accounts, including social returns*

Use case

Smart meter-enabled voltage control improves energy efficiency and grid resilience by providing visibility of voltage levels beyond substations. Trials show that optimising voltage using smart meter data can reduce consumption, lower bills, and cut carbon.

Smart meters enable consumer-led flexibility by providing near real-time data, allowing consumers to shift usage and support grid stability. Smart meters enable services such as the Demand Flexibility Service (DFS) which can reward households for reducing demand.

Smart meters replace manual readings with automated, half-hourly data, reducing costs, potential errors, and enabling more accurate settlement and billing. They also help identify and support vulnerable customers more effectively.

*The research models base case and best case scenarios e.g. current rollout versus 100% rollout*

Potential gross benefit across GB consumers

**£572-770m**  
 from Conservation Voltage Reduction (CVR) voltage control

**£103-139m**  
 from avoided overvoltage

**£1-1.5m**  
 from Winter DFS

**£415-560m**  
 from excess energy to customers enabled by smart meters

**£312-420m**  
 from operational savings of the full smart meter rollout

**£185-250m**  
 of social return from using smart meters to identify vulnerable households

*Total annual gross benefits of £1.9bn at 100% rollout*

*Lifetime benefit*

# Smart metering rollout

## Original objectives of smart metering

- Accurate billing
- Near real time data on consumption and usage cost to consumers through their in home display (IHD)
- Reduction of consumers' energy consumption through behaviour change
- Reduced energy supplier operating costs
- Enabling future energy system innovation (such as smart grids)

## Original technical specification for the GB smart metering system:

- Half-hourly measurement and storage of electricity consumption
- Remote meter reading
- Near real-time data provision to an in-home display
- Support for Time-of-Use tariffs
- Credit and prepayment functionality
- Load limiting, outage logging, and power quality data (including voltage)

Originally, the UK Government planned for suppliers to take all reasonable steps to install smart meters in "all homes and businesses' by 2019."

## Where we are today

Smart meters have met the original objectives for the overall smart metering implementation programme and enabled services such as the demand flexibility service in winter and time of use tariffs from suppliers.

- The reduction in consumers' energy consumption is disputed. However, smart meters have enabled many apps with behavioural insights that can be used by consumers to help reduce their energy usage based on the more accurate billing and data generated by the smart meter.

On the technical side of the GB smart metering system, some smart meters do not operate as intended (with 7.4% operating in non-smart mode at the end of Q1 2026). Furthermore, for Distribution Network Operators (DNOs) trying to access voltage data, more than 30% of smart meters did not respond in the BEETS trial and there are latency issues related to cellular (2G and 3G) as well as long-range radio.

Technical needs and requests from suppliers were met, however DNO requirements were not the focus of the original rollout.

- While not the purpose nor is it required of a smart meter, load limiting is a functionality that is offered. However, it's method of function has changed from SMETS1 to SMETS2 and it's not currently in use. Ongoing projects, such as LCP Delta's Smart ReStart, are investigating its usage.
- Voltage is currently recorded by the meter at 1-minute intervals, although DNOs can only retrieve it in 30-minute average intervals. 1-minute data would improve project planning for DNOs. Trials to retrieve the 1-minute voltage data found only a 57% success rate.\*

\*Smart Meter Innovations and Test Network (SMITN)

# Voltage Control

Smart meter-enabled voltage control provides a significant opportunity to improve energy efficiency, grid resiliency and deliver savings to consumers.

Maintaining voltage within statutory limits has historically been challenging due to limited visibility beyond substations, leading to widespread overvoltage and inefficient appliance operation. Smart meters change this by offering voltage measurements beyond substations at the grid-edge or “end of the line”, enabling DNOs to identify and correct overvoltage conditions.

Evidence from trials such as BEET and DataMate shows that using near real-time smart meter data to optimise voltage at the system level can reduce consumption, lower bills, cut carbon, and increase hosting capacity for DERs. Scaled nationally and after improvements in access to real-time voltage measurement data, voltage optimisation could unlock hundreds of millions of pounds in annual consumer savings.

Overall, smart meters provide essential voltage visibility and data measurements assuring safe and effective delivery of efficient, resilient, and future-ready LV network operations.

Two scenarios were used to value the benefits of each of the smart meter use cases.  
Base case assumes a 74.3% smart meter rollout across GB, the best case assumes 100%

## High-level policy support requirements

- Real-time voltage measurement data at grid-edge to support DNOs adjusting operational voltage limits and anticipating grid failure (currently smart meters provide near real-time data half-hourly).
- Timely access for network operators to smart meter voltage measurements, collected from DCC (via ‘Read Network Data’ Service Request or via a new and improved system).
- Continued innovation project support, supporting developments that avoid voltage inefficiency and reduce voltage driven constraints.
- Consideration of the ENA’s consultation on Modernising Statutory Voltage Limits, to accommodate both the higher UK voltage limits and the lower EU voltage limits.

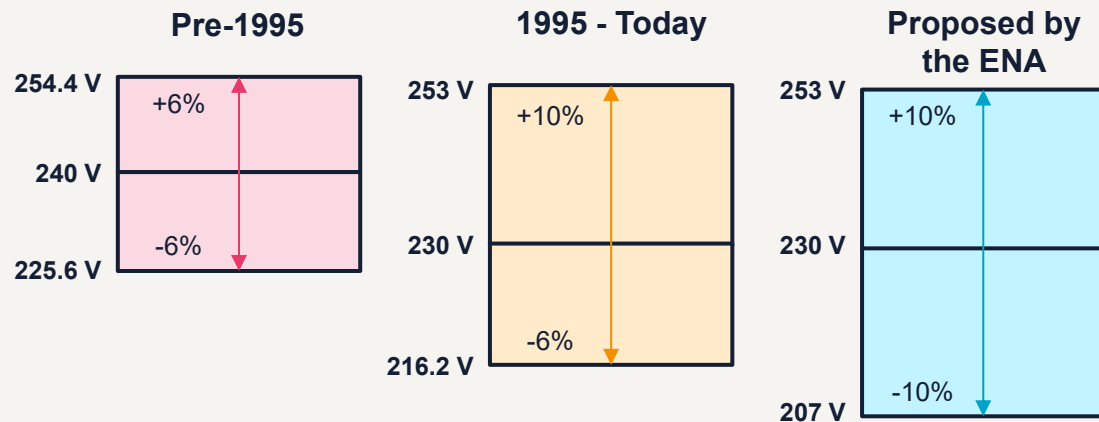
# Voltage Control – Introduction

Voltage Control offers multiple benefits, here we focus on optimisation to improve energy efficiency



**Voltage Control is the management of voltage levels across the low voltage (LV) electricity network to keep them within statutory limits**

In 1994, the European Commission decided to harmonise the standard UK mains voltage of 240V and the European standard of 220V in order to allow the same products to operate across the EU. This led to altered statutory voltage limits so that the harmonised supply voltage must be 230 V +10% / -6%, allowing both systems to operate within a common voltage range.



Most European appliances, including those supplied to the UK market are designed to work around 220V, even though UK supply often averages closer to 240V. As supply voltage affects efficiency of many (inductive) loads, domestic appliances tend to consume more energy than needed. Voltage control towards the lower permissible limit can improve energy efficiency.

**Maintaining voltage within statutory limits is essential for maintaining power quality for grid resilience.** It also prevents equipment damage and ensures equipment works as designed

**Voltage control in LV networks is not automatic.** The tap position in a transformer refers to specific connection points on the windings that allow for voltage adjustments, but which are not automatically adjusted in operation.

**Overvoltage is common in distribution networks to compensate for voltage dropping along LV feeder lines further away from the substation.** Network operators do this to ensure the voltage reaching homes and businesses does not drop below statutory limits, as they do not have visibility of the voltage level at the end of feeder lines.

However, the deployment of distributed energy assets, such as solar panels, can cause an increase in voltage level at the point of consumption, creating a challenge for network operators managing voltage levels.

Voltage optimising devices can be installed at the consumer unit (fuse box) in homes or businesses to ensure voltage remains at an optimum value to minimise energy consumption. However, while voltage optimisers can improve energy efficiency for the end user, they may not always perform as desired if the DNO has no visibility of voltage levels throughout the LV network.

**When adjusting and optimising voltage at a system level, there is a trade off:** between lower voltage improving some appliances' efficiency but simultaneously increasing line losses for the DNO or even damaging appliances.

**This provides an opportunity for smart meters to provide near real-time voltage visibility to support voltage optimisation and grid resilience.**

# Voltage Control – The role of smart meters

Smart meters can revolutionise the visibility of voltage levels at the end of the line, improving grid resilience management

## Accessing voltage measurements from smart meters

**Smart meters are critical to this use case as they provide insight into grid-edge voltage stability by providing voltage measurements.**

While the main purpose of a smart meter is to measure energy and there is no requirement relating to the accuracy of voltage measurements, smart meters can measure voltage with an accuracy of  $\pm 1\%$ .

Voltage measurement data can be retrieved from electricity smart meters using a DCC ‘Read Network Data’ Service Request. This request can be made by import suppliers as well as electricity distributors. Distribution network operators often have visibility at substations but not for variations beyond that point in the LV network. Data from smart meters could provide similar visibility within the low voltage network.

**Optimise voltage measurement collection using a sample of smart meters.**

To avoid volume and performance limitations for processing data via smart meter gateways and the DCC radio network, it is recommended that voltage readings are taken from a subset of smart meters within a primary substation’s area half-hourly, instead of from every smart meter.

Smart meters are typically configured as standard with a 30-minute voltage averaging period; however, this can be changed to a 10-minute averaging period which would provide a more granular view.

## Acting on voltage data to improve grid resilience

**By accessing smart meter voltage measurement data, network operators can have visibility through the LV network to better manage network voltage levels and support grid resilience.**

DNOs currently have visibility of voltage levels at substations but not beyond that, at individual homes and businesses. Smart meters themselves do not directly change the voltage, but provide the data required for networks to identify overvoltage and undervoltage conditions and adjust voltage accordingly at the system level to deliver savings safely.

This use case utilises existing smart meter infrastructure and data request methods without the need for a voltage optimiser at the consumer unit (fuse box) in homes, which would come at an additional cost to consumers.

The opportunity lies in harnessing this data to deliver savings, as DNOs do not currently analyse and act upon voltage measurements from smart meters under business as usual.

**By reducing incoming voltage, voltage control is estimated to be able to save 5-8% annually in electricity costs.** There are other potential uses cases and benefits of Voltage Control, such as enabling further Distributed Energy Resources (DER) integration while maintaining grid stability, that are not included in this figure. **+ 5-8%**

# Voltage Control – Case Studies

BEET provides a trial example of the savings that are possible when using smart meter data for voltage control

## Boston Spa Energy Efficiency Trial (BEET)



**Approach:** Half-hourly smart meter data is used to optimise voltage via “BEET-Box” devices, to achieve Conservative Voltage Reduction.



**Result:** Reduced voltage, reduced consumption, reduced cost. Improved hosting capacity for EVs and PV.

- + £28 Estimated average annual household energy bill saving\*
- + 20kg Estimated carbon reduction per household
- + 3% Average reduction in voltage from voltage optimisation\*\*



**What next?** The trial period ended in September 2025. Northern Powergrid plan to rollout the concept to the majority of customers (up to 80%) in their operating area by 2033.

\* based on several factors, including Ofgem’s definition of typical usage and assumed unit costs of £0.30 per kWh.

\*\* based on measured data from November 2023 versus November 2024.



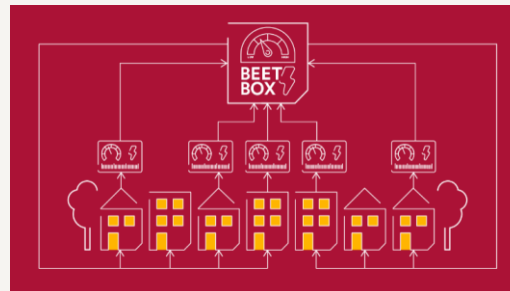
**BEET is a £1.3m Northern Powergrid innovation project helping around 15,000 households and businesses around Boston Spa and Wetherby to reduce energy bills.**

BEET utilizes a specially developed technology, the **BEET-box**. Smart meter voltage data feeds into the BEET-Box, which applies an optimisation algorithm to the data every 30 minutes to determine the most efficient voltage to supply on the 11kV network at that time and the adjustment to the level of voltage required. The BEET-Box sends this voltage target to the network management system (NMS) which in turn adjusts the supplied voltage (by adjusting the automatic voltage control (AVC) relays at the 33/11kV substations) to provide only the level of power that appliances need to work effectively.

This is known as **Conservation Voltage Reduction (CVR)** – reducing distribution system voltage away from inefficient overvoltage to reduce energy consumption and peak demand.

Find out more:

<https://www.northernpowergrid.com/beet>



# Voltage Control – Case Studies

Ongoing trials show why smart meters are important to near real-time voltage control, resulting in savings to consumers

## Voltmetric

**Voltmetric is a £1m SSEN Distribution innovation project aiming to establish a new Voltage and Power Quality index for quantifying the value of different voltage interventions.**

Voltmetric combines smart meter and LV monitor data to create voltage and power quality health indices. The trial aims to provide the basis for a new incentive framework to be developed by Ofgem in this area, supporting the ability of networks to invest accordingly to improve voltage and power quality.

The methodology of the project related to smart meters, where the results will be of particular interest, include:

- Identifying the data required to determine a Voltage and Power Quality index, including data relating to smart meters
- Implementing a data collection method and frequency
- Running test cases to verify network intervention approaches

Find out more on the [project page](#).



**Keep an eye on this, trial completion is due October 2026.**

Started in April 2025, this trial is ongoing and could lead to tangible change in relation to the direction of investment and intervention to avoid voltage driven constraints. The role of smart meters is likely to be vital in providing the data needed for the index, with learnings in relation to data collection.

## DataMate

**DataMate is a £127k UK Power Networks innovation project aiming to crowdsource data from grid-edge-connected devices to enable DNOs to obtain data proactively and effectively manage voltage challenges stemming from the increasing number of LCTs connecting to the network.**

UK Power Networks has seen a rise in voltage complaints from customers experiencing tripped EV chargers or PV inverters, caused by the voltage limits of LCT equipment being triggered. Usually, when voltage complaints arise, self-serve voltage recorders are provided to customers to capture data. The process is a reactive response, often involving numerous customer visits, resulting in a slow speed of complaint resolution.

DataMate sought to establish a platform to allow DNOs to harness data, conduct root-cause analysis, improve granular visibility and proactively identify voltage incursions, as the data is available from customers' own LCTs but DNOs cannot currently unlock the data.

The fragmented nature of LCT providers' data and systems also adds further complexity and cost as DataMate expects to pay LCT providers (data holders) for the data provided. **Smart meters provide another, less expensive way of delivering the same value, providing near real-time voltage measurement data.**

Find out more on the [project page](#).

**+£4.4** Estimated average annual household energy bill saving\*

\* based on an estimated £37.1m per annum saving (from DataMate enabled voltage optimisation) and 8.5m customers across UKPN license area

# Voltage Control – Value Potential

There is considerable value potential to DNOs and consumers from CVR voltage control and avoided overvoltage

## Total potential value in GB from Voltage Control

In the BEET trial, 15,000 customers were estimated to save £28 each annually. If rolled out nationwide, it could reduce household bills by up to £770m. Northern Powergrid’s estimates are based on these assumptions:

- £0.30/kWh electricity unit cost
- 3% voltage optimisation
- 3,100 kWh typical domestic annual consumption (for savings per customer), and 85,600 GWh GB annual consumption (for GB savings)



These figures include the total benefit for GB including the savings for:

- Consumers: annual savings for network services & annual savings on energy bills
- Networks: reduced operating cost, avoided reinforcement, avoided monitoring devices & reduced DNO labour costs

Doubling voltage optimisation has a higher impact to potential annual savings than reducing the unit cost. As total electricity consumption is expected to continue increasing, future trials and innovation projects to further improve voltage optimisation across GB will have an increasingly significant impact on savings to consumers.

In the DataMate trial, UK Power Networks estimated the financial benefit across its license area which serves 8.5m customers. In the table below these benefits are estimated across GB (29.6m electricity meter points).

		Estimated Saving (£m)	
		Across UKPN area	Across GB
Network Operators	Financial Benefit		
	Reduced operating cost	159.5 – 178.6	555.4 – 621.9
	Avoided reinforcement <small>(i.e., transformer upgrades)</small>	10.4 – 20.9	36.2 – 72.8
	Avoided monitoring devices <small>(i.e., in LV substations)</small>	10.1	35.2
Consumers	Reduced DNO labour costs	10.2	35.5
	Annual saving for users of network services <small>(e.g., faster resolution, increased LCT utilization)</small>	2.7 – 2.9	9.4 – 10.1
	Annual saving on consumer energy bill	37.1	129.2



## Potential opportunity and value

There are significant financial benefits to both consumers and networks from voltage optimisation enabled by smart meter data. Meter asset providers and operators could consider new product offerings or business models that would enable its participation in the value chain. For example, developing a new hardware update or widget that would be rolled out in future smart meter models that would provide networks will accurate, near real-time voltage measurement data.

# *System Optimisation via Flexibility*

Balancing electricity supply and demand is more challenging as we use more intermittent renewables such as wind and solar. Flexibility means adjusting when and how we use energy to keep the system stable whilst exploiting these variable and often abundant resources.

Smart meters support flexibility by providing near real-time data, so consumers can be incentivised to shift usage or to reduce demand at busy times. One example is the Demand Flexibility Service, which rewards households for cutting energy use during peak periods. This helps avoid switching on extra fossil-fuel plants, saves money, and supports a greener grid. Without smart meters, these services would not work fairly or at scale.

In short, smart meters and flexibility make the energy system more affordable, smarter, cleaner, and more resilient.

Two scenarios were used to value the benefits of each of the smart meter use cases. Base case assumes a 74.3% smart meter rollout across GB, the best case assumes 100%

## High-level policy support requirements

- Allow licensed aggregators and grid operators (not just suppliers) to send commands via smart meter signals.
- Ensure homes have compatible hardware, either through next-generation meters with APC or standalone APC devices.
- There is an ongoing consultation, “[Smart Secure Electricity Systems](#)” (SSES) aimed at defining load control licence regulations and conditions. Industry needs this clarity.

# System Optimisation via Flexibility - Introduction

Flexibility is the balance of supply and demand, and we focus on the solutions to maintain frequency.

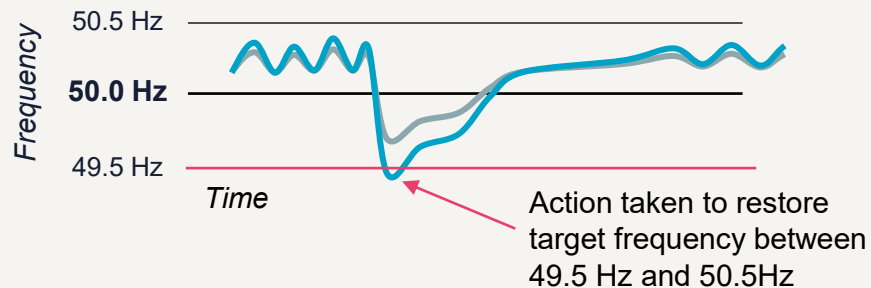


**Flexibility is the ability to dynamically balance fluctuations in supply and demand under varying conditions.**

Flexibility in the electricity system refers to the ability to modify generation or consumption patterns in response to external signals (e.g. price) to maintain balance between supply and demand in near real-time. This is critical because:

- Renewable energy sources like wind and solar are intermittent, unlike fossil-fuel plants which are dispatchable.
- Electrification of transport and heating increases demand variability.
- GB's grid must operate securely while meeting decarbonisation targets (Clean Power by 2030, Net Zero by 2050).

Frequency fluctuations reflect the balance between supply and demand. Frequency falls if demand is greater than supply, and rises if supply is greater. NESO is responsible for keeping the frequency within  $\pm 1\%$  of 50Hz, illustrated below.



## Traditional sources of flexibility

Historically, the GB electricity system relied on large, transmission-connected assets and operational measures. These remain critical today, and include:

- Transmission-connected generation: Gas and nuclear plants provide inertia, frequency response, and reserve.
- Industrial & Commercial flexibility: Large users can reduce or shift load during peaks, e.g. turning down processes.
- Reserve services: Products like Short-Term Operating Reserve cover unexpected demand or generation changes.

## New and emerging sources of flexibility

The transition to a low-carbon system introduces new flexibility solutions:

- **Consumer-led flexibility:** Smart meters enable consumers to participate in flexibility through time-of-use tariffs and flexibility events and can leverage their smart connected devices like EV chargers and heat pumps.
- Energy storage: Batteries and long-duration technologies absorb excess renewable generation and discharge during scarcity.
- Distributed generation: Small-scale renewables and CHP connected to distribution networks provide local flexibility and ancillary services.
- Interconnection: Cross-border links enable imports / exports for balancing.
- **Local flexibility markets:** Aggregators group small assets (individual consumers relying on smart meters) into Virtual Power Plants (VPPs).
- Low-carbon dispatchable power: Hydrogen-ready turbines and biomass provide backup during prolonged, low renewable output.

# System Optimisation via Flexibility – The role of smart meters

## Role of smart meters in flexibility services

### The smart meter infrastructure enables consumer-led flexibility and VPPs relying on domestic assets

Smart meters in Great Britain are a critical enabler of domestic flexibility because they provide the digital infrastructure for near real-time data exchange, dynamic pricing, and automated control.

- Smart meter functionality goes beyond simple billing and underpins several flexibility services which did not exist before the roll-out of smart meters.

Smart meters allow granular consumption data to be collected and transmitted securely through the Data Communications Company (DCC) network.

- This data is recorded in half-hourly intervals and supports accurate measurement of demand shifts during flexibility events, such as the Demand Flexibility Service (DFS).
- It also enables suppliers and aggregators to forecast demand more accurately and design tariffs that incentivise flexible behaviour.

Smart meters enable time-of-use (ToU) tariffs and dynamic pricing when combined with granular data and remote tariff updates via the DCC. Consumers can be provided price signals that encourage them to shift usage to off-peak times or periods of high renewable generation.

*Data transfer from smart meters to operators is constrained by the DCC network, with readings typically retrieved once per day. Enhancing communication infrastructure would enable more frequent data collection across the GB smart meter network and provide greater network benefits.*

Smart meters strengthen grid resilience by improving situational awareness and enabling rapid demand-side action during system stress.

- Near real-time data could help operators detect emerging issues and respond quickly, while flexibility services such as DFS reduce peak demand and mitigate blackout risk.
- Automated control and accurate forecasting also reduce reliance on costly backup generation and support faster restoration after outages.

## Acting on smart meter data for flexibility services

The half-hourly consumption data from smart meters is a key enabler for flexibility and incentivising consumers to increase, decrease, or shift their electricity use over time-of-use tariffs and control services. Key smart meter functionality for flexibility include:

- Half-hourly consumption data – needed to settle flexible tariffs and to verify response in flexibility events.
- Remote, near real-time readings – enables suppliers and networks to monitor load patterns and spot issues or opportunities.
- Data access framework – consumers can authorise suppliers, aggregators, or others to access their half-hourly data for services like DFS and smart tariffs.

Smart meters act as the digital backbone for a more flexible, affordable, and secure electricity system

# System Optimisation via Flexibility – Case Studies

Smart meters are essential to the offering of system optimisation via flexibility for domestic consumers

## Demand Flexibility Service (DFS)



**Approach:** Half-hourly smart meter data used to pay consumers and businesses to shift or reduce demand during peak consumption periods.



**Result:** Total demand reduced during the peak consumption period lowering the need to fire up fossil-fuel plants.

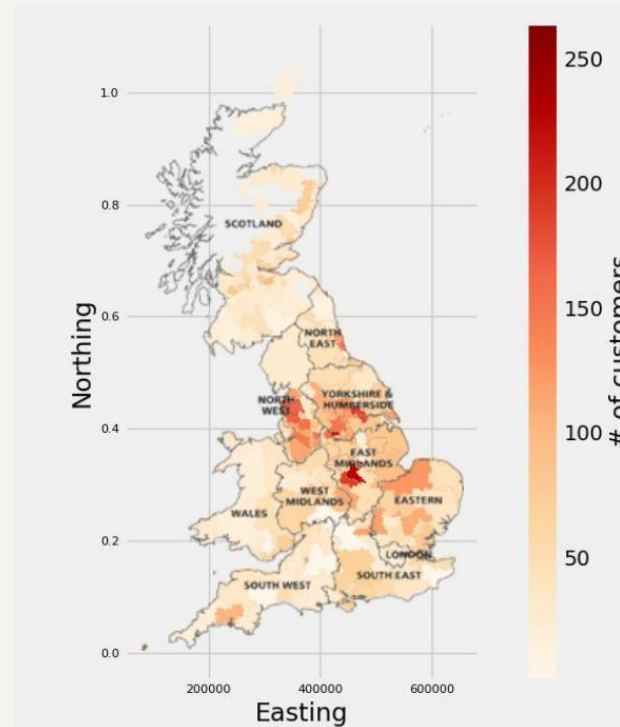
+ 1.98M Electricity supply points that took part in winter 2024/25 events

+ 3.9GWh Total demand reduction across all events in winter 2024/25

+ £944k Payments for delivery of flexibility in winter 2024/25



The DFS launched in Winter 2022/23 has evolved from a winter contingency measure to a year-round merit-based flexibility tool driving consumer participation and system resilience.



Consumer location heat map for Winter 2022/23. Source: [NESO](#)

### How it works

To participate in the DFS, households require a smart meter that enables half-hourly electricity metering data.

Smart meters allow NESO and suppliers to see when consumers reduce their electricity usage, half-hour by half-hour. That half-hourly data is used to (1) build a “normal use” baseline, (2) compare it with what consumers did during a DFS event, and (3) calculate how much flexibility was delivered and how much money should be paid.

Without a smart meter, NESO couldn't verify delivery of flexibility.

### Smart meters & DFS

*Without smart meter data, the DFS service could not work at a national scale or with any real accuracy or fairness.*

# System Optimisation via Flexibility – Case Studies and Modelling

## SP Energy Networks & Octopus Energy “Windy Day Fund”

A 2022 UK trial in Dumfries & Galloway and Ayrshire (Scotland) explored how domestic demand flexibility can help absorb excess renewable generation that might otherwise be curtailed, while giving tangible financial benefits to participating households.

Around [8,692](#) households in the SP Energy Networks distribution area were invited to opt in to the event, with around 2,500 households participating.

- Octopus Energy targeted periods of high renewable generation and low demand, inviting eligible smart-meter customers to increase usage during selected two-hour windows. Households raising consumption by more than 10% received free energy for that period, with higher rewards for doubling usage.
- The average reward for participating customers was £5, with some saving up to £73. Across six events, total demand increased by ~20 MWh.

Excess energy that is curtailed has many potential use cases which have been explored in the UK.

- In Ireland, using excess (curtailed) wind energy to heat domestic hot water for fuel poor households has been studied which could save the Irish state [€4 million by 2030](#)
- In GB, wind generation exceeding grid capacity led to DESNZ offering [discounts on electricity costs](#) for data centres located in high wind generation regions.

## System optimisation value in GB via flexibility

- In the Winter 2024/25 Demand Flexibility Service (DFS), 1.98 million participating smart meters (with 19.1 million smart meters operating) enabled a total demand reduction of 3.9 GWh and total payments of £944k for delivery of flexibility.
- Scaling up the figure from the Winter 2024/25 DFS to the smart meter rollout today and a full smart meter rollout, gives a gross total potential benefit from the Winter DFS:

*£1.08 million across GB* **Base case**

*£1.46 million across GB* **Best case**

- Taking the curtailed average benefit of £5 in free energy for customers across six events and applying this to 197 curtailment events in 2025 and ~3 million participating households, results in a gross annual benefit from using curtailed energy of:

*£415 million across GB* **Base case**

*£560 million across GB* **Best case**

## *£1.9 billion curtailment cost across GB in 2025*

**While the DFS is already operational, the largest blockers to access are 1) the smart meter rollout not being completed and 2) smart meters that are installed but operating in “dumb” mode, hence not sending half-hourly meter reads.**

Ofgem has [proposed new rules](#) to offer compensation to customers for smart meters not operating in smart mode if not fixed within 90 days.

# System Optimisation via Flexibility – Potential opportunity

Smart meters could further enable automating flexibility, but regulatory support is needed

## Potential opportunity

Smart meters could be used to automate flexibility rather than relying on manual actions from consumers.

- The GB smart metering system introduced an Auxiliary Proportional Controller (APC) function, (defined in the PAS 1878) to allow the throttling of a device's power between 0 and 100% rather than just a power on/off as existed in Auxiliary Load Control Switches (ALCS).
- In practice the APC functionality remains mostly dormant, with no widespread deployment. Additionally, only licensed energy suppliers can send control signals via the DCC network.
- Roughly 60% of installed smart meters today have potential ALCS functionality, but this only offers on/off control.

There is an ongoing consultation, "[Smart Secure Electricity Systems](#)" (SSES) aimed at defining load control licence regulations and conditions.

- As it stands, load control is expected to centre on the energy smart appliances (ESA) themselves including electric vehicles (EVs), EV charge points, heating appliances and batteries.
- Ancillary devices could be used to enable the load control of an ESA, including the use of Auxiliary Proportional Controllers (meeting security expectation as set out in SLC 46).

## Smart Secure Electricity Systems

- By 2028, phase two of the SSES, a minimum common protocol (potentially based on an updated PAS 1878) is planned to be specified.
- In the short term, flexibility control will likely be through the ESA's internet connectivity, using open APIs or standards agreed with industry.
- The smart meters' APC functionality could play a larger role later, but some changes are needed for it to be viable.
  - Notably, expanding access to the DCC-controlled smart meter signals beyond just suppliers is crucial. The new load control licensing may pave the way for licensed aggregators or grid operators to send commands through the smart meter system.
  - Additionally, hardware needs to be in homes. Either through the installation of next-generation meters with built-in APC, or the deployment of standalone APC devices that can receive the DCC signals and modulate appliance load. Industry trials are ongoing to test these capabilities.

### Ongoing consultation

*The UK Government's current stance is 'technology neutral but security-focused', ensuring flexible loads can be controlled in a secure and standardised way. **The APC via smart meters is possible and remains an option under consideration, but it will require further regulatory support and industry uptake to become a practical alternative.***

# Operational Savings

Managing the electricity system and customer accounts used to involve manual meter readings and estimates, which were slow, costly, and the data was often inaccurate. This caused billing errors, disputes, and extra work for suppliers.

Smart meters could change this by providing near real-time, half-hourly data, removing the need for manual reads and making settlement faster and fairer. They also unlock big operational savings for energy suppliers by reducing site visits, cutting admin costs, and improving forecasting. Government analysis shows smart meters could save suppliers billions over time, while also helping identify and support vulnerable customers more effectively.

In short, smart meters take the guesswork out of energy use, cut costs, and enable a smarter, more resilient grid.

Two scenarios were used to value the benefits of each of the smart meter use cases. Base case assumes a 74.3% smart meter rollout across GB, the best case assumes 100%

## High-level policy support requirements

- DNOs are already running initiatives such as VIVID to use smart meter data to identify Priority Services Register eligible customers, but the full benefits will only be realised if access to individual smart meter data is streamlined and improved.
- Mandate the installation of smart meters in all newbuilds to accelerate rollout and futureproof new housing developments.

# Operational Savings - Introduction



**Operational savings reduce the time, cost, and resources needed to manage the electricity system and consumer accounts**

## What do settlement and meter operations look like with analogue electricity meters?

For most domestic consumers without smart meters, suppliers rely on periodic manual reads, either monthly or quarterly, and estimated consumption profiles to reconcile wholesale purchases with actual demand (“settlement”).

- In practice, this means site visits from field personnel, customer-submitted reads, and a back-office process that reconciles differences months later.
- Errors in reads or missing data lead to estimated bills, subsequent back-billing, higher complaint volumes, and costly corrections.

As only periodic manual reads were available, vulnerable customers without smart meters are identified manually or via self-registration on the Priority Service Register (PSR). DNOs conduct extensive engagement and promotion for the PSR which has significant time and cost implications.

- Manual assessment to detect consumers who didn’t self-identify as vulnerable or lacked awareness of their situation can also miss potential vulnerable customers.

## Why does this create operational and customer problems?

Settlement and billing processes without smart meters have to use data which may be estimated data, may not be timely or may have inaccuracies, giving suppliers a poor, potentially erroneous view of when energy is used. This increases the supplier’s wholesale imbalance risk, inflates their back-office workload to resolve disputes, and reduces overall customer trust.

- In addition, to capture the meter readings, field personnel are required to visit premises, enduring overhead costs for energy suppliers and logistical complexity.

## How do smart meters improve the situation and enable grid resilience?

Smart meters will play a key part in replacing periodic or estimated reads with actual consumption data for every half an hour period. This data will be used across industry once the MHHS Programme goes live. This shift enables accurate settlement as opposed to profiles and estimates, reducing imbalance risk and improving forecasting. Automated data flows cut costly site visits and back-office corrections, while eliminating billing errors and complaints. Vulnerable customers can be identified proactively through usage patterns, reducing manual PSR processes.

For grid resilience, smart meters support demand-side flexibility, ToU tariffs, and dynamic control of EVs and heat pumps. Granular data enhances network planning, outage prevention, and integration of low-carbon technologies, strengthening reliability and decarbonisation efforts while enabling a smarter, more efficient energy system.

# Operational Savings – The role of smart meters

## The role of smart meters

### Why are smart meters essential?

For smart meters, no routine, or physical cyclical meter readings, are required which significantly reduces their operational cost when compared to traditional analogue meters, driving costs down for energy suppliers.

MHHS makes use of trusted, secure, high-frequency consumption data at the meter point. Smart meters capture consumption in half-hourly intervals and communicate it over the national network operated by Smart DCC.

- This unlocks settlement reform and the associated operational savings (no routine manual reads, fewer disputes, less back-billing), which simply are not available at scale with legacy, or manual, approaches.
- Ofgem’s settlement reform pages explicitly state smart meters can record every half hour and provide the opportunity to make settlement more accurate and timely. This allows energy suppliers and network operators to match supply and demand more precisely, reducing forecasting errors, imbalance costs and manual processes.

#### New builds

*The smart meter rollout is driven by the energy supplier rollout plans with no current legal obligation to install smart meters in new builds. Mandating smart meters in new builds is an easy way to accelerate the rollout and future proofing new builds, particularly in light of the Labour government’s ambitious housing new build targets.*

### How do smart meters technically enable the flow?

- On-premise measurement & encryption: The smart meter and communications hub collect usage, wrap it in multi-layer encryption, and maintain a home area network (HAN) to interface with the in-home display and devices.
- Wide-area transmission via DCC: Readings are sent via secure wide-area networks (cellular/radio) to the DCC servers. DCC does not retain the consumption data; it securely transports it to the relevant market participants (energy suppliers and DNOs) for billing and, in future, for settlement through the MHHS architecture. All smart electricity meters are scheduled to be migrated to MHHS operations by May 2027.
- Market integration for MHHS: DCC is implementing new user roles, interfaces, and capacity upgrades to support the MHHS Target Operating Model, ensuring the industry can retrieve half-hourly data at national scale with appropriate assurance and testing.

Smart meters take the guesswork out of consumers’ electricity usage and unlock innovative flexibility solutions (both tariff driven and direct) for consumers to take part in optimising the grid.

# Operational Savings – Case Studies

DESNZ’s cost benefit analysis demonstrates the operational savings benefit of smart meters to suppliers

## DESNZ Cost Benefit Analysis of Smart Meter Rollout



**Approach:** Analysis of the costs and benefits of the smart meter rollout based on up-to-date (2019), real world evidence from the programme.



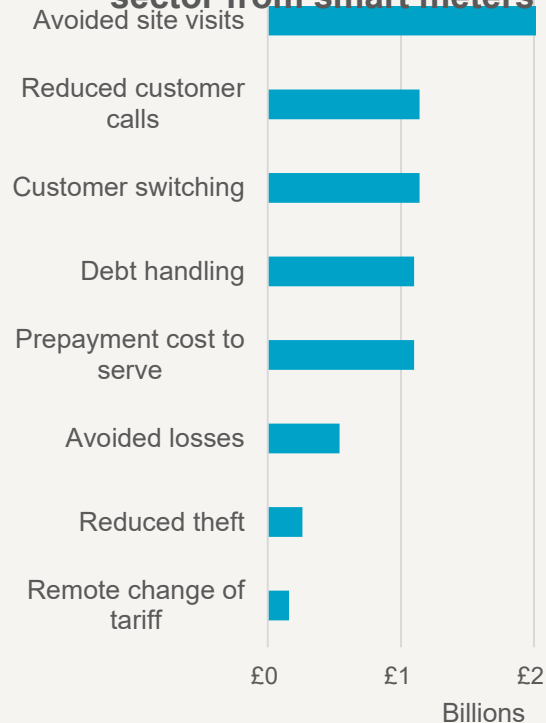
**Result:** The programme’s business case passed the breakeven point in 2019 with every additional smart meter added to the system adding to the positive and growing net benefits. The top 3 benefits to **suppliers** are:

- + **£3.76** Net benefit to suppliers per meter per year due to avoided site visits
- + **£2.21** Net benefit to supplier per meter per year due to reduced costs of customer switching
- + **£1.91** Net benefit to suppliers per meter per year due to reduced cost of call handling



**What next?** As the smart meter rollout continues, the benefits for suppliers will continue to increase. The latest 2025 report estimates the total supplier benefit to be **£8 billion**, using prices discounted to 2025 (based on the 2019 cost-benefit analysis).

**Breakdown of energy suppliers' accrued benefit (2013 – 2034) for domestic sector from smart meters**



**The Smart Meter Rollout Cost Benefit Analysis is the UK government’s assessment of the long-term costs and benefits of installing smart electricity and gas meters across GB.**

The report examines the economic case for the smart meter programme from 2013 to 2034, quantifying impacts across households, businesses and the energy sector.

For energy suppliers specifically, the analysis identifies operational efficiencies as a key benefit: smart meters reduce the need for manual meter readings, cut down administrative costs and improve billing accuracy.

Although supplier benefits are estimated to be lower than in earlier assessments (due partly to shifts in the retail market and increased customer-provided readings), they still amount to £billions over the appraisal period.

The UK Government’s original [2019 cost-benefit analysis](#) and the updated [2025 cost-benefit analysis](#) are available online.

# Operational Savings – Vulnerability and fuel poverty

There is overlap between fuel poor and vulnerable customers with many fuel poor also being vulnerable

## Vulnerability and Fuel Poverty

Vulnerability can be defined in many ways.

The Priority Services Register is the energy industry’s primary method for providing help, support, and adapted services to those who are vulnerable during power cuts. However, it is only one way of defining vulnerability. Eligibility to join the PSR typically includes customers who :

- Use medical equipment reliant on electricity or water
- Live with children under five
- Are blind or partially sighted
- Are deaf or hard of hearing
- Have a chronic illness, anxiety, depression or any mental health condition
- Have a disability

Fuel poverty is focused on whether households can afford adequate energy services. The definition of fuel poverty varies across GB.

- The UK government uses the Low-Income Low Energy Efficiency (LILEE) metric measuring if a household’s home has an energy efficiency rating of band D or below and if, after spending the required amount on energy, the household’s income falls below the official poverty line.
- National Energy Action (NEA) defines households to be in fuel poverty if they need to spend more than 10% of their income on energy to maintain adequate warmth.

## Addressing vulnerability and fuel poverty

There are many ways of addressing fuel poverty and vulnerability. PSR registration can help with accessibility and critical support, but it’s unlikely to solve long-term affordability issues. Below are a few examples of the different support mechanisms available to vulnerable and fuel poor customers in GB.

Fuel poverty intervention examples	PSR eligibility intervention examples
Warm home discount provides fuel poor households with energy bill rebate	Receive priority support during power cuts or emergencies
Energy efficiency retrofits working with energy suppliers, local authorities and housing providers	Access to hardship funding and energy efficient appliances (DSO/retailer dependent)
Energy supplier debt write-offs, hardship funds, payment plans, or repayment holidays	Special help may be provided, if required, through providers like the British Red Cross

# Operational Savings – Case Studies and Modelling

Trials demonstrate why smart meters are vital to vulnerable customer identification and support

## VIVID

Other additional benefits are emerging as smart meters become the standard meter type installed, such as VIVID.

**VIVID is a completed SIF Alpha project that combined energy-sector data (including smart meter data) with local authority and third-sector data to identify vulnerable households missing from the PSR, enabling timely and targeted practical and financial support.**

SSEN and UKPN reported high PSR “penetration” (77% and 67% respectively), but an average PSR gap of ~30%, equating to ~1.4M households across the two, and more than 5M households when extrapolated GB-wide.

Benefits at GB-scale option were estimated at £219M to 2035, assuming VIVID will increase the number of customers added to the PSR by ~7% per year. This includes various weightings, deadweight calculations and optimism bias factors (e.g., 7.5% increase of new PSR customers receive advice, 1.5% increase of existing customers receive advice). The [VIVID discovery phase](#) and [VIVID alpha phase](#) are available online.

DNOs currently lack operationally-scalable household-level access to data for vulnerability use cases. While regulation is moving towards greater aggregated openness and consumer-consented sharing, effective vulnerability identification would benefit from a nationally consistent, authorised vulnerability service. This should provide a clear lawful basis, strong controls and audit, and fast onboarding, avoiding reliance on bespoke and slow project-based approaches.

## Operational savings potential value

- From the UK’s original cost benefit analysis in 2019 of the smart metering rollout, we aggregated the supplier benefits per meter per year including:
  - Avoided site visits, customer switching, reduced customer calls, prepayment cost to serve reduction, avoided losses (difference between electricity entering and leaving the transmission and distribution network) and remote changes to tariff.

**Current rollout (74.3%)**

*£312 million per year across GB\**

**Full rollout**

*£420 million per year across GB\**

- From the VIVID project, the lifetime GB wide benefit from the project was:

*£185 million across GB* **Base case**

*£250 million across GB* **Best case**

As part of their standard licence conditions, DNOs have a duty to actively run processes that identify PSR eligibility when they interact with customers. Smart meters could be a pathway to improve these processes in an efficient and inexpensive way. Policymakers should consider the solutions currently used by DNOs and whether they are the most efficient and up to date.

\*Gross annual benefits, including consideration of operating costs of smart meters

# When can these use cases become useful to the system?

Each use case reaches usefulness at a different point in the smart meter rollout. Below we set out the penetration thresholds needed for each to deliver value.



## Voltage Control

*The management of voltage levels across the low voltage electricity network to keep them within statutory limits*

*Threshold: Low, already broadly achieved*

DNOs currently lack visibility of voltage conditions beyond the substation. To make voltage-control applications useful, they only need a representative sample of smart meters on each LV feeder to understand end-of-line voltages. Once a subset of households per substation has smart meters, DNOs can derive accurate, near real-time voltage profiles.

Full rollout is not required. Beyond 50% penetration, this use case will hit DCC volume and performance limits. With today's penetration already exceeding this threshold, the focus should be on meter placement and observability, to ensure phase coverage and how quickly DNOs can access the data.



## System Optimisation

*Via flexibility; the ability to dynamically balance fluctuations in supply and demand under varying conditions.*

*Threshold: High, but penetration isn't the only factor*

Consumers must have a smart meter operating in smart mode to participate in domestic flexibility schemes. Higher penetration increases the potential volume of flexible demand, thereby increasing system value. However, despite 72% national smart-meter coverage, only ~2.5 million households currently participate in any form of flexibility (~ 10% of installed smart meters). Beyond smart meter penetration, the main barriers are low consumer awareness of flexibility, limited understanding of what smart meters enable, and low trust / interest in dynamic tariffs.

Increasing smart-meter penetration alone will not unlock the value. The real thresholds are behavioural and operational: more consumer engagement, more automation and more meters reliably delivering half-hourly data.



## Operational Savings

*Reduce the time, cost, and resources needed to manage the electricity system and consumer accounts*

*Threshold: Very high, approaching 100%*

Operational savings grow with each additional smart meter installed. But the final benefits, particularly retiring legacy settlement, communication, and meter-management systems, require near-universal coverage. The "last few percent" of households without smart meters will drive disproportionate cost, because maintaining dual systems (smart + legacy) becomes inefficient and expensive.

To realise the full operational-savings potential, the system must reach ~100% smart-meter penetration. In addition to installation, action needs to continue to address non-communicating smart meters. Unlike other use cases, partial penetration does not unlock most of the value for this use case as the benefits are back-loaded.

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