

System Conditions

March 2026



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Introduction

Great Britain's (GB) electricity system is becoming more complex as we transition towards a predominantly clean generation mix. Rapid growth in renewable generation, evolving demand behaviour, and the expansion of distributed assets are reshaping how the electricity system behaves under different operating conditions. Understanding how these interacting factors influence system needs is fundamental to maintaining a secure, resilient, and efficiently managed system.

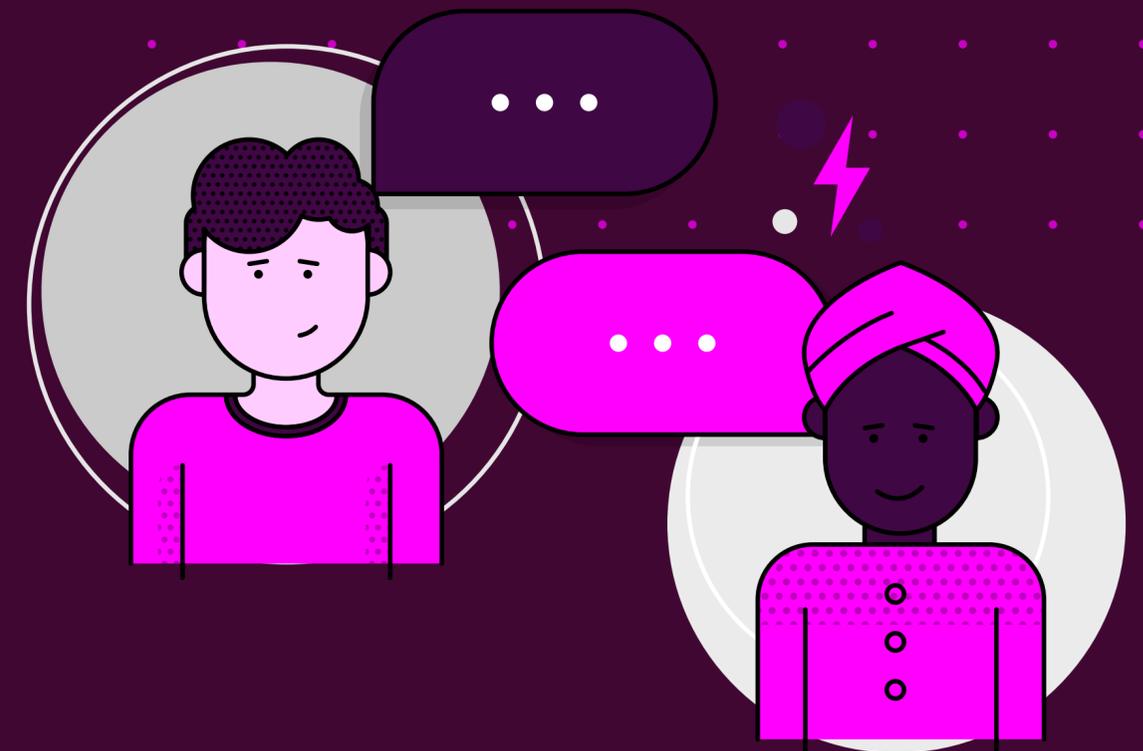
Examining operability under different 'System Conditions' provides a structured way to study how the system needs to operate under a range of plausible scenarios. Similar to the approach taken in last year's Operability Strategy Report (OSR), we have selected system conditions relevant to [Clean Power 2030](#) (CP30) and using updated FES 2025 data. Each illustrative condition represents a distinct set of potential 2030 operational characteristics and highlights the associated operability challenges that could arise as a result. Together they offer a framework for identifying the capabilities, market mechanisms, and operational practices required to maintain energy balancing and system management.

Each System Condition includes a graph showing generation broken down by type, net import/export flows and when storage or flexibility services are acting. Representations of two types of demand are also shown:

- a "net demand" which is the sum of all generation minus storage charging and net exports (i.e. a proxy for underlying GB demand).
- a "net transmission demand" which aims to show demand met at transmission level.

Note that these demands are indicative only.

This document is designed to supplement the [2026 Operability Strategy Report](#) and [Electricity Markets Roadmap](#).





1. A Typical Day

The System Conditions presented in this report focus on the operational circumstances we expect to encounter more frequently as the energy system decarbonises. These include:

- Requirements for reactive power, inertia, and short circuit level (SCL) are delivered through enduring stability and voltage markets. Grid forming inverters play an increasing role in maintaining system frequency and stability.
- Energy storage and other forms of flexibility absorb excess renewable output, minimise curtailment and help match supply and demand by shifting energy throughout the day.



2. Low Transmission Demand

Which typically arises during underlying demand minimums or periods of high embedded generation output, such as a sunny summer day.

- This condition can lead to elevated transmission voltages and reduced system inertia. High levels of distributed generation can also contribute to insufficient downward margin,¹ requiring more flexible resources which can increase demand or reduce supply when needed.
- Periods of persistently high renewable output may necessitate the curtailment of wind or solar via the Balancing Mechanism (BM) to manage network constraints, or to facilitate bringing on generation needed to provide inertia or voltage support.
- Improved forecasting of demand and weather dependent renewables at national and local level will be essential to ensure the right volumes and types of services are procured ahead of real time.
- Any increases in interconnector imports, driven by surplus renewable generation on the continent, can exacerbate operability issues in low transmission demand conditions.



3. High Transmission Demand

Which typically occurs when both underlying demand and transmission connected renewable generation are high, such as on cold, dark winter evenings.

- Dispatchable power remains critical in meeting demand during these periods. We expect unabated gas to continue playing a role up to and beyond 2030 but only where there is insufficient demand response, low carbon dispatchable power, and flexibility from storage and interconnectors.
- Over time, hydrogen to power, biofuels, and carbon capture and storage (CCS) equipped plants may reduce reliance on unabated gas, but the availability of these options will depend on the coordinated development of gas, hydrogen, and carbon transport and storage networks.
- Interconnector exports can exacerbate periods of high transmission demand as they increase the total amount of GB generation required and increase both system loading and constraint management requirements.

¹ 'Downward Margin' refers to the availability of active supply or demand that can be instructed, respectively, to reduce or increase output to maintain energy balance.



4. Supply and Demand Ramps

Which happen when supply and/or demand move rapidly and sometimes in opposite directions at the same time.

- These events are becoming more frequent as demand-side flexibility and storage respond to price changes.
- Our recently developed suite of response and reserve products, supported by stability markets, will need to continue evolving to maintain system frequency and inertia levels under increasingly dynamic operating scenarios.
- Enhanced forecasting, improved situational awareness and better visibility of distributed and flexible resources will strengthen preparedness for managing rapid ramps in supply and demand.



5. Outages

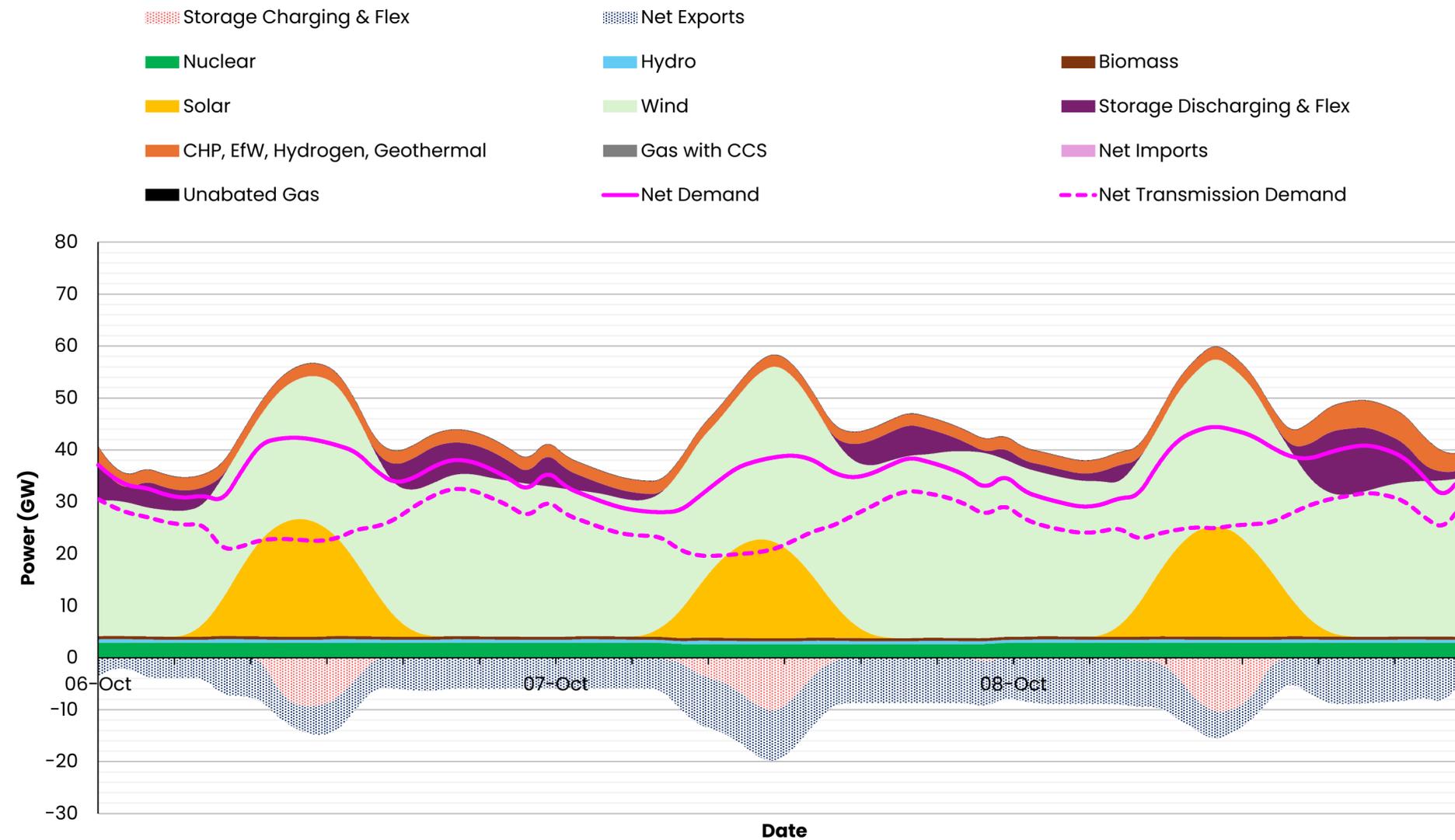
Which are when parts of the system are not available on a planned or unplanned basis, and can alter the operability landscape significantly.

- Outages cannot be avoided as they allow us to maintain existing assets, energise new assets and connect new generation and demand. However, they can also restrict power flows and reduce the system's ability to move power to where it is needed. Ensuring that sufficient generation and flexibility remains downstream of constraints is essential for keeping the system in balance.
- Outages affecting generation, storage, interconnectors, software systems or demand-side assets can impact the availability of resources needed to deliver frequency, voltage, stability, adequacy, restoration, and within day flexibility.
- NESO continues to work to reduce barriers to entry across our markets to ensure greater depth and diversity in service provision. By increasing the range of assets that can provide the services we need, system operation will be impacted less by outages affecting any single asset class.

Throughout this document, we use illustrative examples of System Conditions to explain how the GB electricity system may operate under different clean power scenarios, and to highlight the operability needs and capabilities required to maintain a secure and resilient system more generally. It is worth noting that the challenges present in the 'A Typical Day System Condition' are often also present in the other System Conditions but are not explicitly highlighted again. It is instead assumed that other challenges are in addition to these for the later conditions.

A Typical Day

Figure 1: Illustrative chart showing typical supply and demand in a clean power system before redispatch. GB load is met by clean power generators supported by storage.

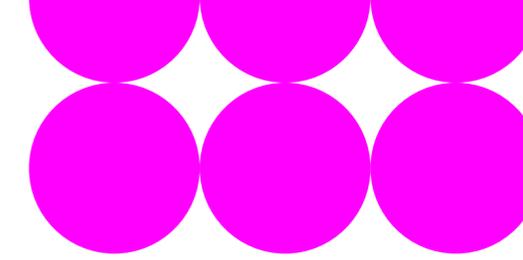


System Behaviour and Context

A typical day in 2030 is characterised by clean power generation meeting most of the national demand, with market dispatch drawing principally on wind and solar across daylight hours and nuclear providing a consistent baseload. Biomass, combined heat and power (CHP) and energy from waste (EfW) contribute steady output, while interconnectors, storage and demand side flexibility shape energy flows through the day.

While the Government's CP30 ambition allows some use of unabated gas across the year, on a typical day all operability needs should be met by low and zero-carbon sources (see Figure 1: A Typical Day).

In this System Condition, the shape of the demand reflects typical flexibility behaviours as demand increasingly flexes to meet supply but with greater intra-day variability. Demand may dip in the early morning as EVs that have charged at lower overnight prices switch off or reduce loading, before solar ramps and outpaces the morning rise in demand. When renewable output exceeds demand through the daytime period, the surplus is managed through a combination of interconnector exports, flexibility actions and charging of energy storage. As solar output falls later in the day and into the evening, storage and pumped hydro are dispatched and interconnectors swing to import to maintain balance, alongside the steady contribution from CHP and EfW.



Operability Challenges

Synchronous generation (such as gas or coal plant but also nuclear, hydro and pumped storage), where electrical and mechanical components are electrically coupled, has historically contributed reactive power (voltage) and stability services. In contrast, asynchronous assets (including onshore/offshore wind, solar and batteries) are electrically decoupled and require different approaches to ensure comparable system services.

Increased penetration of asynchronous generation is part of the underlying technical shift associated with a move to clean power and fundamentally changes stability and voltage characteristics. As synchronous plant provides a lower proportion of supply, the system loses the inherent stability that historically came as a by product of synchronous machines. This includes inertia, which resists rapid frequency change, and SCL, the fault current capability required for protection systems to detect and isolate faults quickly.

The minimum system inertia requirement is currently 120 GVAs but could be reduced to 102 GVAs ahead of 2030.² A reduced minimum inertia requirement is an enabler for clean power operation and reduces system balancing costs. While the risk of these events is low, operating with lower minimum inertia means that, for the same losses of large generation and demand units, the resulting frequency deviations are larger and harder to control. Alongside the reduction in minimum inertia, the system may have to manage a higher largest loss

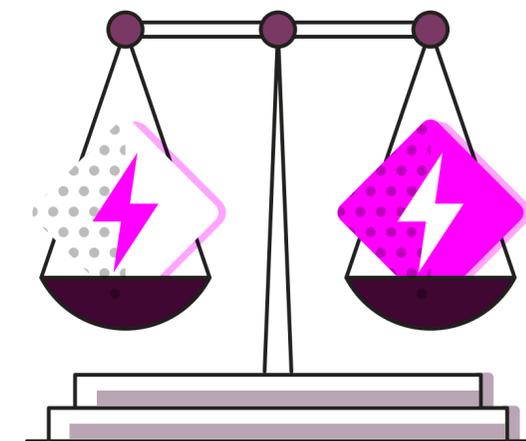
than today. 'Largest loss' is the measure of the largest plausible supply or demand unit on the system that could credibly trip or step-change output at any given time. This largest loss that has to be secured in real time is expected to increase as larger individual assets are allowed to connect to the transmission system (up to a maximum of 1800 MW), making the credible loss of a single unit more severe than historically assumed.

The net effect of the lower minimum inertia environment, a higher largest loss to cover, and increased likelihood of weather-driven deviations in net demand and renewable output impacts the required frequency services. Together they increase both the amount of response and reserve capacity needed as well as the focus on faster acting products (e.g. Dynamic Containment and Quick Reserve).

Voltage management also becomes more locational and dynamic. Daytime solar surpluses and low transmission power flows can lead to elevated voltages in certain regions – especially in areas with less synchronous plant. The balance between the absorption and injection of reactive power must be actively managed to keep voltages within operational limits at transmission nodes and across interfaces with distribution networks. Asynchronous technologies provide different levels of reactive power control and system strength. While this can meet some of our requirements, additional grid forming capability or synchronous condensers are likely to be required to maintain voltage and system stability to avoid relying on unabated gas.

Without the additional grid forming capability or synchronous condensers deployed at the right locations, the system can exhibit lower strength and reduced resilience to transients, increasing the risk of poor post fault recovery or control interaction issues for grid following converters. This is especially important on days where asynchronous generation comprises more than half of total output and replaces the synchronous contribution historically associated with unabated gas.

Although network build out is hoped to reduce the risk of large-scale thermal constraints, local outages (planned or unplanned) can still limit transfer capability and amplify voltage or stability issues on typical days, creating a scenario where redispatch or targeted service deployment is required to maintain secure operation. These outages are required to connect new generation, allow asset maintenance activities and energise new transmission equipment.



² Following the publication of NESO's most recent Frequency Risk and Control Report in August 2025, Ofgem launched a public consultation asking for more information on the proposed reduction of minimum system inertia requirement.

Approach to Operability

NESO manages operability using a blend of market sourced services and real time control measures designed for a clean power system. For stability, long term (Y 4) and mid term (Y 1) markets (formerly the Stability Pathfinders) are used to procure inertia and SCL to the target operating level around 102 GVAs (subject to Ofgem approval and annual review via the FRCR). Residual shortfalls, which may reach up to approximately 35 GVAs under certain operational scenarios, are addressed through additional shorter term system operator actions.

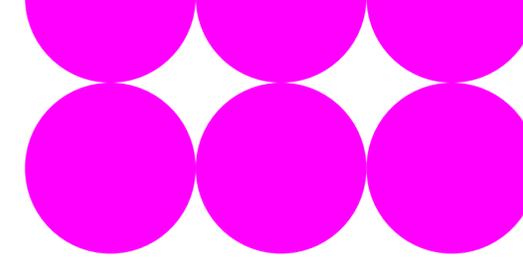
In parallel, we are working with industry on a Grid Code modification that would require newly connected Type D generation modules (≥ 50 MW and/or ≥ 110 kV) and high-voltage direct current (HVDC) systems to provide grid forming capability. This enables asynchronous resources to contribute to SCL and inertial response and reduces reliance on synchronous plant for stability support.

For voltage control, we also make use of transmission owner (TO) assets such as reactors and Static VAR Compensators (SVCs), as well as any assets secured through enduring reactive power markets. Where efficient, targeted network reconfiguration (substation running arrangements and circuit switching) is used to maintain voltages within limits. Reactive power markets enable more effective locational procurement of reactive capability, reducing the need for operational actions.

On the frequency side, the suite of fast acting response and reserve products are aligned to higher largest loss assumptions and a lower minimum inertia level. In line with the Government's CP30 ambition, participation in response products like Dynamic Containment (DC), Dynamic Moderation (DM) and Dynamic Regulation (DR) is overwhelmingly from zero carbon assets and this trend is continuing with the new Quick Reserve (QR) and Slow Reserve (SR). The evolution of frequency products is covered in more detail in the 'Supply and Demand Ramps System Condition', with additional detail in the Markets Roadmap and NESO's [reserve](#) and [response](#) services materials.

Within day flexibility remains pivotal to reduce curtailment and maintain balance with minimal redispatch. Storage absorbs surplus energy when renewable output is high and releases it when output is lower. Demand side flexibility, supported by dynamic time-of-use tariffs (TOUTs), helps to smooth net demand and reduces the need for interventions from the Electricity National Control Centre (ENCC).

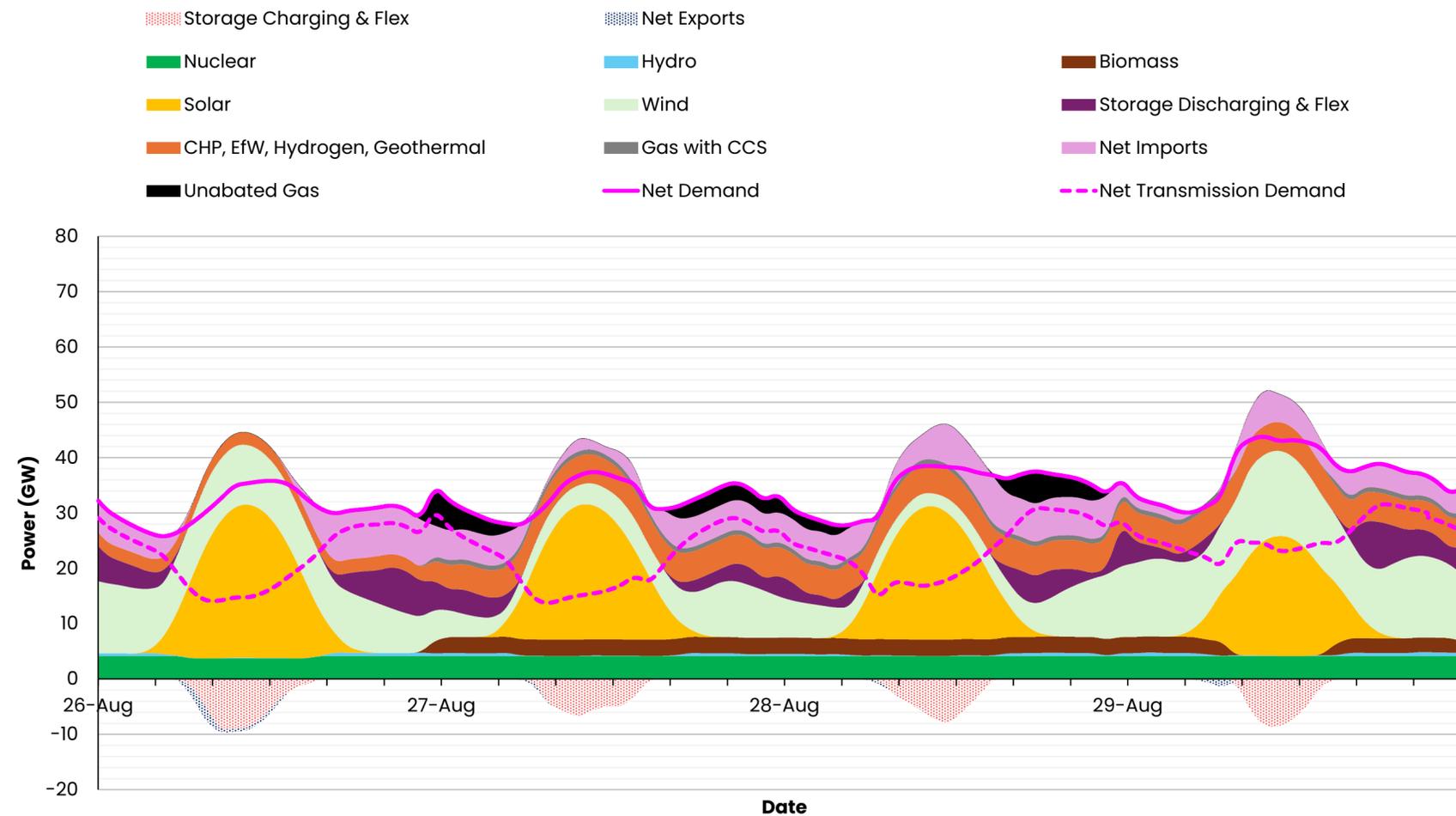




Low Transmission Demand

Summer Minimum

Figure 2: Illustrative chart showing supply and demand volumes during a Summer Minimum System Condition in 2030 before redispatch. The condition occurs due to significant supply from embedded generation (particularly solar). It is managed through storage charging and other forms of flexibility.



System Behaviour and Context

The Summer Minimum System Condition describes periods of extended low transmission demand and high renewable supply typically driven by distribution-connected solar PV and sometimes reinforced by high wind. This can create sustained periods where surplus energy must be managed. Low transmission demand can also occur at other times and many of the operability challenges described here in relation to summer minimum apply more generally across periods of low transmission demand.

Figure 2 illustrates the supply and demand volumes that could be expected during a summer period in 2030, with solar PV generation peaking from late morning to mid-afternoon and supplying most demand during that period. During the early morning, market dispatch primarily meets demand using generation such as nuclear and CHP, alongside wind and solar. This can result in a generation mix that provides limited operational margin. During the midday period, the market primarily addresses excess supply through energy storage charging and other flexibility (including on the demand side). As solar PV output reduces through the late afternoon and ceases to generate in the early evening, interconnectors begin to import and energy storage discharges to satisfy demand needs.

What makes operability in this condition particularly challenging is that, outside the periods of very low transmission demand, additional generation from dispatchable generation (including unabated gas) is required to meet evening and overnight demand.



Operability Challenges

Increased supply variation from weather dependent renewable generation increases the requirement for within day flexibility to maintain system balance. Accurate forecasting of generation output, as well as visibility of the available embedded assets such as batteries, is also key to ensure that we can access and use flexibility most effectively. When large volumes of variable generation are on the system, deviations from forecast output can translate into larger balancing requirements, increasing the response and reserve volumes needed to manage imbalance. In parallel, lower levels of synchronous generation mean reduced inherent inertia provision so the system is more sensitive to disturbances and requires sufficient low carbon resources that can participate in response and reserve services, alongside assets capable of providing inertia.

A further challenge is that we are presently unable to turn down the majority of distribution connected solar PV, because it is outside the BM so sufficient reserves must be available elsewhere to balance the system when required. Without adaptation, this System Condition can also drive lower system strength and an inertia shortfall, reducing resilience to faults. In such cases, even relatively minor disturbances can lead to significant voltage fluctuations, slow post fault recovery and potential generation trips. Grid-following asynchronous assets can be vulnerable to phase lock loop (PLL) instability in times of low system strength, and existing grid following generation relies on sufficient short circuit level support from the grid to operate normally.

Voltage challenges can become severe when high distributed solar PV output coincides with low underlying demand. Elevated levels of generation within the distribution network may lead to the transfer of both active and capacitive reactive power from the distribution network to the transmission network. Regions such as the South West of England are already particularly susceptible to reactive spill-over

due to high rates of solar PV penetration. Here, additional reactive power capabilities are needed to keep voltages within safe operating tolerances on both distribution and transmission networks.

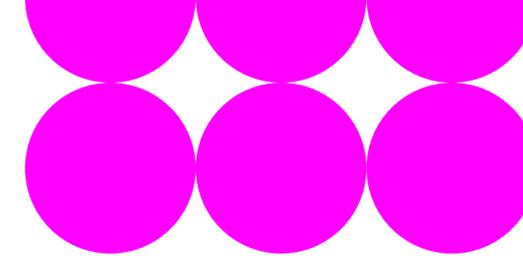
Approach to Operability

We manage this condition by combining market procured services with operational interventions where required. Contracted stability services and enduring markets can alleviate some challenges by securing inertia and system strength. This includes procuring grid forming technology via stability markets and supporting delivery of the proposed grid forming mandate, which increases system strength and helps mitigate PLL risk under periods of low system strength.

Reactive power capability is increasingly sourced in the locations where voltage risks arise through reactive power markets. Where market-based solutions are insufficient in real time, additional interventions may be needed, including redispatch through the BM to manage power flows, create headroom, or enable specific assets to run to deliver voltage control and stability.

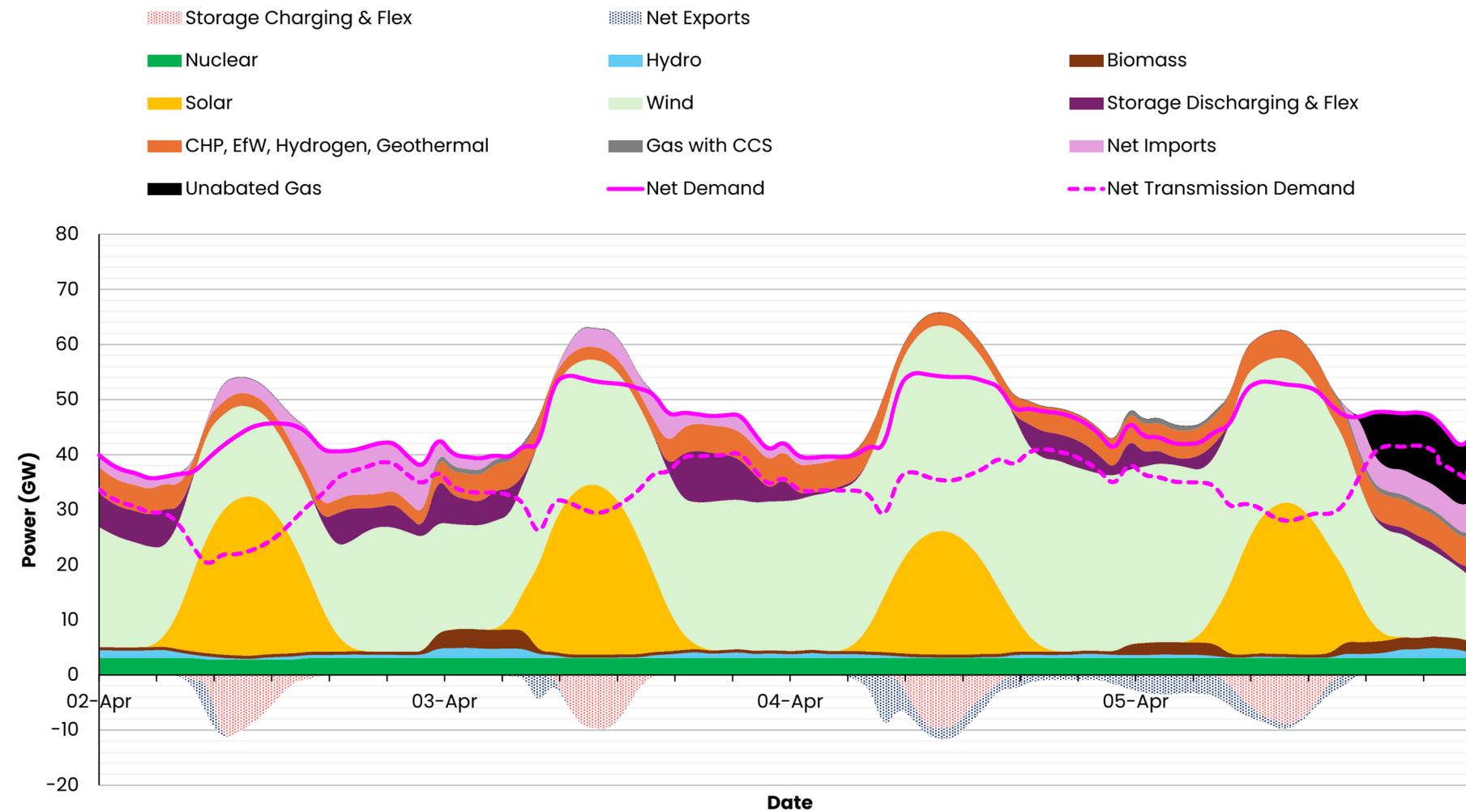
To manage high voltages, we are increasingly procuring reactive power capability, having concluded several network service tenders to provide additional reactive power capabilities across regions where the need is identified. Establishing enduring reactive power markets will enable more effective locational procurement of reactive power and help reduce voltage management actions via the BM.

We are developing tools and techniques to forecast reactive power requirements further into the future. This is with the intention that these improvements will be incorporated into the Centralised Strategic Network Plan (CSNP) to support better anticipation of locational reactive needs and more effective market procurement.



Insufficient Downward Margin

Figure 3: Illustrative chart showing supply and demand volumes during an Insufficient Downward Margin System Condition in 2030 before redispatch.



System Behaviour and Context

The 'Insufficient Downward Margin System Condition' describes periods when demand is principally met by generation – such as nuclear and distribution-connected renewables – that cannot always be turned down as easily as traditional sources. This limits how much supply can be quickly instructed to reduce output to maintain energy balance and frequency following a sudden loss of demand. In this System Condition, it is not possible to access sufficient downward margin from unabated gas and wind generation, so it needs to be found entirely from sources such as interconnectors, storage or demand turn up (which increases transmission system demand and provides the same balancing effect).

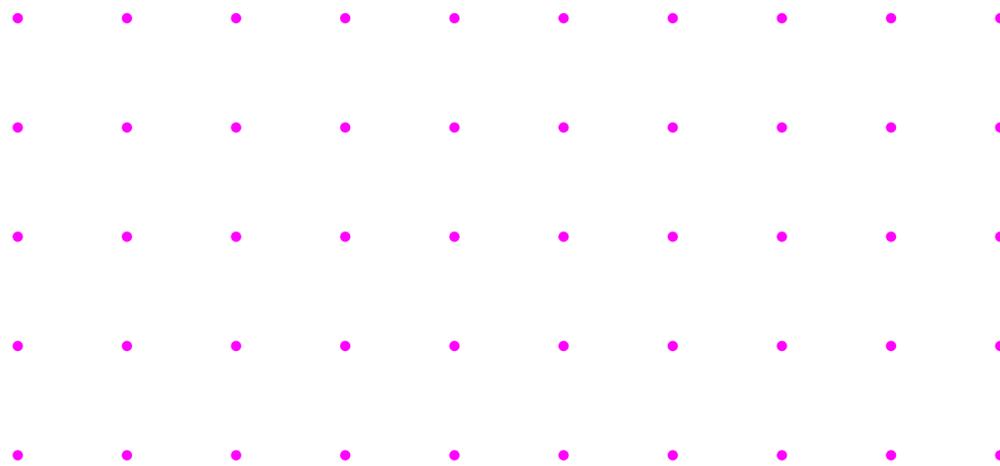
Figure 3 illustrates a representative sequence of days where market dispatch meets morning to evening demand using solar PV, wind, nuclear, CHP and EfW. During this period there are very low volumes of generation that traditionally provide downward margin. During the midday peak, biomass and flexible hydro output reduce while energy storage changes from discharging to charging and interconnectors switch from a net import to a net export position. All of this further reduces available downward margin and tightens the operational space for frequency management.



Operability Challenges

One challenge under insufficient downward margin is maintaining frequency when there is limited controllable turn down available on the supply side, particularly when demand is being met by firm generation and non-BM distribution connected assets. This reduces the footroom available to allow rapid response to forecast error, sudden demand changes, or unplanned events and increases reliance on non-traditional sources of downward flexibility.

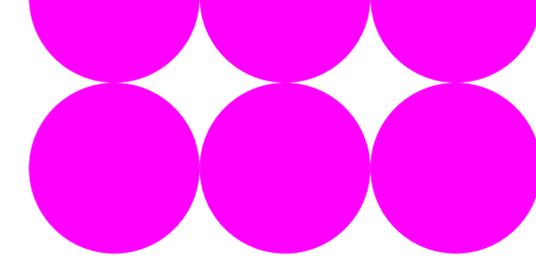
Prolonged periods of unfavourable weather across Europe can lead to times with no interconnector trading, which is most likely during sunny summer weeks when interconnected countries are also experiencing an excess of solar PV supply. In these circumstances, insufficient downward margin becomes more acute and requires greater GB downward margin capability from within day flexibility such as energy storage and variable demand.



Approach to Operability

We manage low downward margin by procuring negative reserve through QR, SR and Balancing Reserve (BR) auctions. Accurate forecasting of supply and demand is essential for procuring the right volume of reserves and ensuring that appropriate services are available ahead of real time. Currently, when additional downward margin is required, we can replace an inflexible unit with one that carries greater reserve capability. For example, this might involve replacing a 500 MW unit that has a Stable Export Limit (SEL) of 400 MW with a 500 MW unit that has a SEL of 200 MW. This retains the energy balance but increases negative reserve by 200 MW.

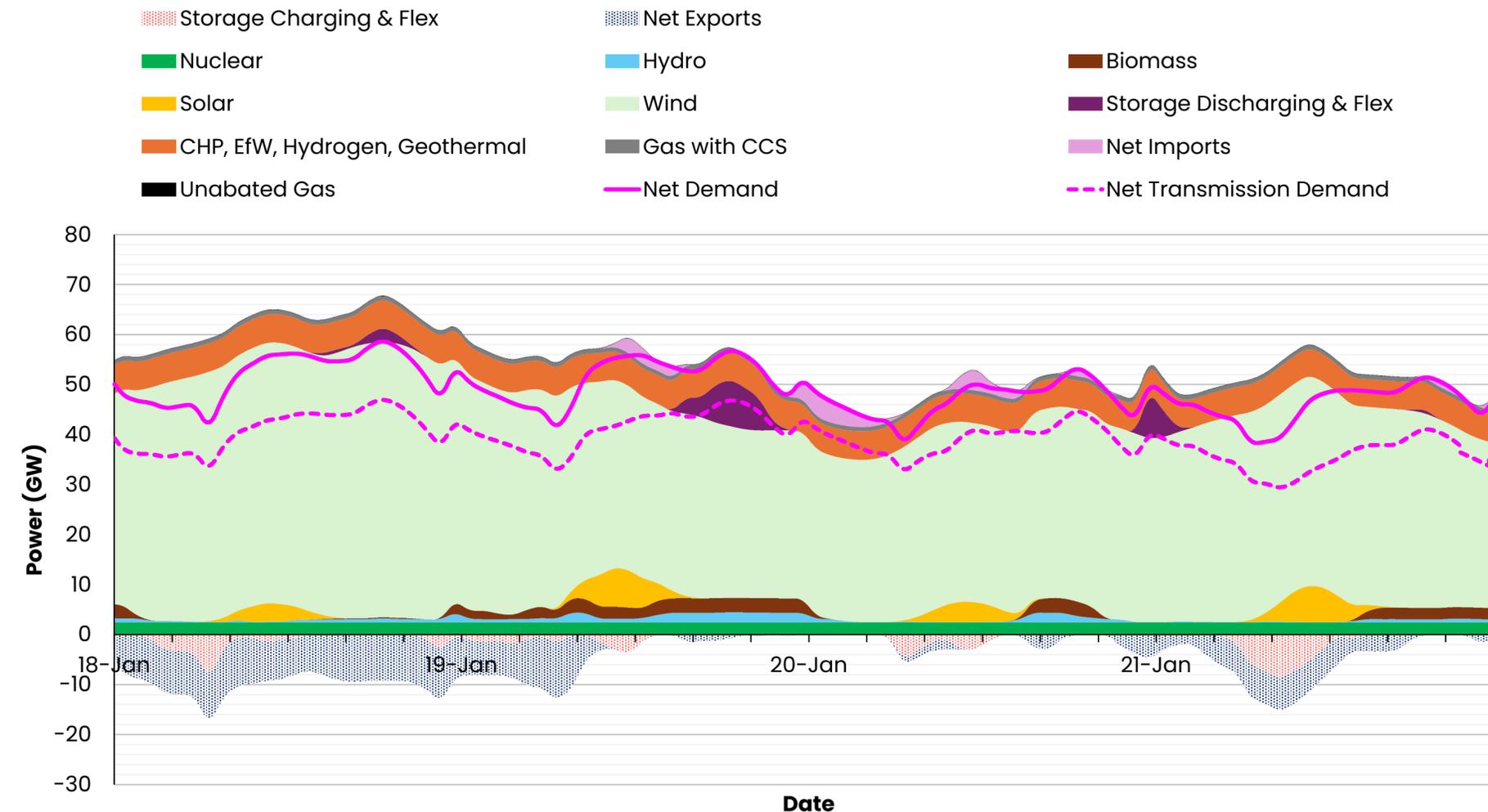
In scenarios where generation turn-down is unavailable - owing to the technical parameters of machines, or a reduced reliance on gas-fired generation - an equivalent increase in downward flexibility can be achieved by raising transmission-connected demand. This can be done by utilising flexible demand or by increasing interconnector exports, both of which help create additional "footroom" on the system. Interconnectors and energy storage can be used throughout the day to support frequency management, particularly during periods of sustained solar output, and the Emergency Assistance service enables NESO and international counterparts to increase or decrease interconnector flows in near real time, within 15 minutes. This provides an additional operational tool for managing the Insufficient Downward Margin System Condition when market trading alone is insufficient.



High Transmission Demand

Constrained Clean Power During High Transmission Demand

Figure 4: Illustrative chart showing supply and demand volumes during the Constrained Clean Power System Condition in 2030 before redispatch. This occurs during periods when renewable output, especially wind, is particularly high.



System Behaviour and Context

The Constrained Clean Power System Condition describes how, even on the highest demand days, periods of excess renewable output can arise. This can coincide with high renewable output in Europe, which can reduce the ability to export surplus energy across interconnectors and increases the likelihood that the system must be balanced using resources within the GB electricity system. In these circumstances, we need to take balancing actions to reduce generation or increase transmission demand while keeping the system within operational limits.

These periods are particularly sensitive to the configuration and utilisation of the transmission network. Higher transfers from generation-rich areas at the edge of the network into centres of demand change power flows and can mean that more of the transmission system is operating close to its limits. Clean power sources can provide reactive power and other services, but requirements are locational. The available resources are connected in different locations to the synchronous plant that historically provided voltage support and system strength. This makes the interaction between energy dispatch, network limits and service procurement more pronounced in this condition than on an unconstrained high demand day.

The build out of transmission is central to ensuring we can meet our operability requirements. Without sufficient capacity, network constraints can limit the volume of low carbon generation that can be dispatched onto the transmission system, driving higher constraint costs and increasing the likelihood of redispatch of unabated gas generation for energy and operability requirements. This risk is particularly important for offshore renewable generation in Scotland, the North and on the East Coast, where thermal limits would otherwise constrain output. NESO's [CP30 Advice to Government](#) recommended 80 network investment projects that must be delivered to avoid such network constraints and enable clean power by 2030.

Figure 4 illustrates a period of high transmission demand over several days. Transmission demand remains elevated for most of the period, with peaks where additional flexibility use becomes more visible. Wind provides the majority of supply throughout, supported by a steady nuclear baseline. Solar contributes during daylight hours but remains relatively small because high demand days tend to occur in winter, when solar output is lower. During the highest-demand peaks, the chart shows an increased contribution from storage charging and other flexible demand actions.

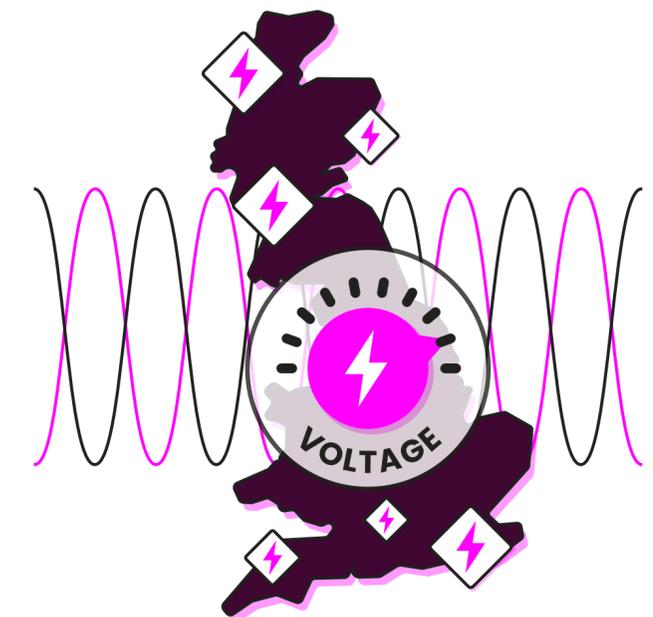
Operability Challenges

Under this System Condition, voltage management becomes more complex as increased transmission flows can change voltage levels and alter where reactive support is needed. In these periods, additional reactive power capability is required to maintain voltages within limits. That capability must increasingly come from clean power sources such as energy storage and synchronous condensers, which can dispatch reactive power independent of real power provision.

The network may be at, or close to, its limits, during this System Condition, which constrains where operability services can be physically delivered. This can affect both energy balancing and the effectiveness of frequency and stability actions, meaning it may be necessary to procure frequency support in the centre of the network and away from constrained interfaces. For example, this is sometimes important where intertrips are used to dispatch more power through existing assets, because procuring frequency services behind these constraints can create operational issues in some extreme circumstances.

This System Condition also increases the interdependence between energy generation and demand, thermal management, voltage management and stability. As these dependencies strengthen, real time operation becomes more complex and requires stronger coordination between operational planning and ENCC actions. An example of increased complexity can be found in a system with greater numbers of HVDC assets as the number of possible flow

permutations increases with each one. Without improved operational tools, it becomes harder to forecast demand and model potential system behaviour under the Constrained Clean Power System Condition. It is also important to ensure there is sufficient flexible demand, generation and storage available to manage demand forecast error and unforeseen changes in system balance, including events driven by trips, intertrips or extreme scenarios such as failures of control software.



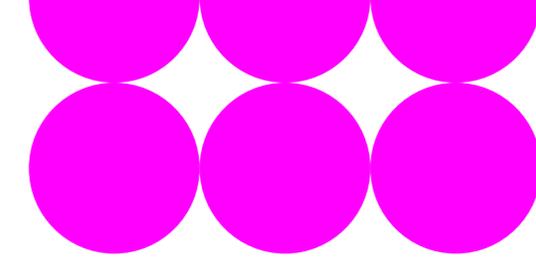
Approach to Operability

The Constrained Clean Power System Condition can be managed through coordinated balancing actions that reduce generation or increase transmission demand when low carbon supply exceeds demand and export capability is limited.

Voltage and stability requirements will increasingly need to be met from clean power sources to achieve the Government's CP30 ambition, including the procurement of reactive power capability from energy storage and synchronous condensers, and the procurement of inertia, frequency response and reserve from a variety of low carbon sources. Because requirements are locational, the operational approach must align wherein the network services are procured with the specific network need in mind, particularly in periods where flows are high and parts of the system are close to their limits.

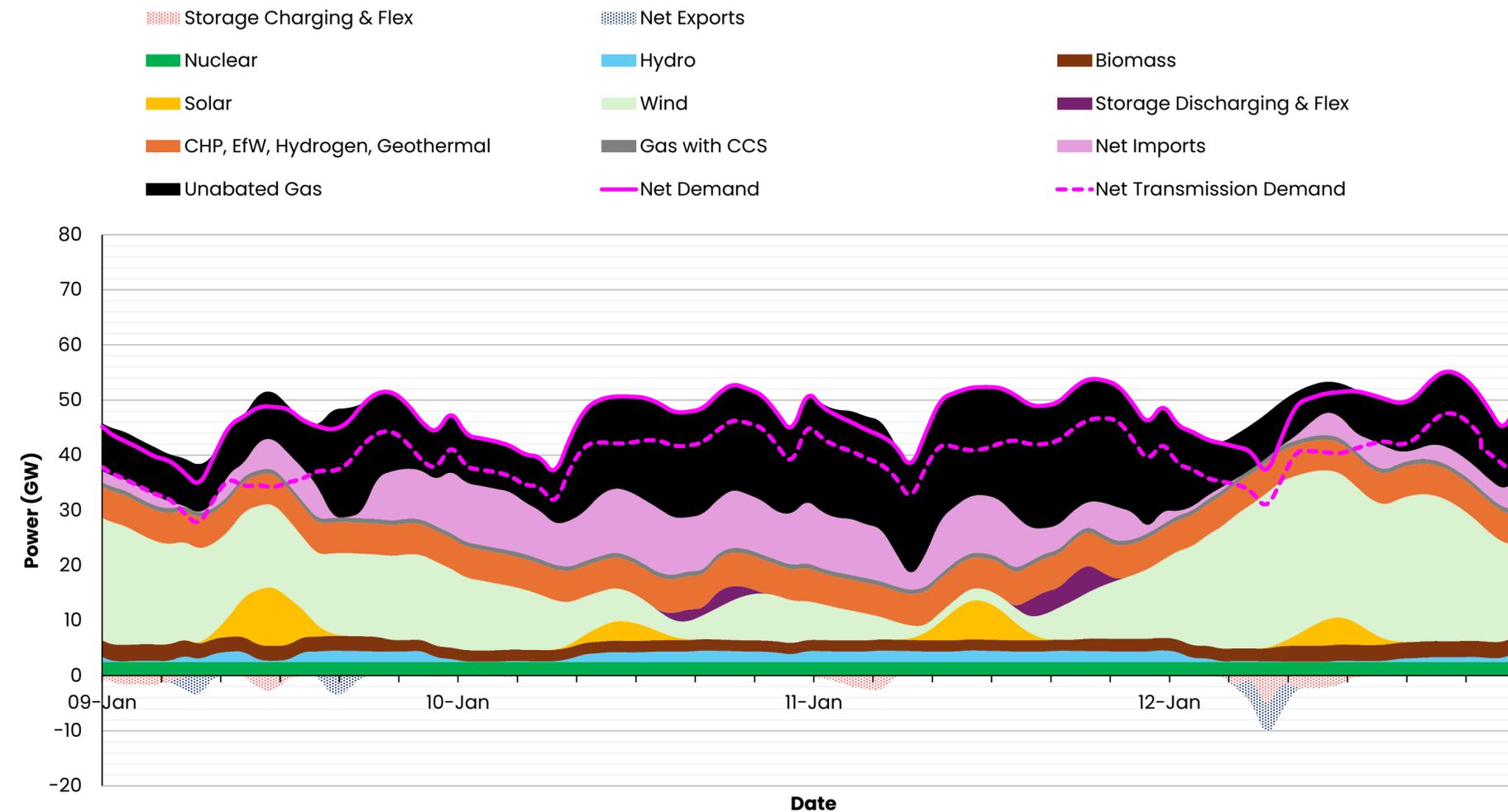
We will also employ greater ENCC innovation and stronger short and long-term operability planning to identify constraints before they become critical. This includes improving the ability to forecast weather-based supply, flexible demand and system behaviour and ensuring sufficient levels of reserve and response are available to respond to forecast error and sudden events. By ensuring a level playing field for assets, the use of new technology, including grid forming assets, supports provision of frequency and inertia services and should reduce the cost of maintaining operability through more efficient use of assets.





Clean Power Shortfall

Figure 5: Illustrative chart showing supply and demand volumes during a period of Clean Power Shortfall System Condition in 2030 before redispatch. This occurs when clean power output and storage is insufficient to meet demand.

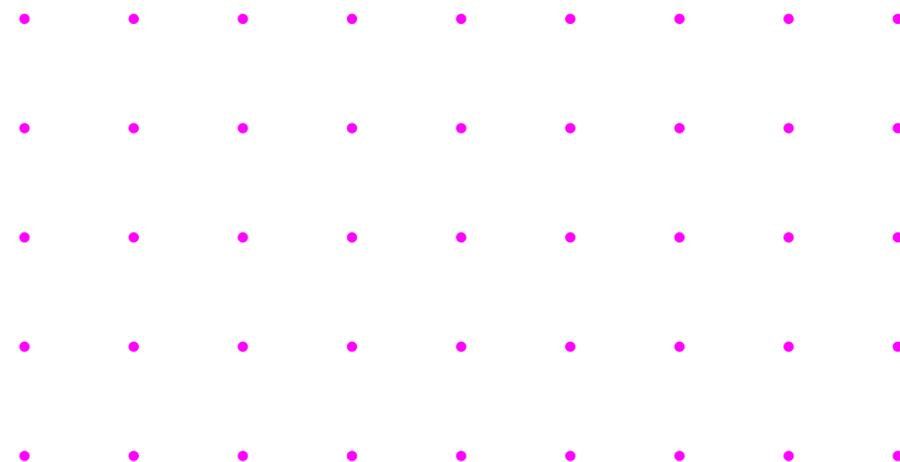


System Behaviour and Context

Clean power shortfalls are when the electricity demand on the GB electricity system cannot be met by clean power generation sources and can occur at any time during the year. This System Condition refers to times when both demand is high and clean power output is low, such as, during cold, dark evenings in autumn and winter that coincide with weather patterns that suppress renewable output across Northern Europe. These periods may be associated with dense cloud and low wind and are sometimes characterised as ‘Dunkelflaute’ or ‘anticyclonic gloom’. In this condition, the market dispatches a wider range of technologies including potentially unabated gas to meet demand across the days as shown in Figure 5. As thermal plant is usually located at places of need, there is likely to be sufficient network capability to transport power between zones, so no redispatch is needed for thermal constraints.

The ‘Clean Power Shortfall System Condition’ is not expected to occur frequently. However, in future sustained low output of renewable generation could cause operability difficulties even in lower demand periods (i.e. not just at periods of peak demand).

Figure 5 illustrates a period of high transmission demand with a clean power shortfall. Transmission demand remains relatively high and follows a day–night pattern, with daily peaks and overnight dips. Supply is met by a combination of wind, imports and dispatchable generation, supported by a steady nuclear baseline throughout. Solar contributes smaller daytime peaks, consistent with shorter daylight hours at this time of year. A persistent contribution from imports is visible across the period, helping to meet demand during both daytime and evening hours. During high demand periods, the chart shows increased contribution from dispatchable generation, including unabated gas, alongside contributions from biomass, hydro/ tidal, and relatively steady CHP and EfW output.



Operability Challenges

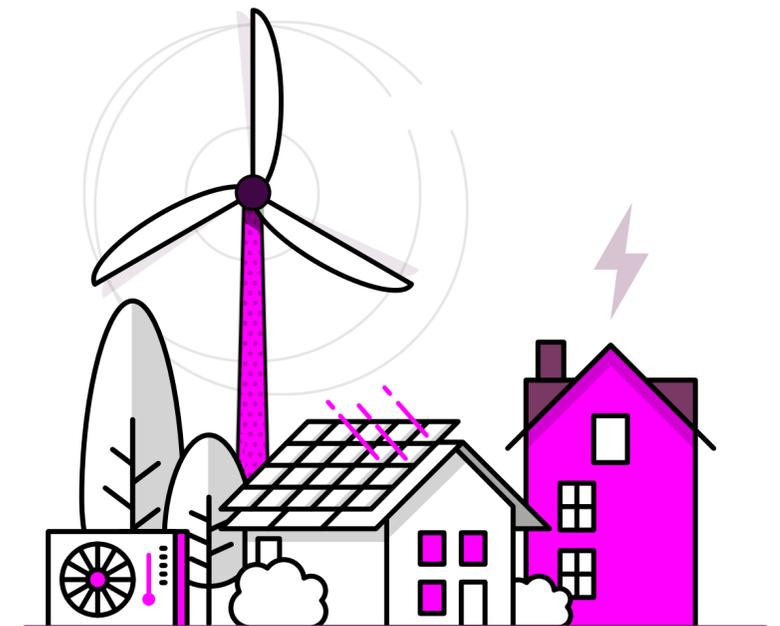
A shortfall of weather dependent low carbon supply tightens the operational margin available to manage forecast error and intraday variability. The system must secure sufficient dispatchable and flexible capability to cover the residual gap between demand and available clean generation, while maintaining operability across frequency, voltage and stability. For short periods, this can be managed with technologies like battery storage and load shifting. However, when low wind and limited solar output persist, the system becomes more reliant on dispatchable low carbon sources, longer duration flexibility, and unabated gas, increasing the importance of ensuring that the right technologies are available, deliverable and responsive.

This System Condition requires greater emphasis on the interaction between demand behaviour and system flexibility as adequacy is the key operability element. Peak demand levels depend on electrification trends and the degree to which consumers and assets can shift or reduce consumption in response to price and system signals. As electrification accelerates beyond 2030, demand peaks may become larger or sharper, increasing the need for flexible demand and sufficient dispatchable capability during renewable shortfall periods.

The use of unabated gas plant is changing, and it is important to be confident that both the gas network and gas power

stations can manage their changing operational profile in an affordable and reliable manner. This includes being able to generate at their maximum capacity following long periods of inactivity. NESO’s Clean Power 2030 Advice to Government explored upstream gas network implications, including modelling under stress events such as compressor loss. It indicated that, under similar asset availability assumptions to today, the gas network is expected to remain within safe operational limits despite changing demands.

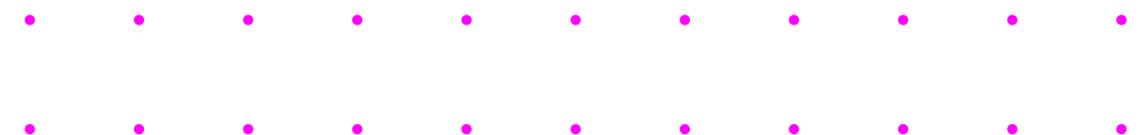
Increased dispatch of low carbon dispatchable generation, and unabated gas, supports operability requirements like voltage and stability due to their synchronous nature.

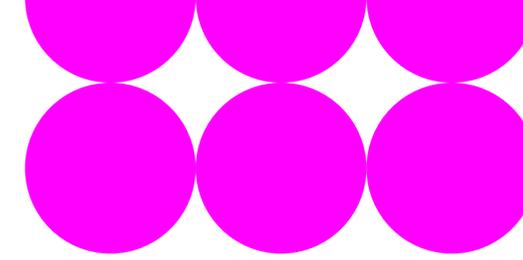


Approach to Operability

In a Clean Power Shortfall and High Transmission Demand System Condition, we would expect the system to be operating with nuclear as the reliable low carbon baseload, and to be dispatching hydro, storage and biomass more heavily during the evening hours to support the peak. We would also expect to use demand side flexibility to reduce this peak demand where consumers and assets respond to high price signals. Interconnectors will also typically respond to price signals, helping ensure that power flows to the market with the greatest need. However, they can be traded using operational tools if required by NESO. Where available and cost effective, low carbon dispatchable options such as hydrogen to power can contribute to reducing the residual shortfall where they are proven to deliver consumer value. Where clean power options are unable to make up the remaining gap, unabated gas may be dispatched to fulfil system requirements, which is consistent with the Government's CP30 Action Plan which allows for some gas dispatch in 2030 for adequacy reasons.

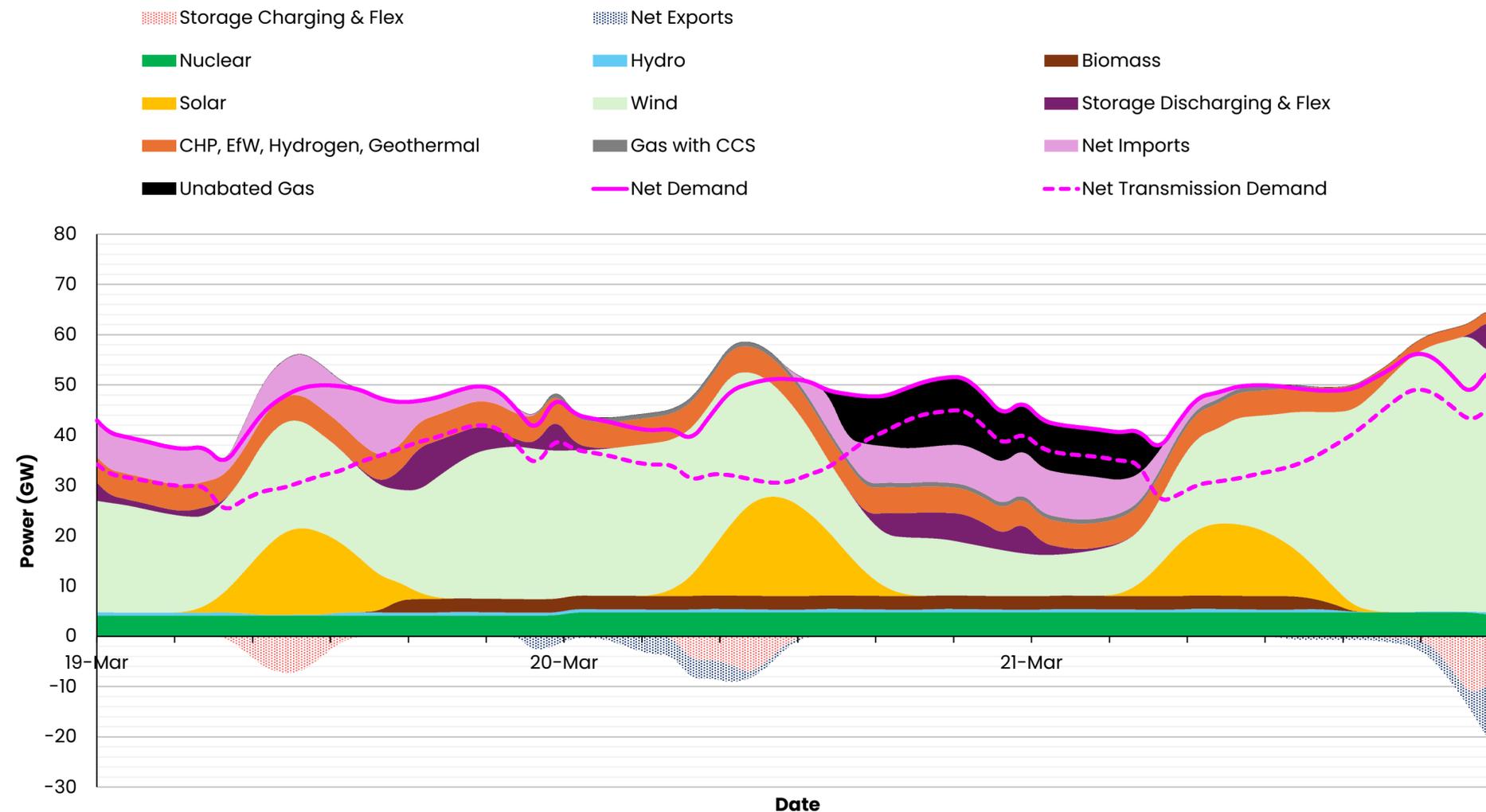
Operationally, these periods place a premium on enhanced forecasting and situational awareness so that we can anticipate reducing operational headroom, manage demand forecast error and respond to unforeseen changes in system balance. Improved visibility of distributed assets and demand behaviour supports better operational demand forecasting and enables more efficient interventions when margins are limited, helping reduce consumer costs.





Supply and Demand Ramps

Figure 6: Illustrative chart showing a Supply and Demand Ramping System Condition in 2030 before redispatch. A sharp downfall in clean power generation is shown on 20 March, with a sharp increase in clean power generation on 21 March.



System Behaviour and Context

The Supply and Demand Ramps System Condition describes periods where generation and demand change rapidly (and sometimes in opposite directions), creating swings in energy balance and transmission system flows. Secure operation requires generation and demand to remain closely matched. This keeps frequency within acceptable limits and protects against loss of supply or infrastructure damage. Sudden changes in power flows are expected to occur more regularly as the electricity system transitions to high volumes of variable renewable generation on the supply side, smarter, more responsive consumers on the demand side (for example from EV charging, batteries and heat storage) and fast-ramping bidirectional assets like storage and interconnectors. In this condition, ramps can materialise within minutes or seconds and may require rapid interventions, particularly where changes in demand or generation are faster than the system can be balanced through self-dispatch and market actions.

Supply and demand ramps occur for a range of reasons such as when weather dependent generation changes significantly and/or while demand moves in the opposite direction. They can also occur when flexible assets respond simultaneously to price signals and shift their net output.

Figure 6 provides an example of how these ramping behaviours can materialise over the course of a day. Solar PV output increases with the rising sun and will often, but not always, coincide with increasing demand at the beginning of the day. Wind provides clean power supply alongside solar generation, with interconnectors contributing additional transmission supply. As solar generation decreases later in the day, it often does so at the same time as consumer demand rises. Although storage and imports via interconnectors can be dispatched, the scale and timing of these responses may vary, and they may be insufficient to meet demand without additional flexible support. In this case, unabated gas may be used to cover any remaining overnight shortfall where clean power options are insufficient.

Figure 6 also illustrates how fast ramping behaviour can occur when wind output changes significantly over a short period. A rapid increase in wind generation can displace other generation, while interconnectors cease importing and storage assets stop discharging. As wind supply exceeds forecast demand, storage moves from discharging to charging, absorbing surplus energy and helping rebalance the system. Flexible demand can respond to the resulting price signals, which can work to address ramps or exacerbate them and this needs to be managed carefully to ensure that the system remains operable.

Operability Challenges

The principal operability challenge under this condition is maintaining frequency and system balance. Imbalances can increase the likelihood and severity of frequency deviations. This risk is amplified when multiple asset classes respond in the same direction to common drivers, such as weather or market price signals, and when changes occur at settlement boundaries or on short timescales that reduce the window for corrective action.

Weather-dependent ramps can also be driven by unified behaviour from subsidised generation. During periods of consecutive negative wholesale prices, generation with Contracts for Difference (CfD) may shut down or reduce output on settlement period boundaries due to negative pricing rules, which can cause large changes in supply over short periods. Ramps in transmission demand can also be experienced in summer evenings when high volumes of distribution-connected solar PV, whose output has suppressed transmission demand during the day, powers down at the same time as underlying demand starts to pick up. This is particularly challenging where we have limited visibility of distribution connected assets.

Price-dependent ramps introduce an additional challenge, because multiple bidirectional assets exposed to price volatility may move quickly and coherently as price signals change. Similar behaviour exists today for interconnectors that respond dynamically to prices in GB and overseas on a half-hourly basis. The effect becomes more pronounced as interconnection volumes increase and storage and flexible demand participation grows. This can drive rapid swings in net demand and supply that require sufficient response and reserve capability and may require additional balancing actions where changes occur within minutes.



Approach to Operability

NESO's primary tools for managing near real time imbalances under this condition are frequency response and reserve services. These services are fast-acting and are available to the ENCC to rectify energy imbalances and maintain system frequency. Improved forecasting allows more imbalance to be resolved ahead of real time. Response and reserve then act closer to real time to manage residual imbalance and maintain system integrity following disturbances. We regularly review response and reserve requirements to ensure they remain aligned to system needs as renewable penetration and flexibility behaviours evolve.

Where changes in demand occur within minutes and seconds, access to fast-acting services in the ENCC is vital. This includes the use of fast-ramping units and services such as QR. We also rely on enhanced market forecasting and situational awareness, including visibility of expected and real time system flows, to understand the size and location of imbalances and to select appropriate actions to rebalance the system particularly during periods of rapid and sustained ramping.



Constrained system due to asset outages

System Behaviour and Context

The Constrained system due to asset outages System Condition describes how planned and unplanned outages across the electricity system and the wider energy system can materially change operability. Outages can affect network assets, generation and storage assets, interconnectors, the gas system, third party control systems and large demand connections. The impact of outages differs across the different System Conditions because of the impact on availability of assets and the ability to transfer power around the network. Planning and coordinating outages will become more complex in future due to the increasing number of affected parties. It will also become more challenging due to the growing need for outages for new connections, strategic reinforcements and maintenance. Figure 7 provides an illustrative view of GB system availability by month from 2022/23 to 2024/25. It shows a marked reduction across all months of the year since 2022, and we expect this trend to continue as network access requests increase due to network reinforcements and connections required for CP30 on top of routine asset maintenance.

Preparing for outages across the energy system is critical to ensure resilience. Planned outages are necessary to maintain and enhance the electricity system during infrastructure upgrades or commissioning. We work with industry to avoid planned outages during times of greatest system stress where possible, including periods of high winter demand. However, winter outages are becoming increasingly common and careful planning of summer outages is now needed due to the low demand System Conditions outlined in this document. Unplanned outages can occur at any time, so operational arrangements must maintain sufficient resilience to manage system stability and frequency during such events.

Operability Challenges

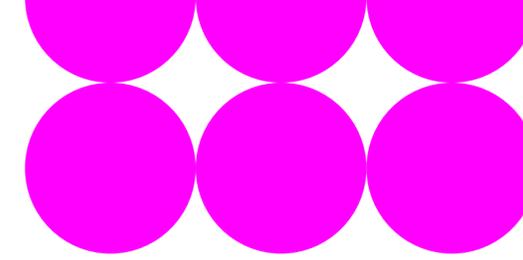
Outages can lead to thermal operability challenges by reducing transfer capability across system boundaries. This can have compounding effects, where reduced transfer capability on one boundary limits generation and power flows across other boundaries. When network capability is reduced, it becomes harder to move power to where it is needed and balancing actions are more likely to be needed within a smaller operational envelope.

Voltage operability can also become more challenging because outages change power flows and impedances on the system. Outages of both network infrastructure and generation and storage assets change how voltage requirements are managed. Voltage control is inherently locational, so the siting and availability of assets capable of voltage control become more important when network configuration changes or outages remove capability.

Outages can also reduce the availability of within day flexibility due to related impacts to associated generation and storage assets. They can also constrain how much and where stability and frequency service provision can be procured. Faults can cause instability in the system and lead to generation trips, which increases the need to manage frequency and stability securely when the network is constrained.

Prolonged network outages can create adequacy and energy balancing risks if they prevent major generation plant from meeting demand for long durations. Planned outages typically account for adequacy needs - for example, they take place at the same time as relevant generation outages. This issue mainly arises during unplanned outages that constrain generation needed at times of high demand, especially if they coincide with a related planned outage.





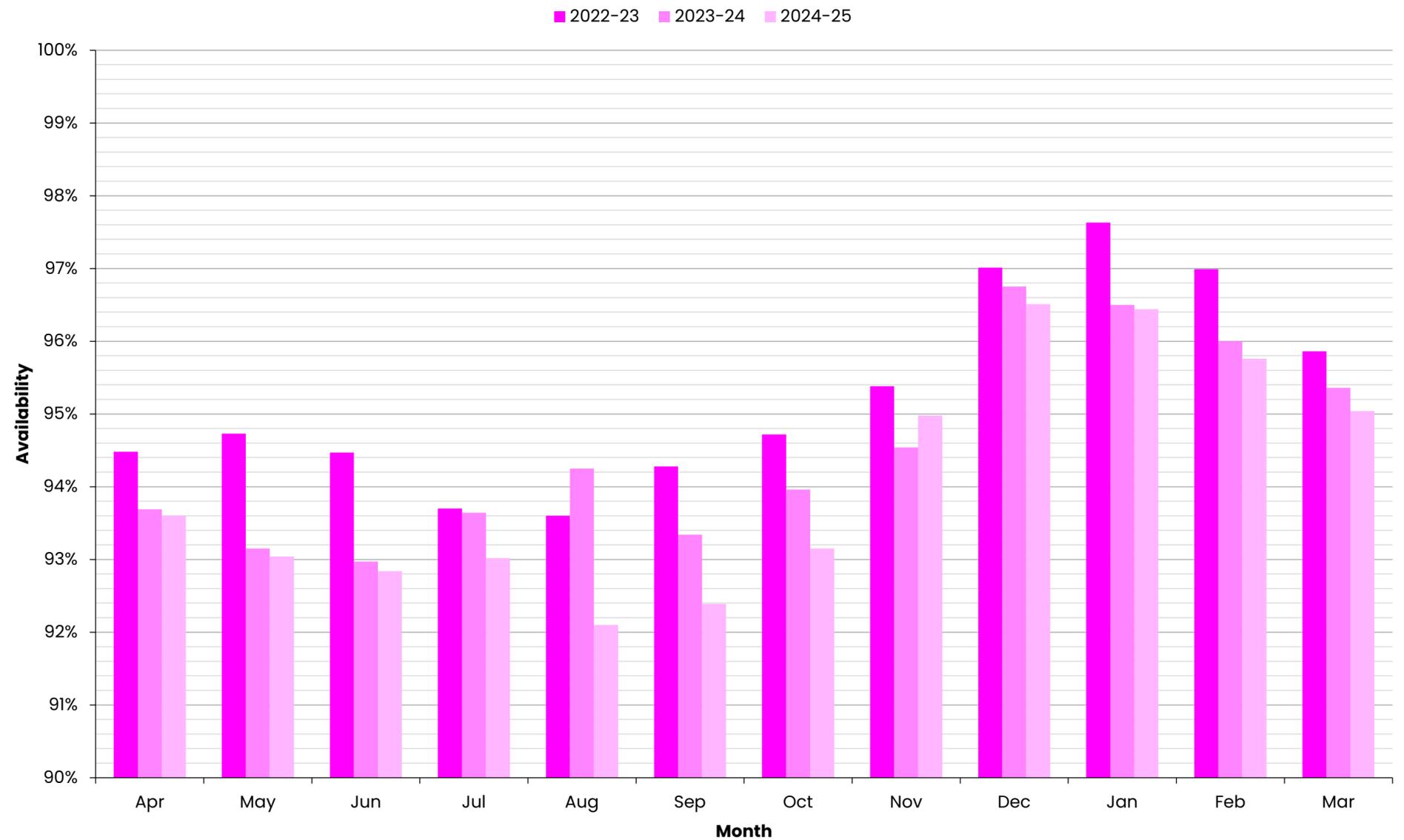
Approach to Operability

We manage outage risk through a combination of forward planning, operational coordination and contingency arrangements. As outlined above, NESO works with industry to coordinate planned outage schedules and avoid periods of greatest system stress where possible.

For unplanned outages, we maintain resilience through operational planning and by holding sufficient margin to cover sudden loss of assets and reduced network capability. We also seek to maintain access to generation, storage and flexible demand downstream of outage related constraints so the system can continue to balance supply and demand when the network is operating with reduced transfer capability.

Operationally, thermal impacts have historically been managed through redispatch of unabated gas and by seeking to increase transfer capability using rating enhancements requested from TOs and the use of intertrips. As the system evolves, effective outage management increasingly depends on having a wider range of dispatchable and non-dispatchable resources. It also relies on sufficient market depth across technologies, so that operability requirements can still be met when some assets are unavailable. To meet the Government’s CP30 ambition, most of the thermal challenges introduced by outages will need to be managed using clean power, but there is a small allowance for unabated gas generation to be used when required.

Figure 7: GB network asset availability by month from 2022/23 to 2024/25



Enablers and Developments

The System Conditions outlined in this report can be managed using current and planned operational tools, but delivering clean power by 2030 requires additional capability and flexibility. Several critical enablers must therefore be delivered. This chapter brings together those developments and the actions that NESO and industry are taking to support secure clean power operation.

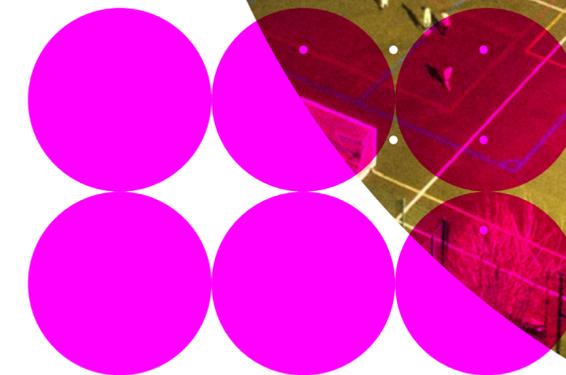
Delivering network capability

Thermal constraints can limit the range of operability actions available to system operators. Network capability therefore is a foundational enabler across all the System Conditions, because it allows both power and operability services to be effectively delivered from source to places of need. Delivery of Transmission Owner (TO) reinforcements, including the 80 priority strategic projects identified in our [CP30 Advice to Government](#), will reduce curtailment and keep redispatch low in more routine operating circumstances. These projects are essential for meeting the Government's CP30 target, as they will reduce the need to run unabated gas generation to meet our thermal operability requirements. These network reinforcements will also reduce the likelihood that network constraints dominate outcomes and drive up costs in both the Constrained Clean Power and Asset Outage System Conditions.

We continue to provide evidence-based advice to Government on multiple factors including networks, and we recognise that if critical network projects are not delivered on time, redispatch and balancing costs will be higher than they would otherwise be. We are supporting the Government by tracking the delivery of all CP30 network reinforcements so that barriers to delivery can be identified early and addressed. We will also use forward looking operability analysis to shape future network upgrades and the evolution of stability and voltage solutions, enabling prolonged operation without unabated gas.

In the High Transmission Demand System conditions, extra network capability reduces the risk that network limits force clean generation to be turned down. It also makes it easier to deliver operability services in the areas of the network that need it most. Generation oversupply, which typically occurs in Summer Minimum, Overnight Minimum and Constrained Clean Power System Conditions, highlights the value of within day flexibility for reducing curtailment and managing constrained periods. For example, longer duration storage can absorb surplus energy when the system is constrained and support the system during periods of Clean Power Shortfall.

Delivery of strategic network reinforcements, as well as asset maintenance and generator connections, requires increased levels of system access. Many more outages are expected to be required in and around 2030 and the [System Access Reform programme](#) includes a holistic, rolling six-year system access plan designed to improve outage optimisation to allow increased network access to take place while maintaining system resilience. The associated ambition to accommodate greater than 80% of all planned outages is an important enabler of future system operation – especially in relation to thermal constraints which are exacerbated by network outages.



Strategic energy planning

Our strategic energy planning underpins all System Conditions by ensuring network development and asset connections are coordinated with service requirements, while also mitigating the risk that new capacity connects faster than the operability capability required to run it securely. A strong integration of operability and energy considerations is critical within our strategic planning activities, so that decisions on the location of dispatchable generation, non-dispatchable generation, storage, demand, and network investment reflect both energy and operability needs together.

As our operability requirements become more locational, strategic planning becomes an increasingly important enabler. We are producing an overarching strategic energy plan for Great Britain that looks beyond 2030, setting out the energy infrastructure that is needed, and broadly where and when it should be delivered, to ensure secure, affordable sustainable supplies of energy. It will be made up of three constituent parts: the Strategic Spatial Energy Plan (SSEP), the Centralised Strategic Network Plan (CSNP), and the Regional Energy Strategic Plans (RESPs).

These components will be developed as distinct but interconnected parts of one coherent plan and will each operate on a three-year cycle. Each plan will contribute a unique perspective: the SSEP for electricity and hydrogen generation and storage infrastructure, the CSNP for GB wide transmission networks, and the RESPs for more localised distribution-level planning. As part of this framework, the CSNP will identify future stability and voltage needs across the

transmission network and determine whether they are most efficiently met through network investment or through enduring markets. Our Transitional Centralised Strategic Network Plan (tSCSNP) is already shaping near-term decisions, including those in relation to CP30.

We are also developing tools and techniques to forecast reactive power requirements further into the future, with the intention that these improvements will be incorporated into the CSNP to support better anticipation of locational reactive needs and more effective procurement.

Connections Reform is supporting the timely delivery of both energy and network service assets by reordering the queue, prioritising delivery-ready projects, and freeing connection bays for service-providing technologies. This will become increasingly important as the SSEP identifies strategically important projects, ensuring they can progress through the connections process in a timely and coordinated way. Together these changes support multiple System Conditions by widening the pool of low carbon service providers and improving the depth of assets available to meet our operability requirements, such as flexible assets needed to manage ramps and low margin.

Markets, procurement, and operational reforms

In a clean power system, unabated gas power stations will not be generating for much of the year, so network and operability services must support zero carbon operation. In almost all System Conditions, secure operation increasingly depends on being able to procure and deliver operability services from

low carbon technologies at the right locations, with the right volumes and to the necessary timescales. Enduring stability markets, reactive power procurement, and the evolution of response and reserve services are all cross cutting enablers. They provide routes for service providers to deliver inertia, system strength, reactive capability, and frequency services without relying on routine dispatch of unabated gas.

Market arrangements also influence how bidirectional assets behave and how efficiently the system can be balanced. The Review of Electricity Market Arrangements (REMA) concluded in summer 2025 with the decision not to implement zonal wholesale pricing, while recognising that two-way flexible assets do not always act optimally from a system perspective under existing arrangements. Following REMA, the Government decided to launch Reformed National Pricing (RNP) to address balancing issues under Pillar 2.³ This includes reforms that aim to improve self-balancing ahead of real time, improve our visibility of market positions, and increase the volume of flexible capacity available within the BM. Pillar 1⁴ of RNP will also consider how to provide more effective locational investment signals to support efficient siting of new assets, in alignment with the SSEP. These market reforms are relevant for Supply and Demand Ramps and all the Low Transmission Demand System Conditions, where simultaneous asset behaviour in response to price changes can amplify system balancing challenges and increase the need for corrective operational actions.

³ Pillar 2: Reforms to balancing and dispatch arrangements to improve operational efficiency.

⁴ Pillar 1: Stronger locational investment signals to drive efficient siting of new assets whilst protecting investor confidence and enabling investment at pace.

Flexibility

Across both Low and High Transmission Demand System Conditions, secure operation increasingly depends on being able to access flexibility that can respond quickly and reliably. In Insufficient Downward Margin and Constrained Clean Power System Conditions, it also includes operational access to demand turn up. Greater availability of flexible demand increases the options available to manage margin without relying on more intrusive actions. Increased deployment of storage, including storage co-located with generation, expands controllable flexibility during surplus periods.

Continued access to interconnector support, including use of Emergency Assistance, remains an important operability tool in situations where cross border capability is available, while domestic options become increasingly important during periods when interconnector trading is limited.

Forecasting, visibility, and operational tooling

Improved forecasting and visibility underpin effective operation across all System Conditions. Improved weather, demand, and renewable forecasting supports more efficient procurement of services ahead of real time and reduces the residual imbalance that is managed in the ENCC. Improved awareness of distributed generation and flexible assets is increasingly important because it affects the accuracy of transmission demand, the ability to anticipate ramps, voltage behaviour, and the efficient procurement and deliverability of services.

In our Low Transmission Demand System Conditions, improved forecasting of reactive power and enhanced visibility of distributed and flexible resources enable services to be

procured ahead of real time in the right volumes and locations. In the Summer Minimum System Condition, improved visibility and forecasting of available battery capacity and system margin supports more efficient use of storage, interconnectors and demand side flexibility during surplus periods. Over time, other energy vectors such as hydrogen production and electrified heating/cooling may also increase overnight demand, reducing the need for actions to manage periods of high renewable output.

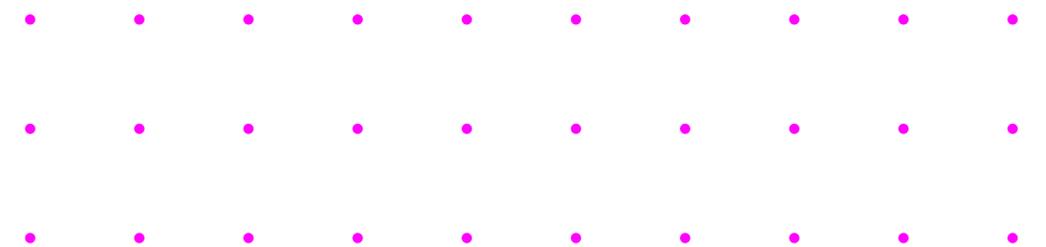
Better system awareness helps reduce balancing costs. This includes improving visibility and forecasting of distributed energy, available battery capacity and system margin. Through our work on Distributed Energy Resources (DER) and Consumer Energy Resources (CER) visibility and access – delivered in collaboration with the Energy Networks Association (ENA) and distribution network operators (DNOs) – and in line with the Smart, Secure Electricity Systems (SSES) programme led by DESNZ, we are improving insight into distribution-connected assets and demand behaviour. This is helping to support more accurate forecasting and stronger operational decisions.

Settlement reform and smart asset coordination

The increasing adoption of domestic smart appliances such as EVs, domestic batteries and heat pumps provides new opportunities to reshape demand profiles and shift consumption toward periods of excess supply. Higher volumes of half hourly domestic demand data can also provide insights into when flexibility is needed and can potentially influence demand. The introduction of Market-wide Half-Hourly Settlement (MHHS) supports greater demand-side

participation through more granular settlement and is expected to support wider access to and use of TOUTs. This can increase the responsiveness of demand, flexibility, EV charging and storage, which strengthens system flexibility but can also sharpen changes in behaviour around settlement boundaries. At the same time, ramping behaviour is expected to be influenced by the growth of bidirectional capacity, including new interconnectors operating on price differentials across markets. It will also be shaped by increasing volumes of distributed assets using automated controls, where coordinated responses can drive unexpected demand swings. Managing these effects reinforces the importance of forecasting and operational situational awareness across System Conditions, particularly in Supply and Demand Ramps and Summer Minimums.

As smart assets and flexibility participation increase, governance and coordination become important enablers for ensuring flexibility behaviour supports system needs. DESNZ is progressing the (SESS) programme to develop standards for smart assets, and Ofgem has established the Market Facilitator role to support alignment of flexibility market rules, with Elexon starting operations in this role in December 2025. The [Ways of Working document](#) published in December 2025 sets out how this will operate in practice.



Dispatchable low carbon power and energy storage

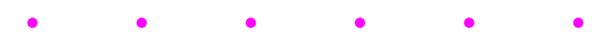
Several System Conditions, particularly renewable shortfall periods during high demand, depend on access to dispatchable capability that can meet demand when weather suppresses wind and solar output. Investment in hydrogen to power, sustainably sourced bioenergy and gas plants fitted with CCS can provide flexible, clean power and dispatchable capability to cover these periods. However, CCS and hydrogen technologies depend on the coordinated development of gas, hydrogen and carbon transport and storage networks. We have taken on the role of strategic hydrogen planning, with first outputs expected in 2026, to inform how hydrogen infrastructure and pathways interact with electricity system operability.

In the Clean Power Shortfall System Condition, dispatchable capability and flexibility provide the capacity needed to maintain security of supply during periods of high transmission demand when wind and solar output are low. Greater access to long duration energy storage and increased interconnection to other markets can also support system resilience during these periods. Oversupply of renewables on high demand days also creates an opportunity for short and long duration energy storage. By absorbing surplus energy during constrained periods, storage can reduce curtailment and support the system during later periods of low carbon supply shortfall.

Resilience

The most robust way to prepare for both planned and unplanned outages is to increase the resilience and diversity of the energy system, including networks, generation, interconnectors, market actors and storage. This reduces reliance on any single critical asset or asset type and improves the ability to maintain operability. We are supporting this through a risk-based approach to system planning and by enhancing technology diversity and market depth, including reducing barriers to market entry so that a broader range of assets can provide the services needed when outages occur.

The mix of power sources available is largely driven by market outcomes, and as the volume of renewable generation connected to the system increases, weather becomes a more prominent driver of supply availability. Encouraging sufficient low carbon generation and improving access to long duration energy storage strengthens resilience during renewable shortfall periods by reducing reliance on unabated gas and providing greater flexibility over longer timescales.

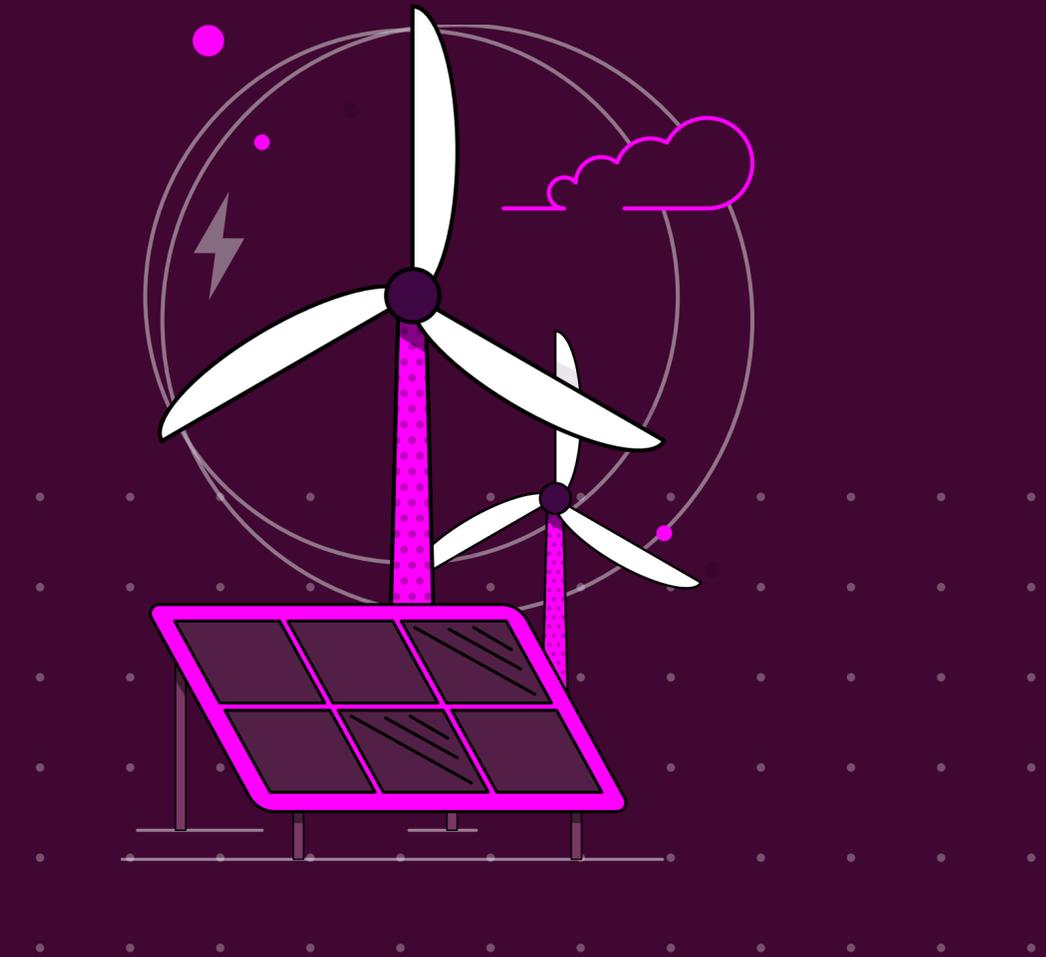


Conclusion and next steps

The System Conditions in this document show how operability in a clean power system is increasingly shaped by the interaction between weather driven supply, increased demand, more dynamic demand behaviour, network constraints and asset availability. Across the System Conditions, challenges often emerge at the points where the system changes state quickly, where requirements are highly locational, or where outages reduce transfer capability and narrow the available operational envelope. These are the moments when visibility, deliverability and speed matter as much as installed capacity, and when having the right capability in the right place becomes critical for secure operation.

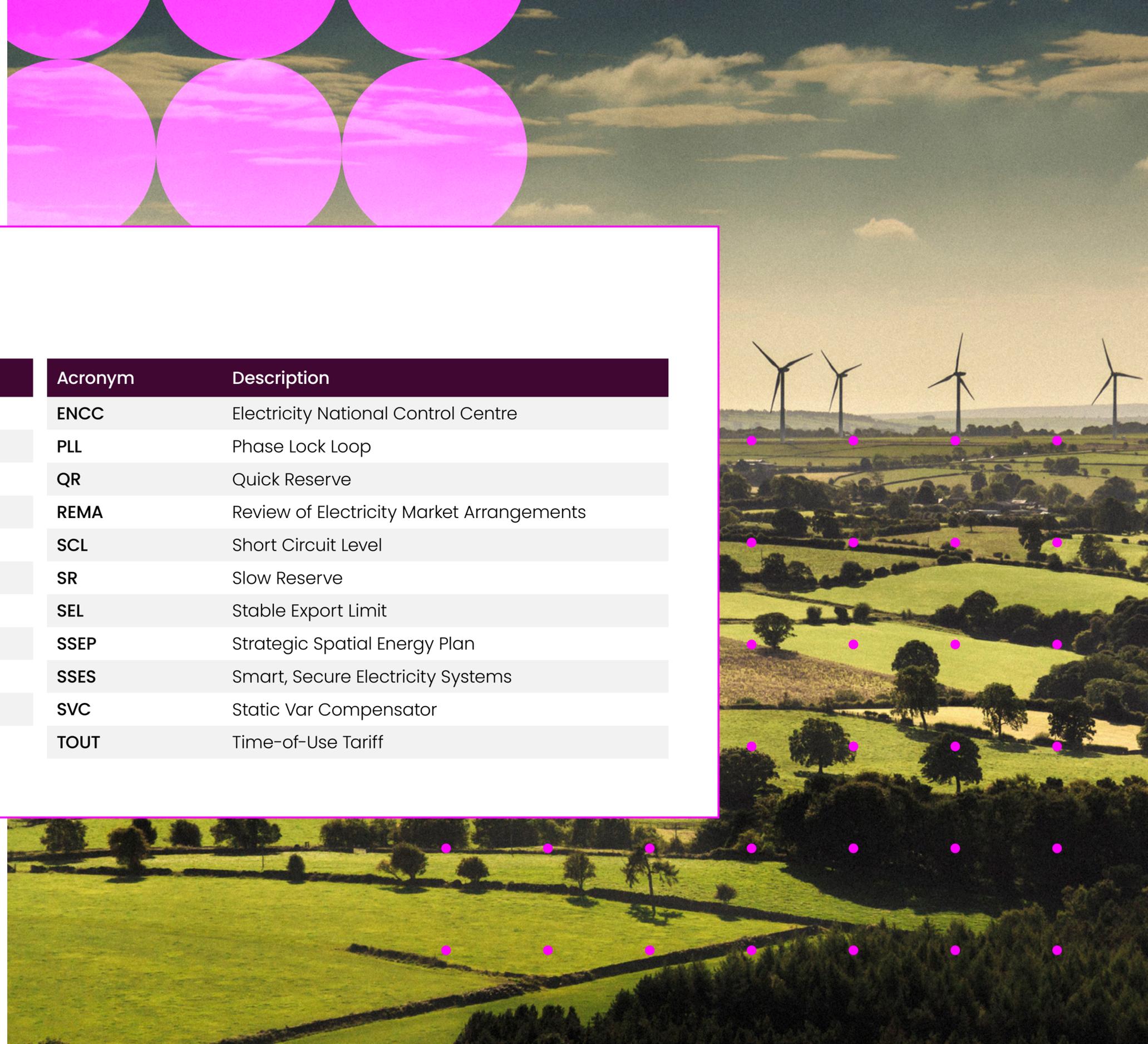
They also highlight why the transition to clean power requires changes to how operability requirements are provided and coordinated. The examples illustrate the growing role of flexibility, the importance of accurate forecasting and situational awareness, and the need for service provision that can be procured and delivered effectively under a wider range of operating circumstances. Taken together, the System Conditions reinforce the value of resilience through depth and diversity across assets and service providers, particularly when the system is affected by constraints, outages or rapid ramps.

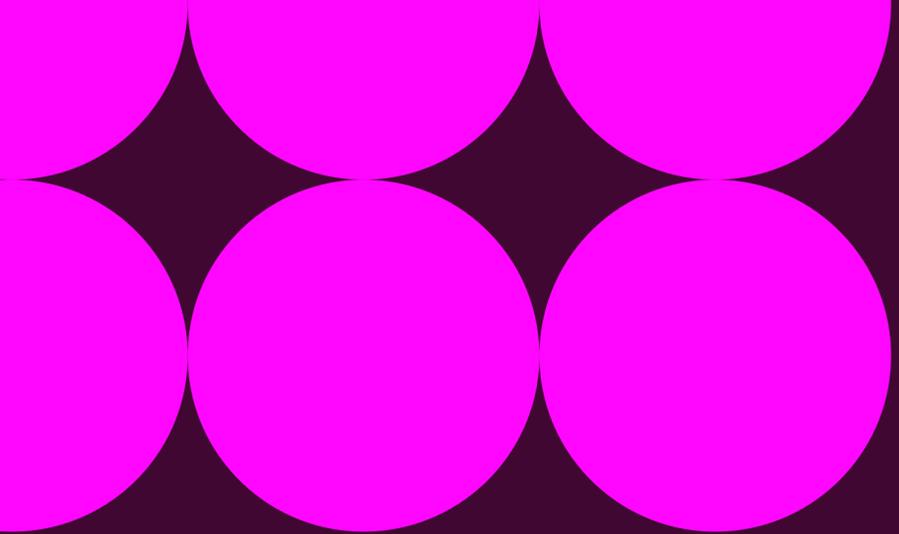
This document is designed to be used alongside NESO's wider publications on operability and markets. Readers looking for detail on how requirements are assessed and procured can refer to the [2026 Electricity Markets Roadmap](#) and the [Operability Strategy Report \(OSR\) 2026](#). Those interested in longer term system design and siting can refer to NESO's strategic planning outputs, including the [SSEP](#), the [RESPs](#) and the [CSNP](#). The System Conditions provide the operational context for why those developments matter, by demonstrating how the system can behave under credible clean power operating circumstances.



Glossary

Acronym	Description	Acronym	Description
BM	Balancing Mechanism	ENCC	Electricity National Control Centre
CCS	Carbon Capture and Storage	PLL	Phase Lock Loop
CER	Consumer Energy Resources	QR	Quick Reserve
CHP	Combined Heat and Power	REMA	Review of Electricity Market Arrangements
CP30	Clean Power 2030	SCL	Short Circuit Level
CSNP	Centralised Strategic Network Plan	SR	Slow Reserve
DC	Dynamic Containment	SEL	Stable Export Limit
DER	Distributed Energy Resources	SSEP	Strategic Spatial Energy Plan
DM	Dynamic Moderation	SSES	Smart, Secure Electricity Systems
DR	Dynamic Regulation	SVC	Static Var Compensator
EfW	Energy from Waste	TOUT	Time-of-Use Tariff





NESO
National Energy
System Operator

