Clean Power 2030

Annex 3: Operability and operations analysis

NESO
National Energy
System Operator

1. Introduction

Electricity network operability means maintaining a stable, reliable and efficient power grid. It enables the system to handle fluctuations in supply and demand, integrate renewable energy sources and respond to potential disturbances or faults. As Great Britain transitions to a clean power system, the operability challenge evolves.

1.1 Methodology

As the Electricity System Operator (ESO), we set an ambition in 2019 that we would be able to operate Great Britain's electricity transmission system at zero carbon for a few hours in 2025. In order to do this, we have transformed our analysis processes, and understood much more clearly what it takes to operate a zero carbon power system and the network services required.

We have developed and implemented new procurement processes over the last five years to enable efficient procurement of the new services while driving innovation. This has been successful and has resulted in the ability to operate a zero carbon electricity system, as well as a much lower cost system to operate, due to dispatching gas powered plant to provide the network services less often.

We have used these established analysis processes and checked the network service requirements with the pathways and network required in 2030.

2. Operability

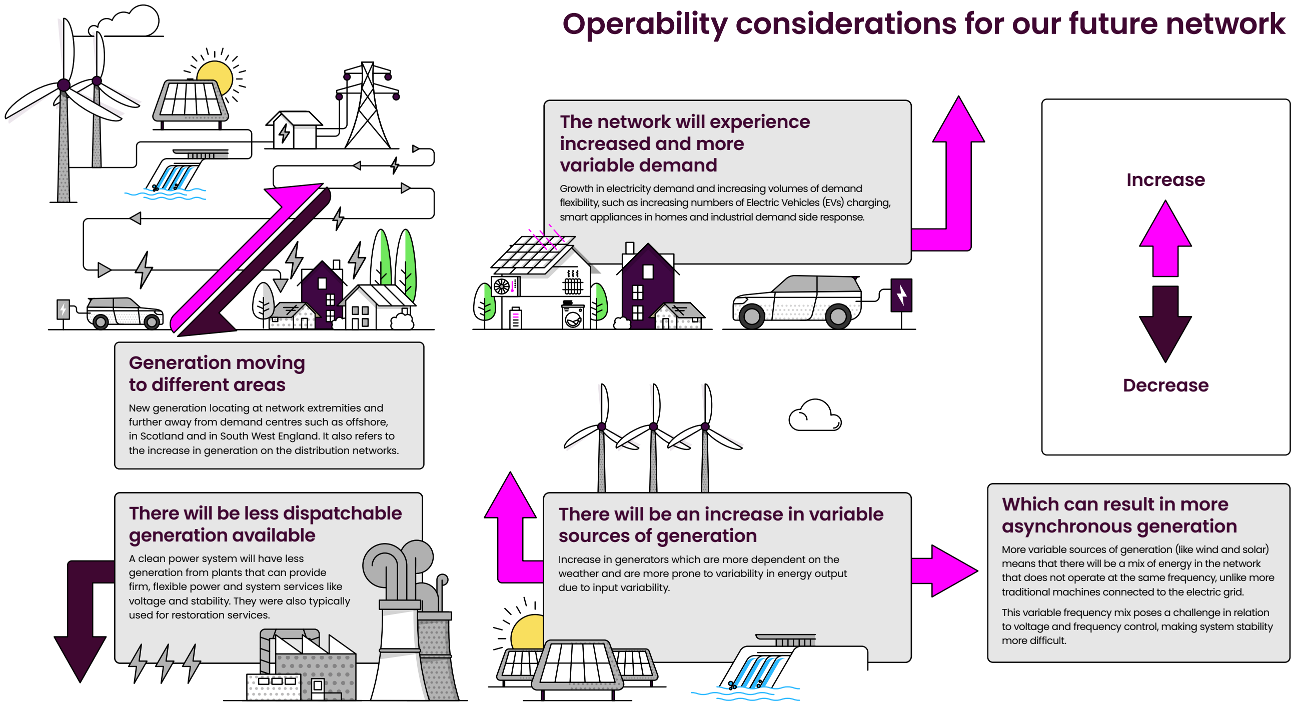
2.1 Great Britain today

We have achieved periods of high zero carbon operation, with a record 92% of the generation mix provided by zero carbon sources on 15 April 2024. We have also managed both the lowest level of power provided by fossil-fuel generation, as well as the lowest carbon intensity on record.

In September 2024, Great Britain's last coal fired power plant closed and, in 2023, renewable energy generated more power across the year than fossil-fuelled generation for the first time.

2.2 Great Britain in 2030

Operating a clean power electricity system in 2030 requires the ability to operate a network with <5% unabated gas across the year. This means securing additional assets and services to maintain safe and secure operation of the system, ensuring a reliable electricity supply to consumers.



Operability considerations for our future network

The network will experience increased and more variable demand

Growth in electricity demand and increasing volumes of demand flexibility, such as increasing numbers of Electric Vehicles (EVs) charging, smart appliances in homes and industrial demand side response.

Generation moving to different areas

New generation locating at network extremities and further away from demand centres such as offshore, in Scotland and in South West England. It also refers to the increase in generation on the distribution networks.

There will be less dispatchable generation available

A clean power system will have less generation from plants that can provide firm, flexible power and system services like voltage and stability. They were also typically used for restoration services.

There will be an increase in variable sources of generation

Increase in generators which are more dependent on the weather and are more prone to variability in energy output due to input variability.

Which can result in more asynchronous generation

More variable sources of generation (like wind and solar) means that there will be a mix of energy in the network that does not operate at the same frequency, unlike more traditional machines connected to the electric grid.

This variable frequency mix poses a challenge in relation to voltage and frequency control, making system stability more difficult.

2.3 Network Services

2.3.1 Stability

Stability is the ability of the system to quickly return to acceptable voltage and frequency limits following a disturbance. Large fossil-fuelled power stations have traditionally supported system stability by providing inertia and system strength. As weather-dependent renewables supply an increasing proportion of electricity demand, the system will become less stable without additional services. Our requirement for system stability primarily covers inertia and system strength (quantified by Short Circuit Level (SCL)).

We currently ensure system inertia is always above 120 GVAs. The system inertia limit is reviewed annually through the Frequency Response and Control Report (FRCR). This limit is expected to be reduced to 102 GVAs in the future to support zero carbon operation, due to the work we have undertaken to prepare for zero carbon operation in 2025. It is expected to remain at 102 GVAs for the Clean Power 2030 operation.

As well as inertia, there will be additional Short Circuit Level (SCL) requirements to maintain stable operation of renewable generation sources and to keep voltage stable during and immediately after system disturbances, as indicated in Figure 1. Most SCL requirements have been identified in the north of Scotland, East Midlands, South Wales and western England regions. For scale, a 2 GW coal-fired power station would have roughly provided a combined SCL support of over 6,500 MVA.

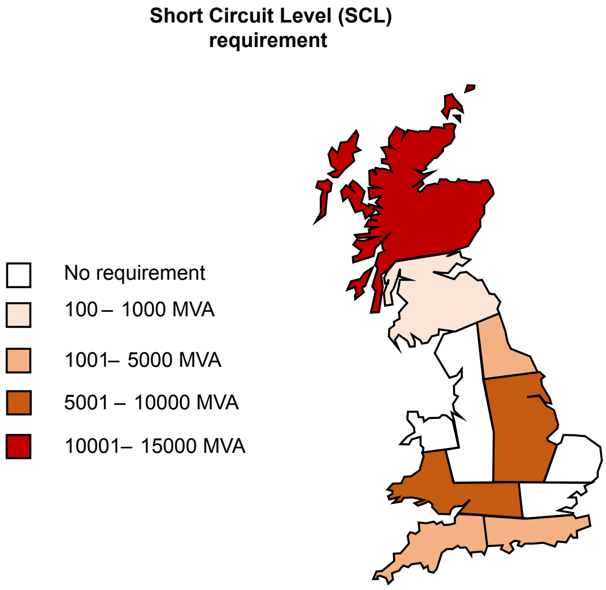


Figure 1: Additional short circuit level requirements for system strength

Installation of new grid-forming technology can reduce additional stability requirements and, alongside obligations in the Grid Code for users, Transmission Owner (TO) built High Voltage Direct Current (HVDC) links with grid-forming characteristics can also play an important role in supporting system stability. To address these network service requirements, we require new assets, new stability markets and policy changes by 2030. These additional network services requirements can be secured and delivered for 2030 by following the existing NESO procurement processes and working with Great Britain's TOs. This is in addition to the volumes already procured through our stability pathfinder projects and mid-term stability markets. Our peak residual inertia requirement in 2030 may be as high as 35 GVAs and will need to be met using a combination of our new stability markets (mid-term and long-term markets) and the Balancing Mechanism.

The NESO Pathfinder projects have demonstrated that the industry is ready and able to provide innovative and traditional solutions to solving inertia and SCL requirements.

The table below sets out additional information on the development and status of stability markets:

Market	Status	Description
Long-term	Available for use subject to requirements	• Will run on a Y-4 basis offering long-term (e.g. 10 years) contracts for the design and build of new solutions or major refurbishment. • This market leverages existing processes from Network Services (formerly Pathfinder) experiences. As such, we currently have the expertise and processes to run these tenders as required. • This market will be leveraged when requirements arise, subject to it being the most appropriate route to market.
Mid-term	In use	• Runs on a Y-1 basis and aims to harness high-availability services in 1-year contract increments. • NESO will continue to grow and use this route to market to procure stability services, subject to there being a stability requirement to procure (and this route being most appropriate for the requirements).
Short-term	Strategic design/ development in progress	• This market is intended to offer NESO an opportunity to fine tune stability requirements closer to real-time, accounting for the diurnal changes in requirements driven by renewable output and demand levels. It may also unlock an additional market opportunity for different technologies and enable revenue stacking with other services. • Further work is ongoing to establish the benefits case and the appropriate point for launching a day-ahead market, as well as efforts to better understand the intricate operation of novel grid-forming technologies. • The launch of this market is dependent on this work and the nature of future stability requirements.

2.3.2 Frequency

Frequency is a measure of the balance between supply and demand in real time. NESO is responsible for maintaining system frequency close to the target of 50 Hz.

Frequency control is achieved through two types of service: response and reserve. Frequency response services are automatically activated using a measurement of frequency to determine an appropriate change in active power. Reserve is dispatched manually by a control room operator following an observed event or in anticipation of a system need. Both response and reserve can deliver a change in active power, provided by a source of either generation or demand.

As we decarbonise, response and reserve services allow us to manage the increasing energy fluctuations associated with increasing variable generation and less dispatchable power on the system. To continue managing frequency reliably and economically, we procure set volumes of response and reserve either through our ancillary services or by setting aside capacity within the Balancing Mechanism (BM). Frequency response and reserve can be delivered through a range of technologies, including both supply and demand side resources for quick response and reserve replacement energy.

In 2030, we expect to need approximately 4.8 GW of response: 2.2 GW of this is for high frequency events and 2.6 GW for low frequency events. Our expected reserve need is around 11.6 GW: 6.4 GW of positive reserve to replace the loss of generation and 5.2 GW of negative reserve to replace any demand loss. In our pathways, there are sufficient volumes of response and reserve capacity to ensure these operability requirements are met.

2.3.3 Voltage

Voltage levels must be maintained within acceptable statutory limits for stable system operation. Reactive power is the key to managing voltage and we need means of absorption for when voltage is too high and injection when it is too low.

Voltage management on Great Britain's transmission system has typically involved the use of regulated equipment owned by TOs and conventional power stations (such as gas and coal). Moving to a clean power network requires the identification of new solutions as conventional generation will be running less. While renewable generation and batteries can provide reactive control capability, it may not be running at times of need or at the right locations. It may, therefore, be necessary to procure additional reactive power support.

The heatmap on the left and right in Figure 2 present an overview of high-voltage (reactive power absorption) and low-voltage (reactive power injection) requirements respectively. Most additional high-voltage support requirements have been identified in South Wales, west of England, West Midlands and the north west of England. Similarly, additional low voltage support requirements have been identified in the north west of England, West Midlands and east of England. To put the heatmap ranges into perspective, the highest injection requirement of 1300 MVar in Figure 2 is roughly equivalent to the combined contribution from a 2 GW coal-fired power station.

To address these needs, we require new reactive assets, new reactive power markets and policy changes by 2030.

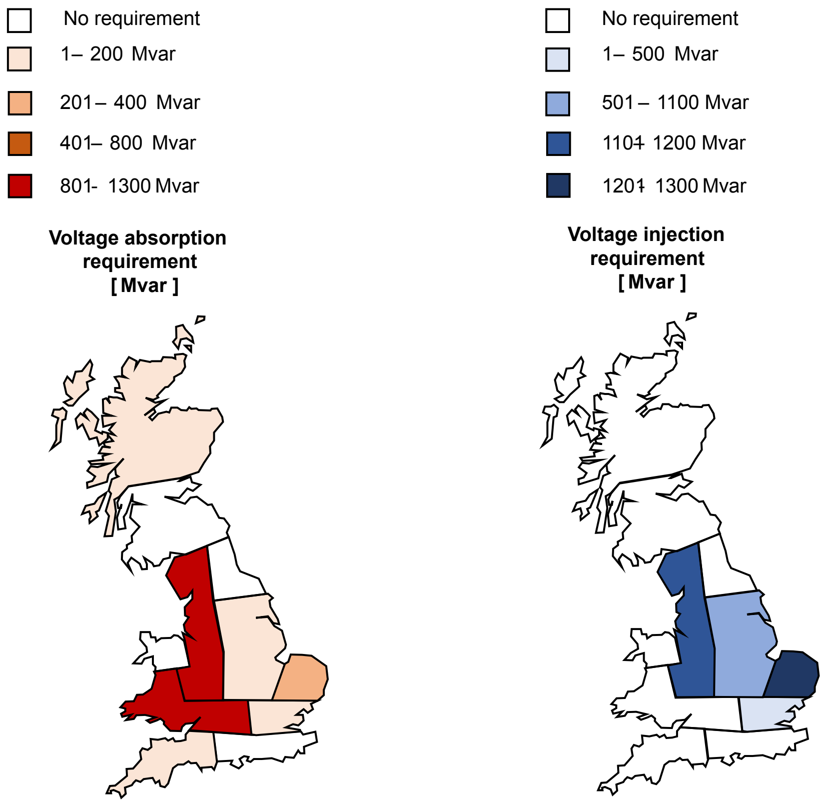


Figure 2: **Additional reactive power requirements**

The table below sets out additional information on the development and current status of voltage markets:

Market	Status	Description
Long-term	Available for use subject to requirements	• Will run on a Y-4 basis offering long-term (e.g. 10 years) contracts for the design and build of new solutions or major refurbishment. • This market leverages existing processes from Network Services (formerly Pathfinder) experiences. As such, we currently have the expertise and processes to run these tenders as required. • This market will be leveraged when requirements arise, subject to it being the most appropriate route to market.
Mid-term	Strategic design/ development in progress	• NESO continues to refine the design of the mid-term market based on the recommendations of the Market Design project. • NESO are working towards completing this by April 2025, in line with current BP2 deliverables. • The outcome will determine the timing for the implementation of the mid-term market, accounting for identified system requirements. • The view is that the development of this market will be complemented by external engagement through BAU processes to foster relationships with the industry.
Short-term	On hold	• This aspect of the market is indefinitely on hold until the associated dependencies are resolved. • After this, further NESO analysis is required to determine the value of a day-ahead service for voltage procurement beyond the mid-term and long-term markets. • It should be noted that, rather than securing the system, the primary function of the short-term (D-1) market would be to further reduce voltage-related costs, rather than act as a mechanism to ensure operability.

2.3.4 Thermal

Power transfers across the network need to be managed as they are limited by physical, safe operational limits on the transmission assets. Once these limits are reached, NESO needs to turn down the generation to ensure the flows are within the limits. This process is a constraint.

There are many ways to manage a constraint. As detailed in the Network annex, new transmission build is required when the cost-benefit assessment shows it is better to build an asset rather than to constrain generation. It would be inefficient to build a network that removed all constraints and they will still exist even after all required assets are built.

Therefore, further solutions can be deployed, for example:

- Intertrip schemes. Immediately following a fault, the generation is automatically reduced.
- Automatic network management schemes. Dynamic automated real-time monitoring and management of generation output on a small regional basis.
- Grid Enhancing Technologies (GETs). Devices such as Dynamic Line Ratings, which give a rating based on current weather conditions, can lead to a much higher transfer capability.
- Long-duration storage. In the right place, it can absorb the excess generation and mitigate the constraint.
- Optimising the coordination and timing of system access requests.
- Constraint markets. Market solution to managing constraints on the network.

2.3.5 Restoration

We have a licence obligation to implement the Electricity System Restoration Standard (ESRS) by 31 Dec 2026. This obligation requires that we restore 60% of the British transmission demand within 24 hrs and 100% in 5 days following a partial or total shutdown.

Our pathways do not undermine our ability to deliver on this obligation. We will continue to embed our restoration strategy, which removes market barriers to entry for non-traditional generation to provide restoration services across the network.

It is understood that, if there was a system restoration requirement that whilst the gas generation is available in 2030 and beyond then it will be used to restore the British electricity system, much as it would be today.

We will also continue to publish our annual Assurance Framework, which describes how we monitor our ability to always comply with ESRS during a regulatory year.

2.3.6 Stakeholder views

We have had feedback that battery technology is evolving at pace, meaning it can provide greater support in ancillary services beyond frequency response. Wind should be used for restoration and other services, but currently, the CfD model doesn't incentivise involvement in those markets.

A stakeholder shared an example of their experience of NESO constraining generation across the DNO network too onerously and they suggest that, in some cases, a less-severe approach and less curtailment would suffice, keeping more generation contributing to the system. The resolution is sharing more data with the DNOs and, together, constraints can be managed in a more targeted way. Stakeholders also recommended that NESO's operational teams upskill to better understand regional networks so they can apply knowledge of local constraints, markets and consumers to their real-time operations roles.

Stakeholders have commented that they see NESO's role in developing a digital spine and that we should support these areas and use cases for this work should be identified so it can add value across these areas.

Stakeholders have said that it's critical that NESO invest in their IT infrastructure, including IT system upgrades, on-network monitoring technology deployment and flexibility market reforms to better encourage investment in technologies that meet clean power.

Many stakeholders at our forums had a general ask for NESO to implement a consistent governance process when procuring ancillary services to help with participation of new applicants into the market. One said that it's important to ensure that sufficient long-term investment signals exist for the provision of all ancillary services to meet requirements as the system decarbonises.

One stakeholder has raised that it is essential that the flexibility available be used to deliver value across the whole system, be it managing energy on the system or managing constraints across voltages. Coordination of these use cases is paramount to ensuring efficient operation.

2.3.7 What is needed

Significant changes in regulatory frameworks and development of new services are required, some of which are highlighted below:

- Transmission owner support to reserve connection bays in a timely manner for future ancillary services tenders.
- Acceleration of connections for solutions successful in future ancillary services tenders.
- Acceleration of Grid Code changes to mandate grid-forming (GFM) capability for new inverter-based resources (IBR) to support the provision of grid stability services.
- Acceleration of Grid Code changes to mandate fault ride-through (FRT) capability for large demand users, e.g. data centres and electrolysers to ensure cost-effective planning of response and reserve services.
- Acceleration of Grid Code changes to mandate reactive power provision from existing and new IBRs, e.g. wind farms, batteries (irrespective of their active power output level). This is to ensure that reactive support from these devices is available when they are needed the most, e.g. during light load conditions when the risk of voltages being close to their upper limit is high.
- Acceleration of mandating provision of all user plant models in both electromagnetic transient (EMT) and root mean squared (RMS) format. This is critical to performing reliable and detailed power system analysis for different system conditions and to devise cost-effective mitigations.
- Closer coordination (supported by underlying policy and regulation changes) with distribution network operators (DNOs) to better model distribution networks and further understand how distribution network assets (e.g., embedded generation) could be harnessed to support (in a cost-effective manner) the system's voltage/stability needs in 2030.
- Consideration of global supply chains' ability to meet UK demand for new assets to operate the electricity network safely and securely using clean power sources.
- Designated projects to get priority connections as they are critical to system security or operability.
- Reservation of land for designated projects or where locational requirements are identified.
- For restoration, the main enabler is the Electricity System Restoration Standard, which goes live 31 Dec 2026.
- NESO will need to develop its sourcing plan based on the identified requirements for voltage and stability and how the long-term markets can be leveraged through BAU procurement processes.

3. Operations

3.1 Great Britain today

The NESO Electricity National Control Centre (ENCC) plays a crucial role in maintaining electricity supplies for consumers by constantly monitoring and balancing the supply and demand for electricity in real time. This operation ensures that the power grid remains safe and stable, preventing disruptions. The ENCC also coordinates responses to unexpected events, such as equipment failures or sudden changes in demand, ensuring that consumers receive a consistent and dependable electricity supply.

3.2 Great Britain in 2030

We have considered the requirement for changes to enable the ENCC to continue to operate the system safely, securely and at lowest possible cost to end consumers in our pathways.

3.3 Basis of our analysis

We note that the ENCC has remained robust in this responsibility as the British electricity system has evolved over the years: the challenges posed by an accelerated transition are well understood. The changes noted below, many of which are already in flight, will enable the transition to be achieved efficiently to the benefit of the end consumer. However, we do recognise that our systems have not always kept up with the pace of change in the industry and we are determined to be proactive and design systems that can be flexible and adapt quickly to future challenges.

3.4 What is needed

Enabling the efficient operation of the system along the pathways detailed in this report will require a significant acceleration of developments to how the ENCC operates this considerably changed system.

Applying a digital-first mindset means we will use and share data more effectively and our systems, processes and people will leverage the right tools, technologies and training to operate a clean power system. An example of this is our ability to access increasing volumes of demand side response. We will achieve this by ensuring we receive accurate data which then supports these services being properly represented across our systems and processes alongside more established generation assets, enabling cost-effective balancing actions.

NESO recognises that we have not always been able to take full advantage of new technologies connected to the network as quickly as the industry needs, for example batteries, due in part to insufficient capability of legacy IT systems. However, we are confident that, through this analysis and other ongoing workstreams, we have identified and are in the process of instigating the changes required within the Control Centre, and support functions, that will allow us to operate a clean power system in 2030. Our investment in digitalisation and Artificial Intelligence (AI) will need to increase to realise this.

Our activities will fall broadly within the following categories:

Systems

Our tools will need the ability to integrate whole system data sources into accurate forecasts & models to enable efficient decision-making in an increasingly decentralised power system.

Work to incorporate primacy rules & the visibility of Distributed Energy Resources (DERs) will require acceleration to ensure effective co-ordination of DNO-connected services.

Continuing development of our Open Balancing Platform & Volta project are needed to ensure effective bulk dispatch & whole energy optimisation.

Data

Continuing to develop an integrated approach to data standards & sharing across industry to enable whole system optimisation. This approach will be enabled by continued investment in our Virtual Energy System (VirtualES) data sharing infrastructure.

Continue to identify and progress innovation projects focused on system and data opportunities for 2030. Analysis has identified accurate forecasting and modelling as one of the key system functionalities required.

Process

Ongoing reviews of all Control Room processes to enhance efficiency of operational co-ordination with our customers.

Ensuring our people & processes remain agile to respond efficiently to any delays to key investments, ensuring that new capabilities are delivered when required.

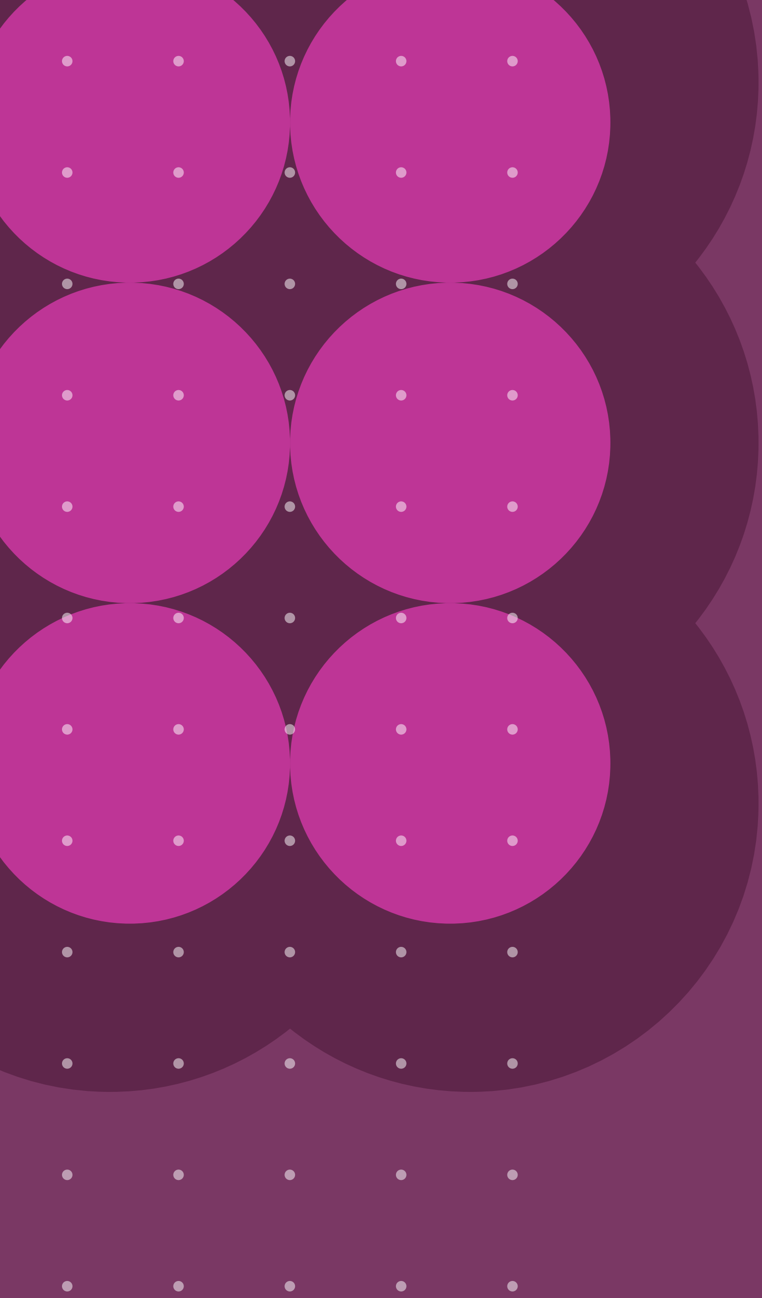
Transparency

Our ability to efficiently answer market queries with technical proficiency needs to be enhanced to build trust across all operational interfaces & with end consumers.

Accelerate efforts to make sharing of data on Control Room decision-making more proactive.

People

Increase the support provided to our highly trained & experienced Control Room staff by accelerating investment to enhance our data analysis & operational co-ordination capabilities with dedicated roles in these areas.



National Energy System Operator
Faraday House
Warwick Technology Park
Gallows Hill
Warwick, CV34 6DA