Network Challenges as we Progress to Net Zero

WinGrid Conference

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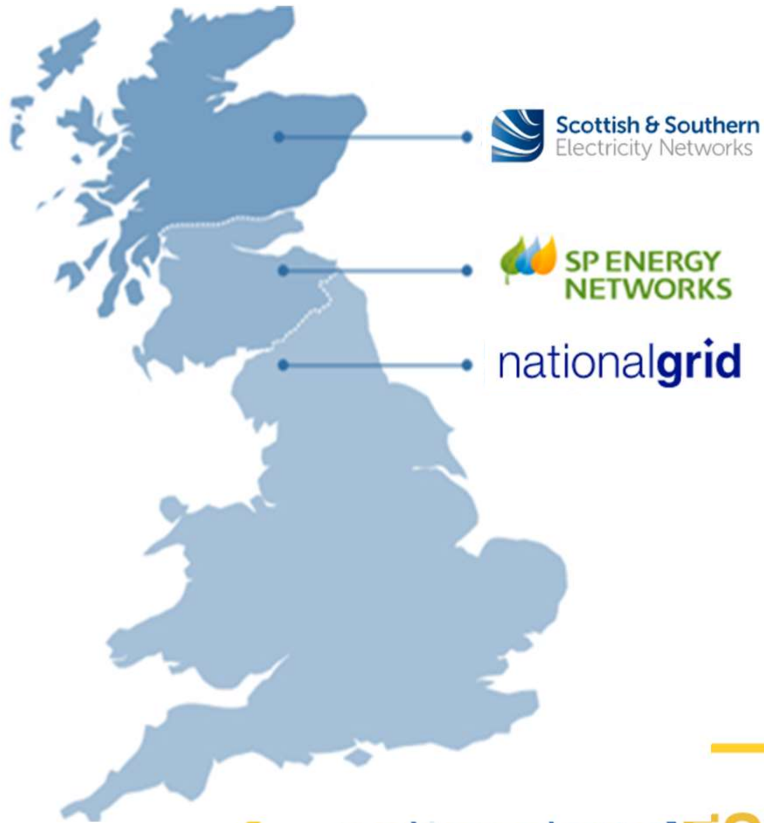
National Grid ESO's role

- Operates and balances the system
- Widens access, promotes competition
- Network recommendations
- Operational planning
- Connection agreements
- GB charging and billing

The **transmission owners** (TOs) own, build and maintain Britain's transmission infrastructure.



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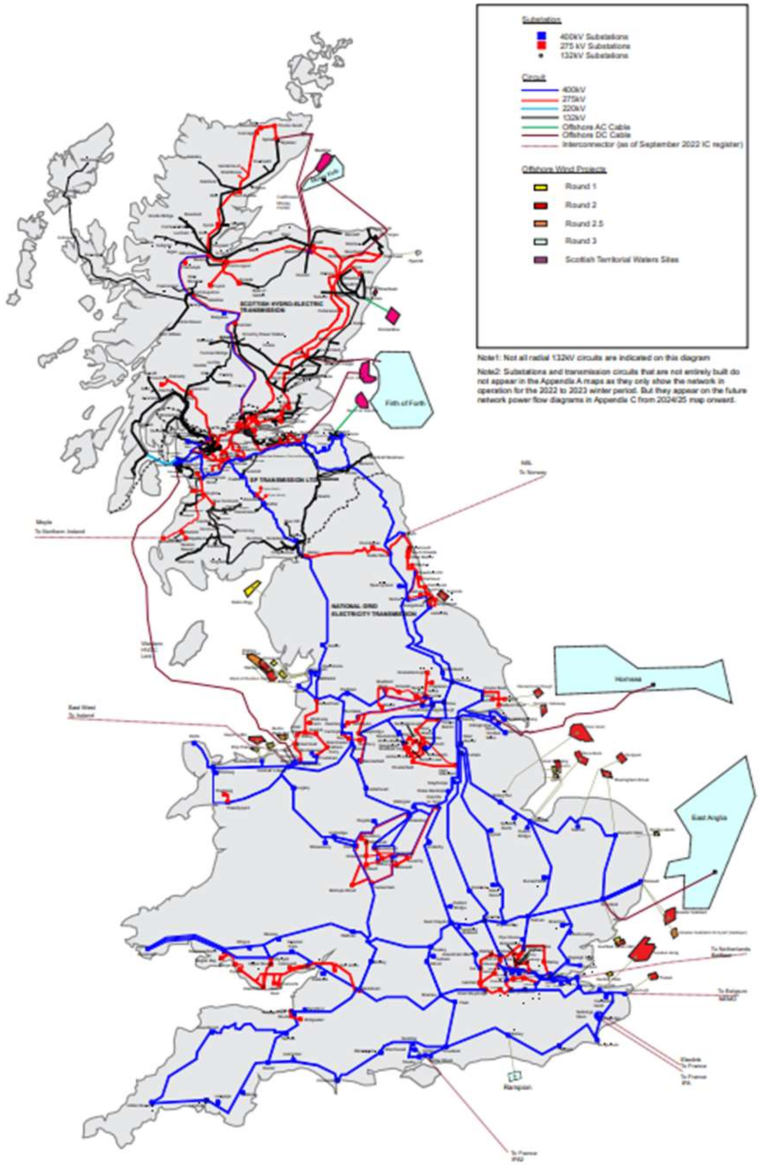
The existing GB transmission system was built around large fossil fuel power plants, many of which were in the midlands

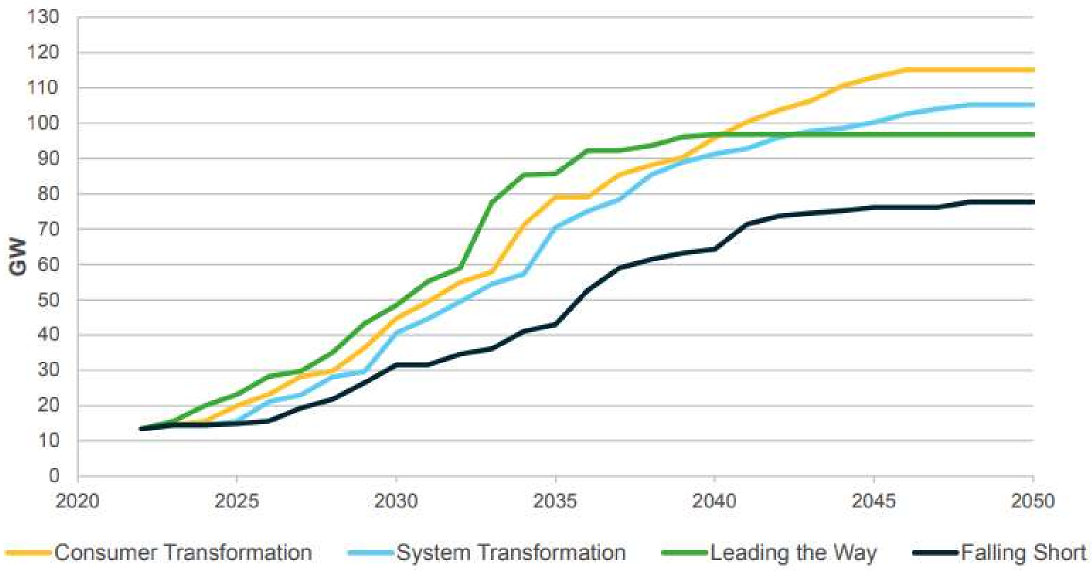
- Highest demand is in London/ the south east
- 400kV lines to transport long distances (blue)
- 275kV in and around cities (red)
- 132kV classed as transmission in Scotland (black)
- Offshore wind farms connected individually
- Interconnected with mainland Europe and Ireland
- Connect and manage used to connect new renewable generation quicker.



Offshore Wind Development

The UK Government has an ambition for 50GW offshore wind by 2030 and 100+GW may be in place to achieve net zero by 2050

Figure ES.11: Offshore wind capacity in GW, excluding non-networked wind



UK Offshore wind targets

- UK Government target of net zero greenhouse gas emissions by 2050
- Ambition for 50GW offshore wind by 2030

Source: ESO Future Energy Scenarios, July 2023

The Offshore Transmission Network Review has been facilitating the increasing levels of offshore wind

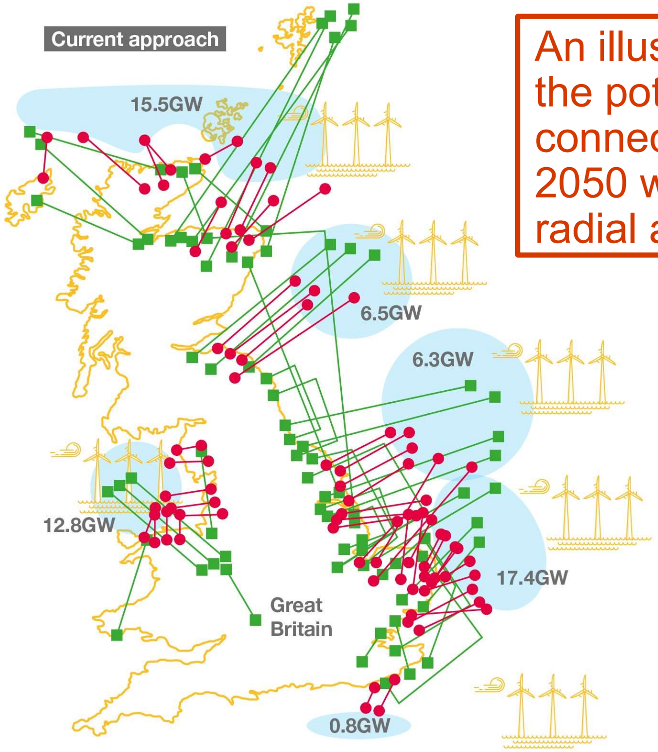
Offshore Transmission Network Review Objective:

To ensure that the transmission connections for offshore wind generation are delivered in the most appropriate way, considering the increased ambition for offshore wind to achieve net zero. This will be done with a view to finding the appropriate balance between environmental, social and economic costs.

Led by the Department for Energy Security and Net Zero. Project partners include:

Ofgem (UK energy regulator), ESO, Crown Estate, Crown Estate Scotland, Welsh and Scottish Governments, Department for Environment Food and Rural Affairs (Defra), Department for Levelling up, Housing and Communities (DLUHC).

A more strategic approach to network planning will be needed to connect these volumes and reduce the impact on consumers, the environment and communities



An illustration of the potential connections in 2050 with a radial approach

Source: National Grid ESO Offshore Coordination Phase 1 Final Report, December 2020

The Holistic Network Design (HND) is a first and significant step towards a more centralised and strategic approach to network planning.

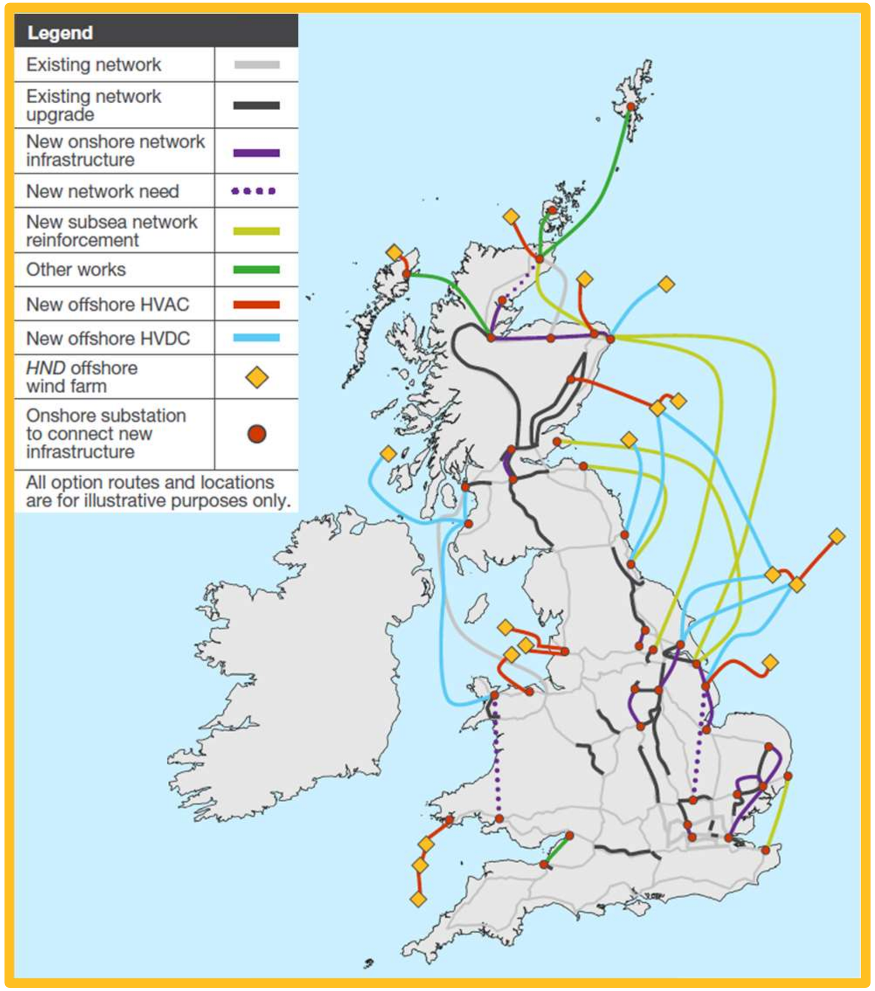
It balances the four objectives of:

- Cost to consumers
- Deliverability and operability
- Impact on the environment
- Impact on local communities

And both connects offshore windfarms and transports the electricity to where it will be used.

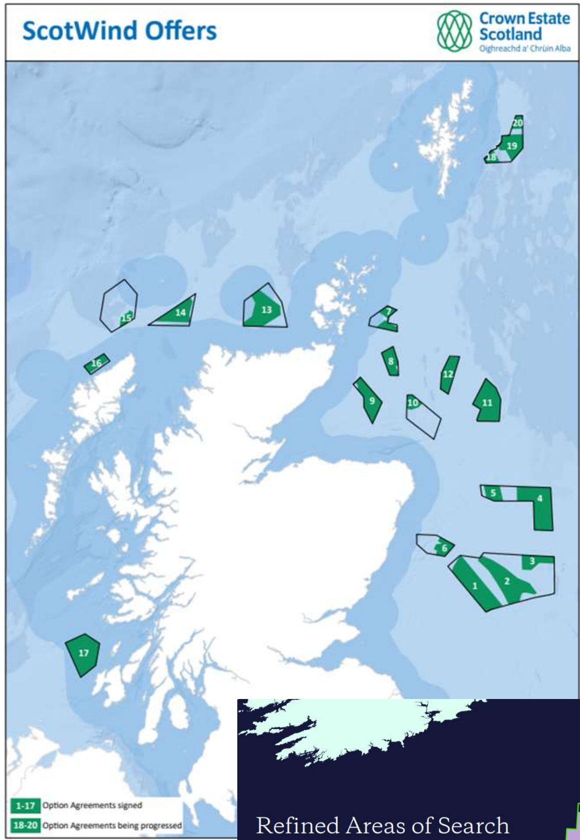
The Holistic Network Design is a first and significant step in centralised strategic network planning

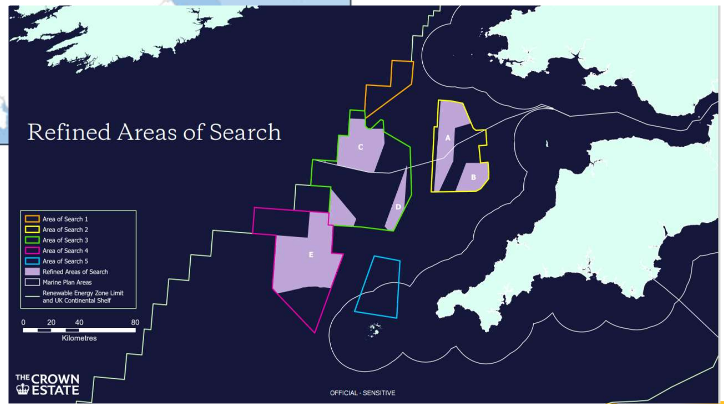
- The holistic network design helps get Great Britain towards achieving the ambition of **50 GW of offshore wind by 2030.**
- **A first of its kind, integrated approach** for connecting 18 in scope offshore wind farms (23 GW) to Great Britain and transporting the electricity generated to where it will be used.
- **Balances the four objectives** of cost to consumers, deliverability and operability and impact on the environment and on communities.
- Identifies and distinguishes **onshore transmission projects** that are **required to facilitate the 2030 ambitions**.
- Includes **£54 billion network investment** onshore (£22bn) and offshore (£32bn).
- Ofgem's Accelerated Strategic Transmission Investment (ASTI) process aims to **accelerate the key onshore transmission projects** required to deliver 50 GW offshore wind by 2030.



The HND Follow Up Exercise extends this further to incorporate more offshore wind

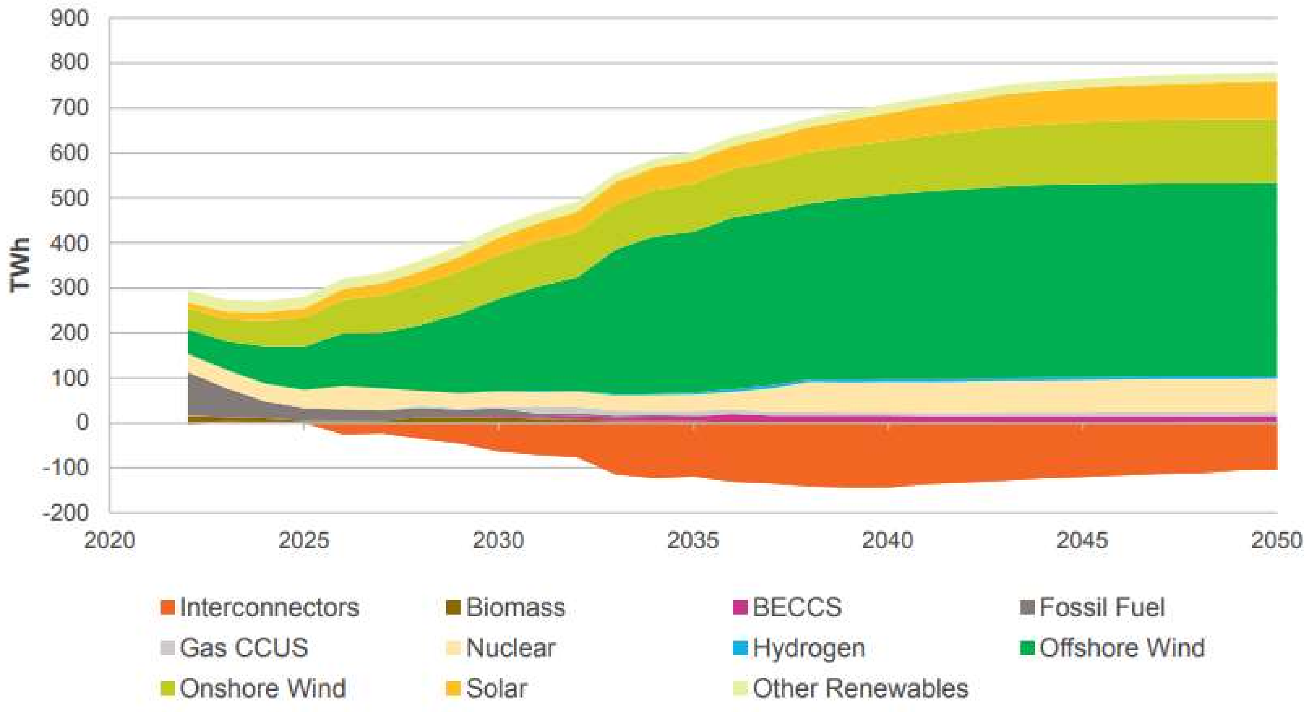
- The HND Follow Up Exercise is considering an additional **21 GW of ScotWind,** which was not in scope for the initial phase.
- It is also considering an **additional 4GW of floating offshore wind projects** anticipated in the **Celtic Sea.**
- Brings the **total offshore wind** with connections to **78.5 GW.**





A more strategic approach to network planning will be needed to connect the generation required to meet net zero

Figure ES.07: Electricity generation output by technology in Leading the Way



Key change projects will be vital to the transmission network being an enabler to net zero, including:

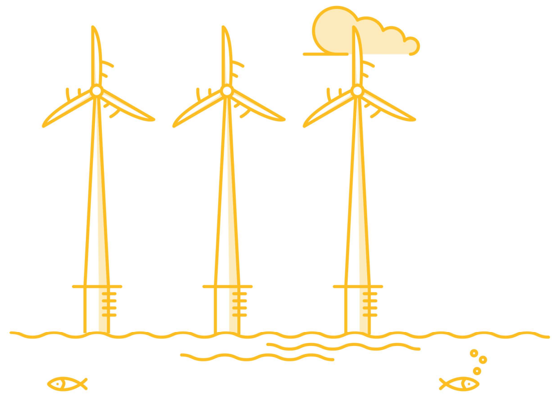
- Ofgem's Electricity Transmission Network Planning Review
- OTNR Future Framework
- ESO Connections Reform
- Future system operator
- Changes to the planning regime
- Strategic Spatial Energy Plan

And supported by the right regulatory framework.

Source: National Grid ESO Future Energy Scenarios, July 2023

There are a number of challenges that need to be overcome in GB to enable the facilitation of this level of offshore wind

- Sufficient certainty early enough in the process
  - For network investment
  - For generation investment
- Facilitative regulatory and planning regimes
- A strategic plan for siting the offshore wind in relation to demand
- Balancing the rollout of the network and the impact on the environment, communities and cost
- Supply chain availability in a competitive global market



Zero Carbon Operation

Zero carbon operation

- Government ambition
  - 100% zero carbon 100% of the time by 2035
  - 50GW offshore wind by 2030
  - 10GW of H2 by 2030

Our plan for 2025:

- For short periods we can operate the transmission system carbon free and can accommodate all the zero carbon generation the market provides

Our plan for 2035:

- Zero carbon operation all the time
- Manage new challenges of flexibility and adequacy

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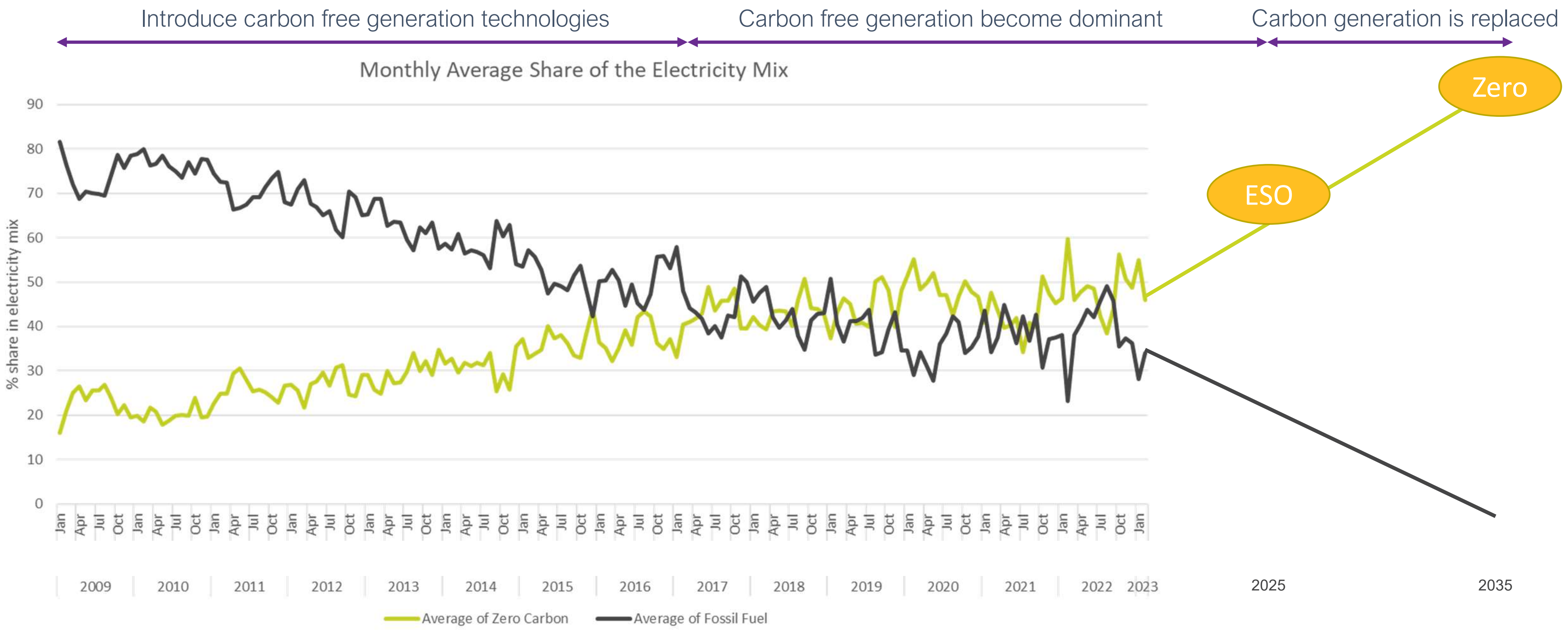
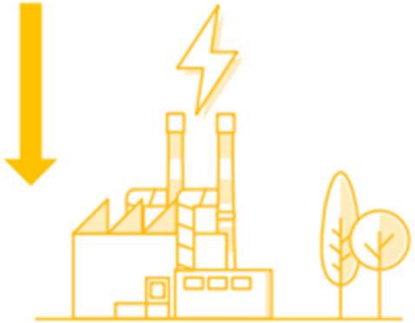
The carbon journey so far



By 2025 the ESO has a target to operate the Transmission network carbon free for short periods
By 2035 the electricity network needs to operate carbon free all year round

The gap to 2035

Year round zero carbon operation in 2035 introduces a further change and two further challenges to system operation.

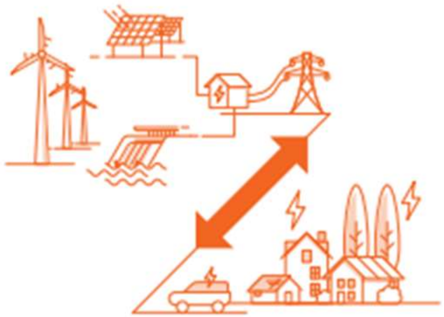


Less dispatchable generation

More asynchronous generation

More variable and unpredictable demand

More variable sources of generation



Generation moving to different areas

The gap to 2035

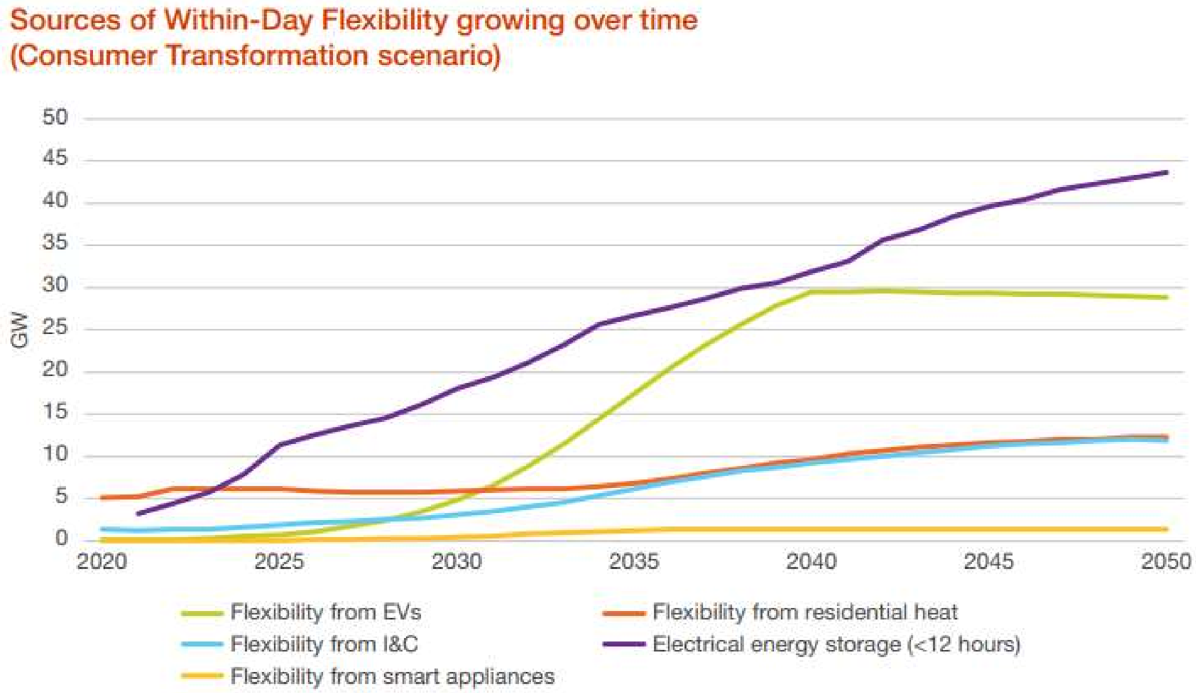
Flexibility – the need to move energy around in day to keep the system balanced

Problems

- How to move energy from variable sources
- How to reduce peak demand by moving it to another time
- How to smooth out variability in demand and generation to reduce system stress

Solutions

- Consumer flexibility
- Flexible demand
- Interconnectors
- Energy Storage



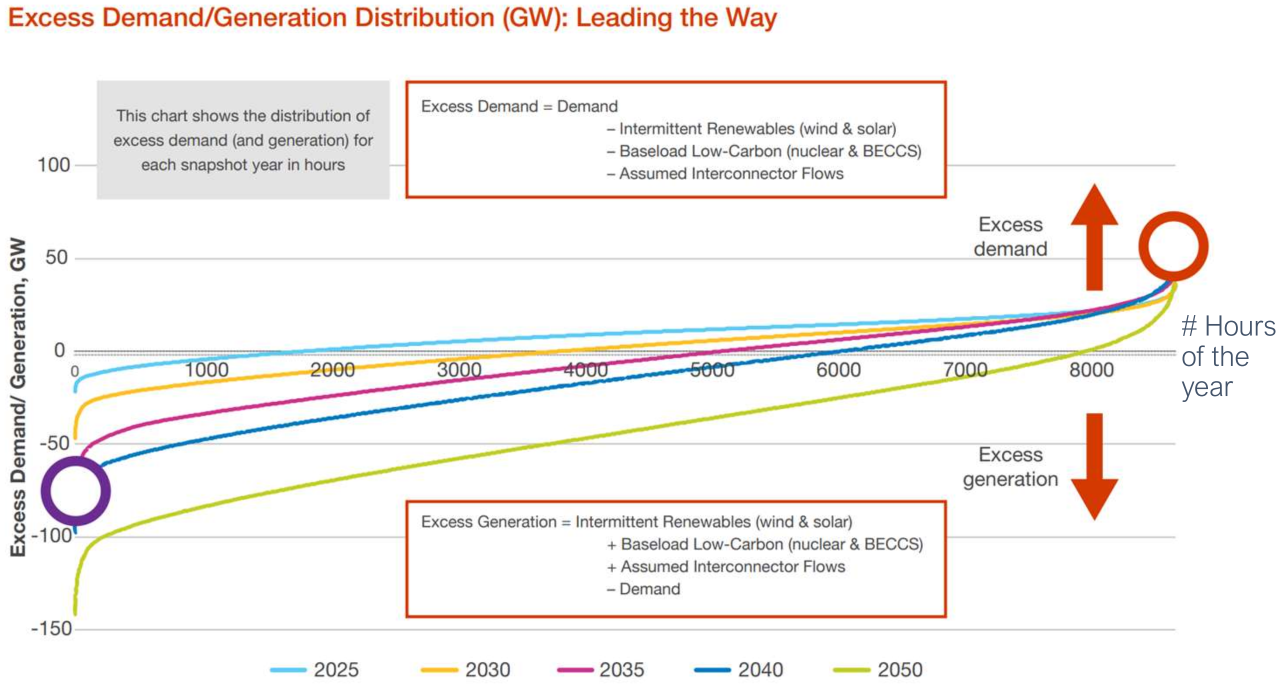
The gap to 2035

Energy Over and Under Supply

By 2035 there could be excess demand in nearly 50% of hours in the year.

Excess demand solutions
- Carbon capture generation
- BECC generation
- Nuclear

Excess demand and generation solutions
- Very long duration storage
- Hydrogen production and generation
- Increased variable demand
- Interconnection



Operability Strategy Report 2023

Reliable Network

Stability
102GVAs The level that system inertia must remain above for secure zero carbon operation in 2025

Operationally, this level of inertia can be maintained via existing system behaviour and our stability pathfinders. Future procurement of stability services will be to ensure economic system operation.

We are working to ensure our policy on managing low fault infeed levels is fit for purpose for the future system.

Voltage
2200MVAr The volume of new reactive capability needed to economically maintain a compliant network in 2025

Our need to absorb reactive power continues to increase, driven by decarbonisation of the electricity system and continual decline in reactive power demand.

We are exploring options to access new sources of reactive power, reduce voltage costs in the short term and define long term future reactive needs.

Thermal
2030 When we expect GB to be a net annual exporter of electricity by

Significant growth in renewable generation and interconnection continues to drive a need for more network capacity.

We are enabling the transition to Net Zero by mitigating rising constraint costs, contributing to network planning reviews and enabling the connection of renewable generation and new technologies.

Restoration
100% Of national demand restored, within 5 days, under the new restoration standard in the event of a power outage

The new Electricity System Restoration Standard also requires 60% of regional demand to be restored within 24 hours (in all regions).

We are beginning to use learnings from Distributed Restart to enable DER such as solar, wind and hydro to provide restoration services and reduce our reliance on fossil fuel generators.

Balancing the System

Frequency
2500MW The maximum requirement for Balancing Reserve by 2025

More variable sources of generation, increasing volumes of demand flexibility and price driven coordinated behaviour of assets, such as EV's and interconnectors, create more challenging balancing conditions for the ESO.

New services such as Balancing Reserve and Static Recovery will help us manage these new challenges.

Within-day Flexibility
46GW Volume of expected Within-day flexibility from storage and demand by 2030 in Leading the Way

Changing the timing of demand, mainly with smart appliances and storage, will become the main source of within-day flexibility in the 2030s.

Understanding the contribution of this to system needs, starting with peak demand, will be critical for efficient zero carbon operation.

Adequacy
>50% By 2035 in leading the way, there will be surplus generation in more than half of the year.

There is no trade-off between adequacy and net zero. We can deliver adequacy in a fully decarbonised power system.

Investment in at least one new reliable low carbon technology such as nuclear, carbon capture storage (CCS), hydrogen or long-duration storage will be needed.

https://www.nationalgrideso.com/research-and-publications/system-operability-framework-sof

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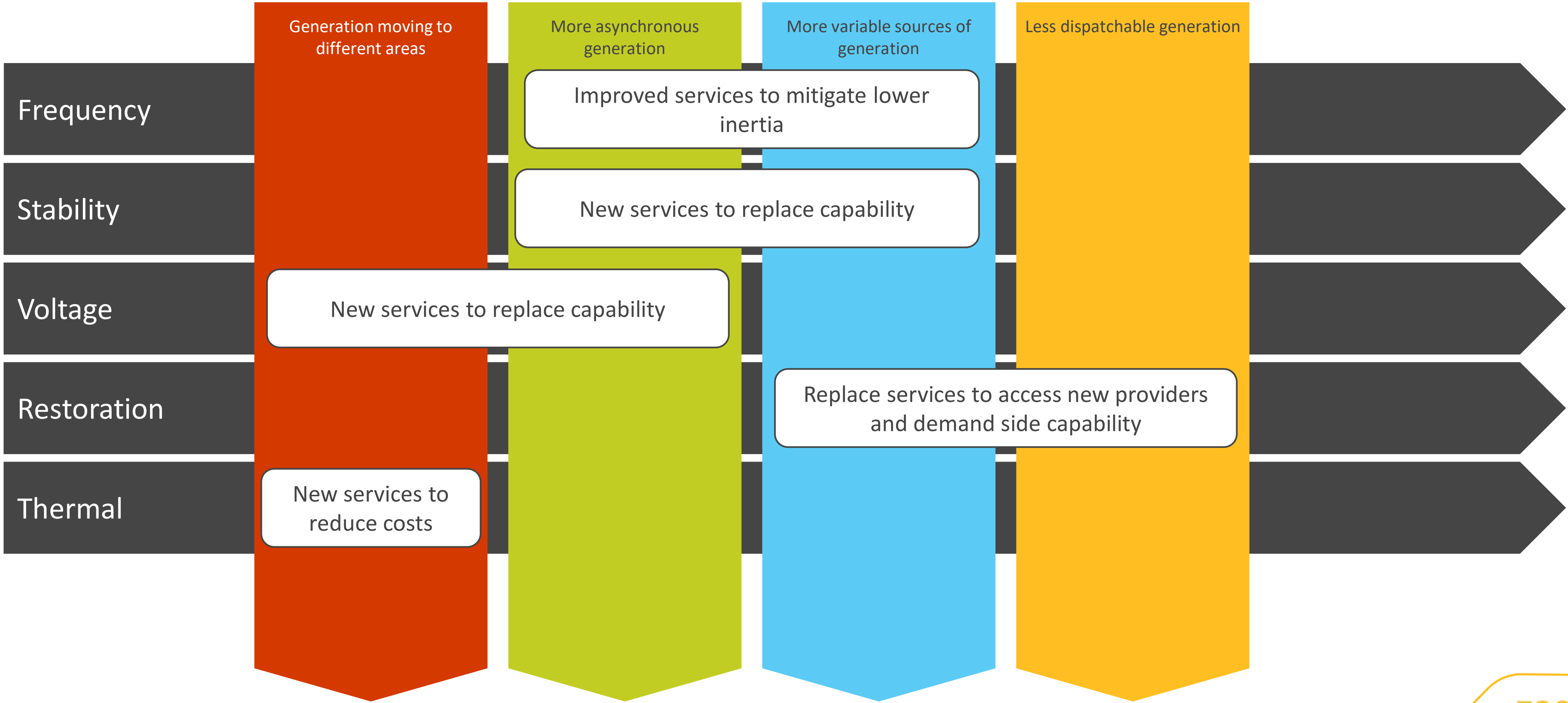
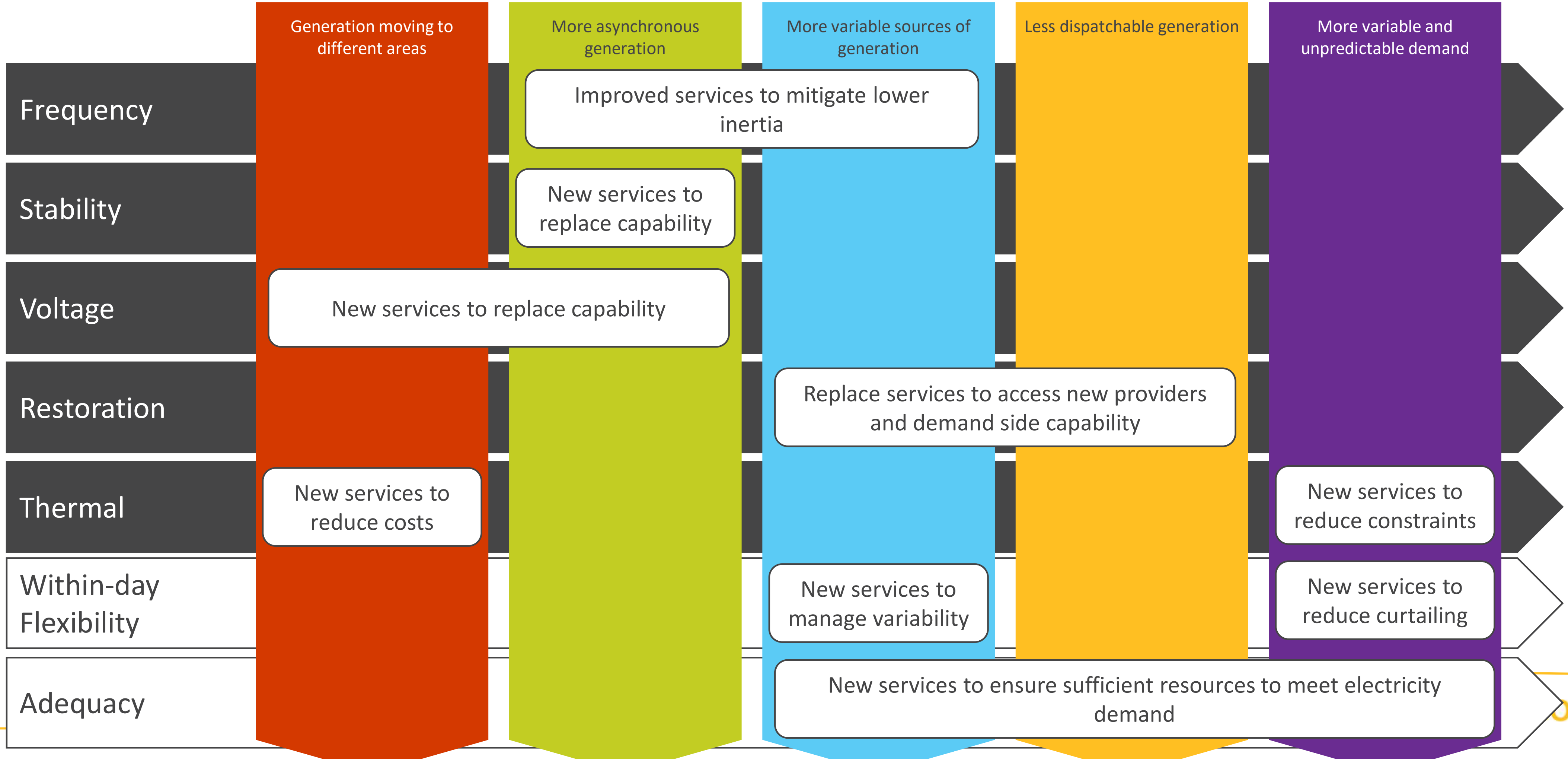
The current challenges and how we are meeting them

Each of these changes brings about five **engineering challenges** which have to be resolved using new and existing technology to operate a zero carbon network.



The gap to 2035

Getting to zero carbon operation in 2035 introduces a further change and two further **challenges** to system operation which have to be resolved using new and existing technology to operate a zero carbon network.



Summary

The carbon journey
We have successfully integrated zero carbon sources into everyday system operation.

Meeting the current challenges
Manage a system with large and increasing amounts of zero carbon sources.
By 2025 our plans will enable us to operate the Transmission network carbon free for short periods.

Closing the gap to 2035
Delivering flexibility services and ways to overcome over and under supply of energy.
By 2035 the electricity network needs to operate carbon free all year round.

Market Development

Markets Roadmap

The Markets Roadmap outlines the ESO's plans to reform our markets to enable zero-carbon operation by 2025 and fully decarbonise by 2035

The markets roadmap also:

- Provides key insights into the different ESO markets as well as the key drivers for reform.
- Gives stakeholders confidence that we are making the right market reform and design decisions.
- Shares strategic questions we are currently tackling and signposts how industry can work with us to answer them.

Markets Roadmap webpage

Market Design Framework

Markets Roadmap – voltage

We are developing our procurement strategy as our voltage management requirements continue to rise

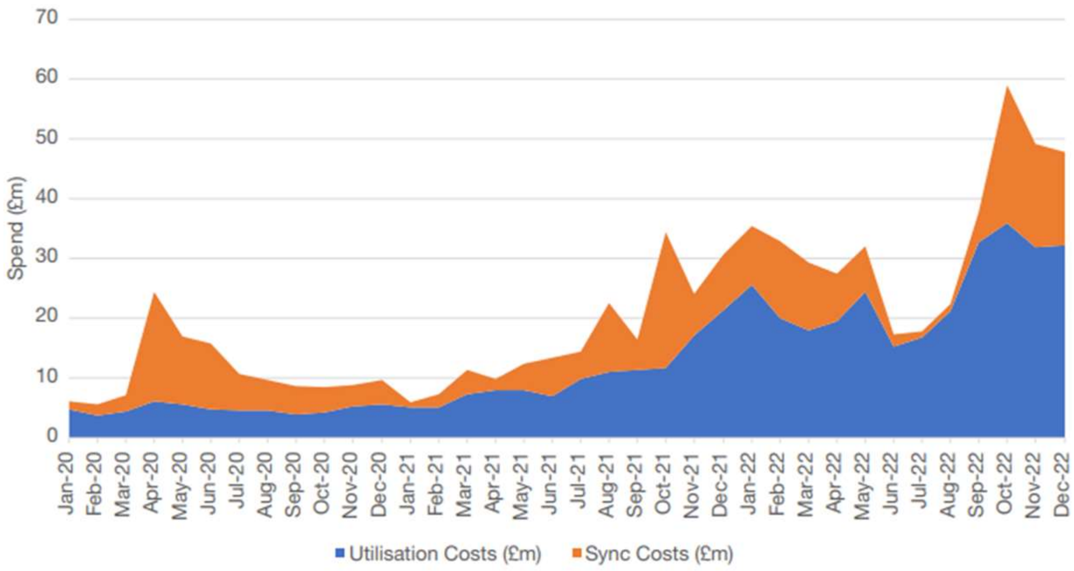
What happened in 2022:

- Voltage management requirements continued to grow
- The default payment rate increased due to gas prices
- We identified an estimated 3.4GVar of capacity from existing units
- Our Mersey Pathfinder delivered £12.6million in savings and is forecast to save £25.3m across 2023/24.

What is happening 2023 and beyond:

- Exploring how to harness this additional 3.4GVar
- Pennines New Services Procurement go-live in 2024
- Continue to develop our enduring market design

VT Figure 3: The utilisation and synchronisation costs between 2020-2022



Note: revenue recovered by the Transmission Owners related to their reactive compensation equipment cannot be identified within their overall Regulated Asset Base (RAB). The above chart, therefore, does not represent the full cost to consumers of voltage management in 2022.

Markets Roadmap – Stability

Two more stability pathfinders concluded in 2022 whilst costs associated with increasing system inertia trebled in comparison with 2021.

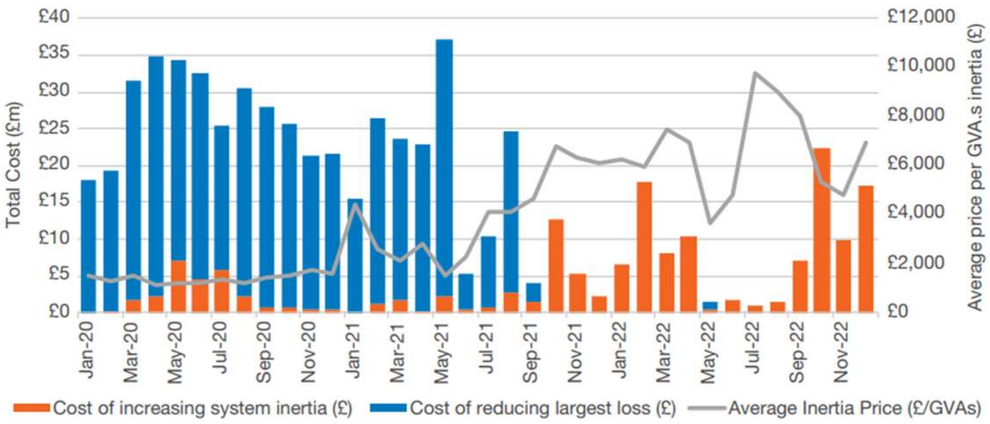
What happened in 2022:

- Actions taken to reduce the size of the largest loss decreased very significantly.
- Actions to increase system inertia doubled in volume and trebled in cost (£104m) due to greater penetration of renewables and high gas costs.
- Stability Pathfinders 2 and 3 secured >20GVA.s inertia and >23GVA effective SCL, including the first grid-forming battery storage solutions.

What's happening in 2023 and beyond:

- Lowering the minimum inertia threshold via FRCR (120GVA.s) will reduce the costs associated with managing system inertia.
- The Stability Market Design innovation project recommends three discrete markets – a long-term (Y-4), mid-term (Y-1) and short-term (D-1).
- A mid-term Y-1 stability market will be initiated in 2023 to access high-availability inertia as a cheaper alternative to the Balancing Mechanism.
- D-1 and Y-4 markets will be developed in parallel.

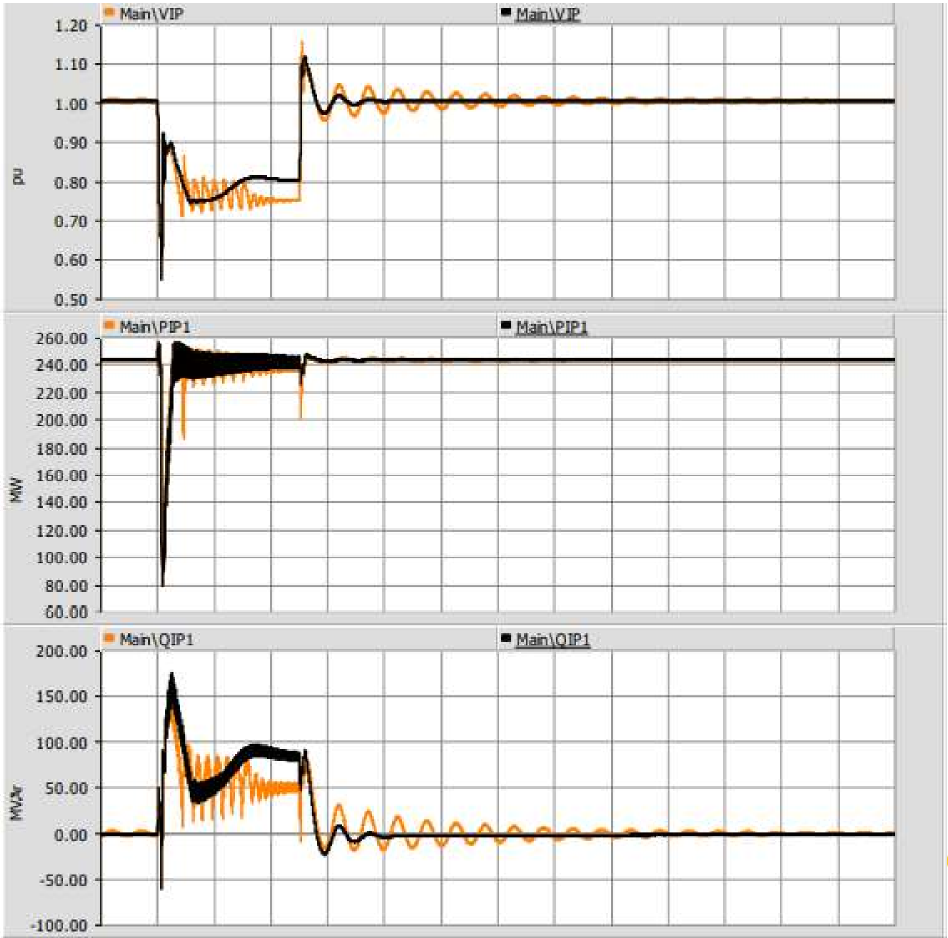
ST Figure 3: Inertia management costs: Jan 2020 - Dec 2022



ST Figure 1: Total volume of contracted inertia (GVA.s) through stability pathfinder 1, 2 and 3.

System Strength Management

- Minimal SCR (MSCR) is the minimum SCR required for IBR to maintain stable operation.
- With reduction of system SCL, it becomes challenging for generators to meet the grid code requirements
- There is a risk that existing generators might not remain compliant with reduced SCL
- Tuning parameters may improve the performance under low SCR, however it is case by case and hard to determine the limit.



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System Strength Management

- Many TSOs have attempted to apply a consistent assumption for MSCR across their network. Examples are shown in the table.
- If the SCR is above these levels, the likelihood of instability is low. However, there is no clear cut without a detailed EMT study.
- Generally, controllers could be retuned to reduce the minimum SCR for an IBR. However, there are cases when this was not successful.
- Additional challenge of control interaction under low SCR
- SCR method works better for single IBR connection, when rest of system can be represented as an equivalent voltage source
- More work needs to be done for multiple IBRs connection

	MSCR at TIP	Connection type
AEMO	3	AC
EirGrid	2	HVDC
VDE	2	HVDC
GB experience	3	AC

Inertia Monitoring

Implemented two new “first-of their-kind” inertia monitoring tools

- GE Digital solution providing:
  - Regional based
  - Real-time monitoring based on Phasor Measurement Units (PMUs)
  - Day ahead forecasting per settlement period using operating data (demand, wind, solar & synchronous inertia)
  - Verified against loss of load events
  - Operating since late 2021, currently Scotland only based on PMU availability
  - Full GB availability limited by NGET PMU rollout
- Reactive Technologies solution:
  - GB wide 5 minute real-time monitoring
  - Uses ultra capacitor to provide “controlled” signal onto frequency
  - Measured across GB in distribution network
  - Operating since July 2022, mainly over periods of high renewables

Inertia Monitoring - Data Verification

- Internal review of data
- Data Analysis being undertaken independently by National Physical Laboratory (NPL*) to:
  - Assess both products alongside internal evaluation.
  - Establish regional representation
  - Establish standardisation for measurements
- Comparison of 6 months data
  - Strong correlation with synchronous inertia (>0.85)
  - Confidence values within 10% for 95% of measurements
  - Initial indication of regional variations
  - Detailed analysis of periods of high renewables ongoing
- Incorporate into ENCC situational awareness summer 2023
- Potential data publication (depending on commercial agreements)

* NPL is an institute developing and maintaining the national primary measurement standards. It is a Public Corporation owned by the Department of Business, Energy and Industrial Strategy (BEIS)

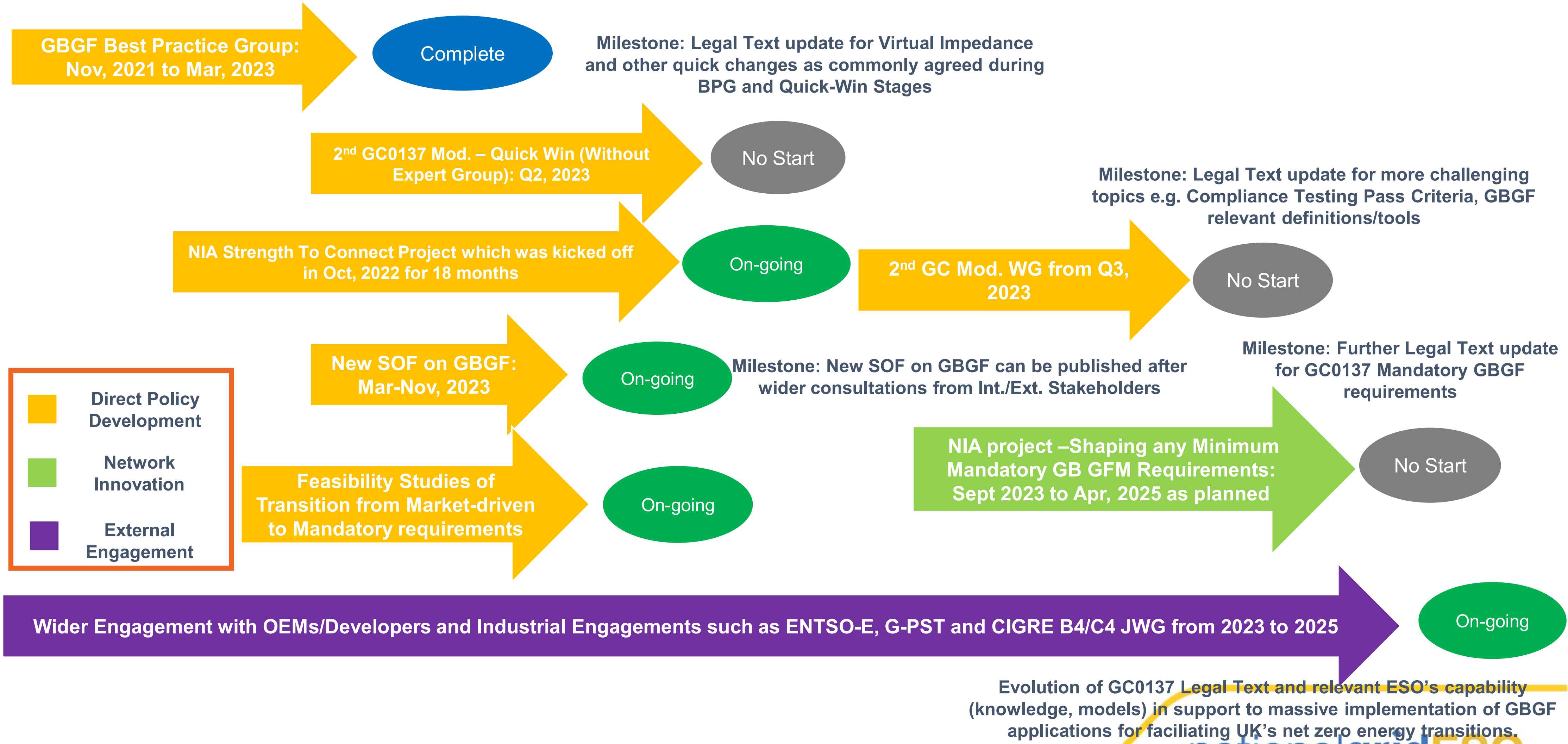
Future of GB Grid Forming

The penetration and proportion of Grid Following (GFL) based IBRs on the GB energy system will increase hugely into the foreseeable future.

A number of challenges are foreseen below. How best can we address these issues?

- Q1: How much Grid Forming (GFM) capability will be required on the system to manage operability issues?
- Q2: Should GFM capability be mandated?
- Q3: How can we assess interoperability issues between GFL/GFM-based IBRs and Synchronous Machines?

ESO's Future Strategic Roadmap for GB Grid Forming Development



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Q & A