Electricity Ten Year Statement

#ETYS2022

nationalgridESO

Contents

Foreword

Welcome to our Electricity Ten Year Statement (ETYS). The ETYS is the ESO's view of future transmission requirements and the capability of Great Britain's National Electricity Transmission System (NETS) over the next 10 to 20 years

Electricity is a modern-day necessity, and our role as the Electricity System Operator (ESO) is to make sure every home and business across Great Britain has access to a safe, reliable, and affordable supply at the flick of a switch. Over the past year, both the devastating war in Ukraine and the ongoing cost-living-crisis has underlined the importance of reaching Net Zero. A fast transition to Net Zero bolsters our energy security and reduces our exposure to volatile international fossil fuel resources. prices, by harnessing abundant renewable and low carbon energy.

As we transition to the Future System Operator (FSO), we will continue to drive the transformation to a fully decarbonised electricity system by 2035 which is reliable, affordable, and fair for all. The FSO will also undertake additional responsibilities covering strategic network and market strategy planning across both gas and electricity to provide a whole energy system view. Through this new approach we can create long-term energy security and deliver sustainable economic opportunities across the country. Renewable and low-carbon generation is a key piece of the puzzle and a well-connected and reliable transmission system will be vital in achieving net-zero targets.

The Electricity Ten Year Statement (ETYS) sets out the future transmission requirements and capability of Great Britain's National Electricity Transmission System (NETS) over the next 10 years. We analyse the impact of our Future Energy Scenarios (FES) to help us understand where investment and development is required to help us achieve our zero-carbon ambition whilst maintaining a safe and reliable network. This document does not recommend what, or where, network development should take place.

This is an iterative document building on the analysis conducted in previous years. The statement sets out the needs case for transmission development across GB's NETS. After the publication of the ETYS, the ESO invites industry to submit options as to where, how, and what transmission development should be built. The ESO then evaluates these proposals and makes reinforcement recommendations through the Network Options Assessment (NOA) process which, this year, will be published as part of the second transitional Centralised Strategic Network Plan (tCSNP2).

To achieve our net zero future, we recognise the need for the ESO and wider industry to analyse the transmission system against a wider range of conditions. Currently, the ETYS focuses on securing the network against a winter-peak scenario, traditionally the peak-demand scenario observed across the year. With the ongoing rise in intermittent and converter-based technology, we need to expand our view of system needs across a wider range of scenarios and network conditions across the year.

We have continued to develop our year-round thermal analysis tool as we look to expand ETYS to integrate a wider range of system needs and share our latest developments in a dedicated chapter within ETYS.

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In order to meet our ambitious decarbonisation targets, the pace and scale of transmission development must accelerate. We welcome Ofgem's recent decision on the new Accelerated Strategic Transmission Investment (ASTI) framework to support the accelerated delivery of strategic electricity transmission network upgrades needed to meet the Government's 2030 renewable electricity generation ambitions.

Our network planning process is changing as we are transitioning to a new Centralised Strategic Network Plan (CSNP), and we are working in collaboration with Ofgem on the Electricity Transmission Network Planning Review (ETNPR) to review our network planning processes to ensure that the network design and investment processes in Great Britain are fit for the future. During this transition there will be some iterations of a transitional CSNP (tCSNP) to continue informing network planning and investment decision whilst we develop the enduring CSNP process.

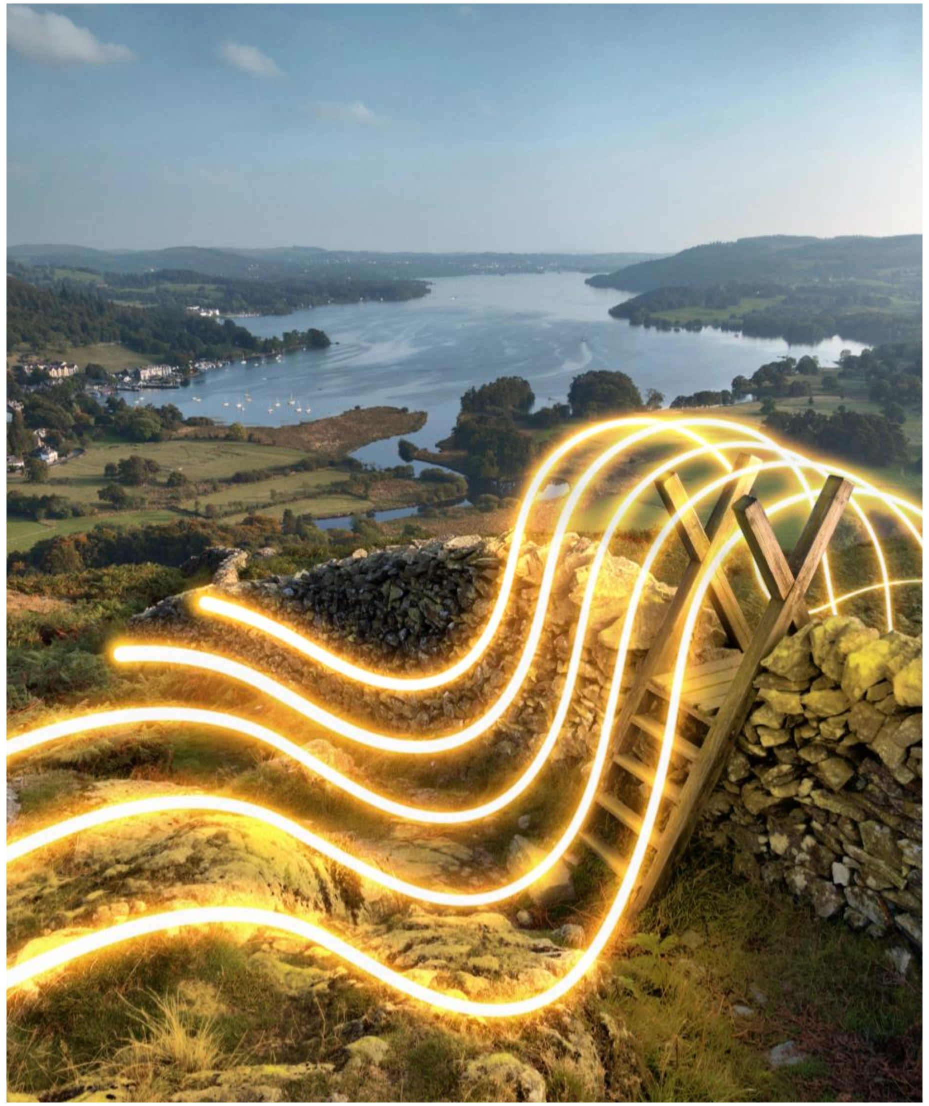
The enduring CSNP will proactively identify, design, and progress investment in the transmission network onshore, offshore, and across vectors. In addition to economic assessment, the CSNP will also consider environmental and community factors earlier in the planning cycle. To support the development of the CSNP, Ofgem published their decision to allow us to publish the ETYS by 31st January 2023 and an updated NOA will be published, as part of tCSNP2, by 31st December 2023.

We are continuing to facilitate the growing volumes of offshore generation through the ongoing Holistic Network Design follow-up exercise (HNDFUE) which is considering additional offshore wind connections from the upcoming Celtic Sea leasing round and the remainder of the ScotWind offshore leasing round. The 2022 ETYS report does not include any of the outcomes or recommendation of the HNDFUE as the project is still in progress, although offshore wind projects considered by the HND and HNDFUE are factored into our generation background (as per FES 2022). Any new network needs that are identified will be further assessed in the upcoming tCSNP2.

Thank you for your continued feedback on the ETYS process. It is vital that we present our data in a way that is useful to the industry, acting as a catalyst for debate. We appreciate continued feedback and encourage you share your views on how we can further improve the ETYS. You can contact us at transmission.etys@nationalgrideso.com

As we transform our network planning processes, we encourage you to stay up to date with our latest developments by signing up to our monthly newsletter.

Julian Leslie
Head of Networks,
Electricity System Operator (ESO)



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Key Messages

Key Message 1

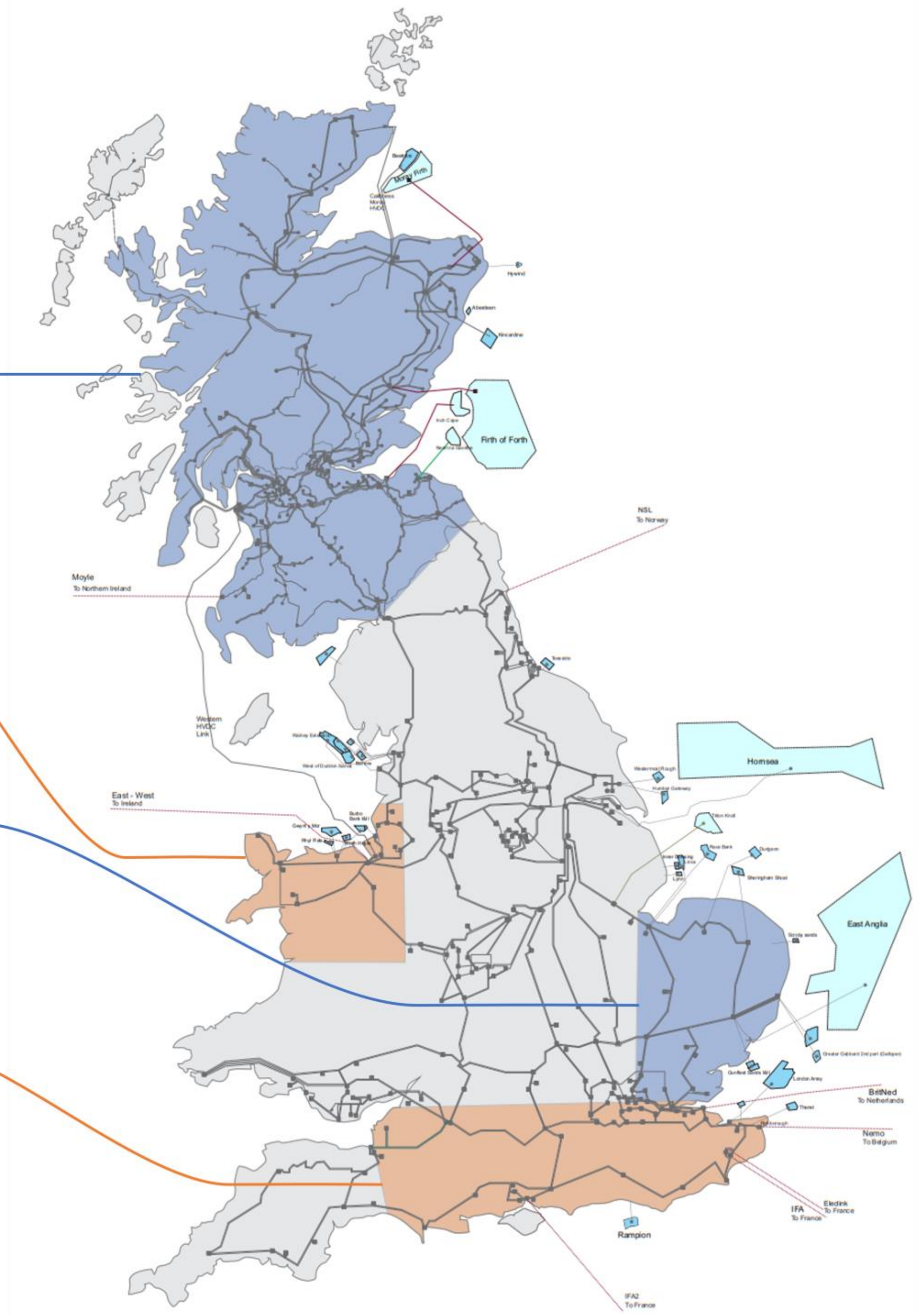
In the next decade the GB Electricity Transmission System will face growing needs in a number of regions

Required transfers across Scottish boundaries are expected to almost triple from today to 2030. The coordinated approach of the Holistic Network Design (HND) provides additional transfer capability to these boundaries, especially B6, and will relieve some of the constraints across Scottish boundaries from 2030 by providing new routes for power flows. Offshore wind generation projects considered by the HND and HND Follow-up Exercise (HNDFUE) are factored into the ETYS's generation background (as per FES 2022).

Required transfers across North Wales boundaries are expected to quadruple between 2027 and 2032 to a maximum of 11GW in the Leading the Way scenario. Large amounts of generation, including new offshore wind generation is expected to connect in this region.

In the East Anglia region, growth in low-carbon and renewable generation over the next decade will continue, potentially reaching a total installed capacity of over 13GW by 2030, up from 5.5GW today, across all FES scenarios.

Interconnector and storage capacity is anticipated to exceed or match transmission connected generation in the South of England around 2030 across all FES scenarios. This will cause network flows in the region to be heavily dependent on interconnector flow conditions and could bring large swings in power transfer which will need to be carefully managed.



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Key Message 2

Click on the boundary names to view the boundary flows

Timely delivery of network reinforcements will significantly help reduce network constraints

The *ETYS* describes the network capability by looking at the maximum secured power transfer between two regions or the power transfer across a boundary.

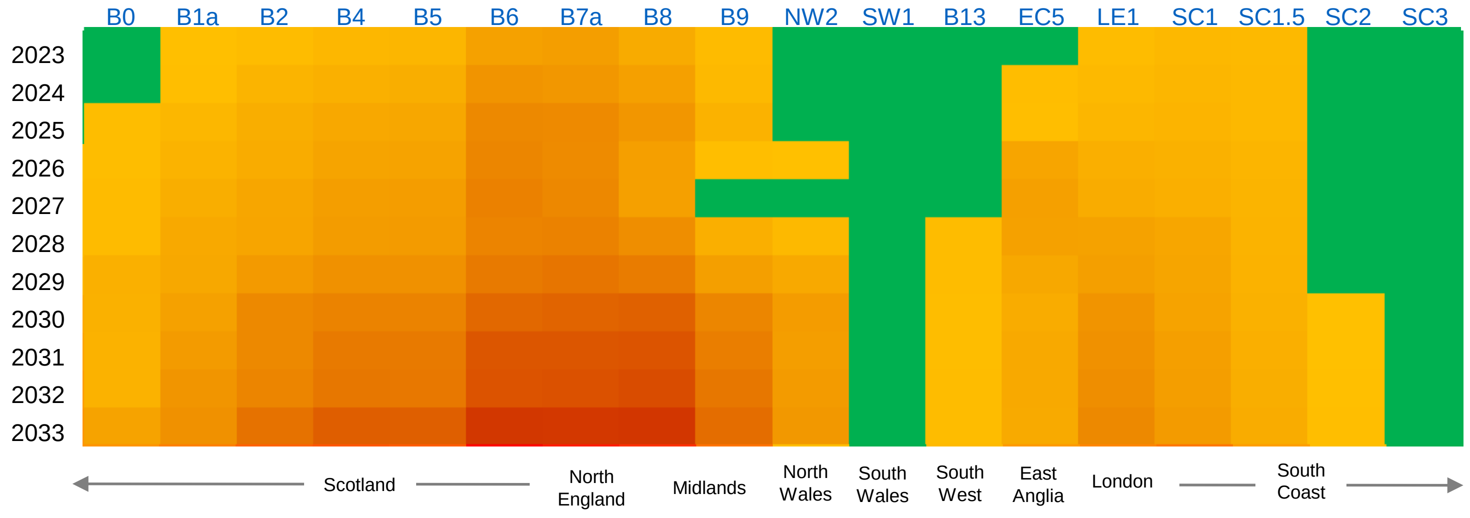
To operate the network safely, we must make sure that the power flows across the boundary do not exceed the capability of the system between the two regions. To prevent this, we must take actions to constrain generation which can incur significant costs.

The two heatmaps to the right illustrate the impact of the network reinforcement options recommended in the NOA 2021/22, showing how these options can significantly reduce constraints by increasing the power transfers across boundaries.

We welcome Ofgem’s decision to accelerate strategic onshore electricity transmission projects through the new Accelerated Strategic Transmission Investment (ASTI) regulatory framework. This recognises the scale and pace required to deliver the Government’s 2030 renewable energy ambitions. Ofgem expect this will have a net benefit to consumers of up to £2.1bn in reduced constraint costs and carbon savings, contingent on timely project delivery.

The ESO is also proactively developing non-build solutions for regions where a short-term requirement has been identified. For example, the EC5 Constraint Management Intertrip Service (CMIS) is being launched to reduce constraint costs across the EC5 boundary (found in East Anglia) for the 2025 – 2030 period by offering additional network management options during real-time network operation. This follows the success of our Constraint Management Intertrip Service now in operation for the B6 boundary.

Excess flows beyond boundary capability **if no action is taken** to reinforce the system



Excess flows beyond boundary capability **with NOA 2021/22 recommended options applied***

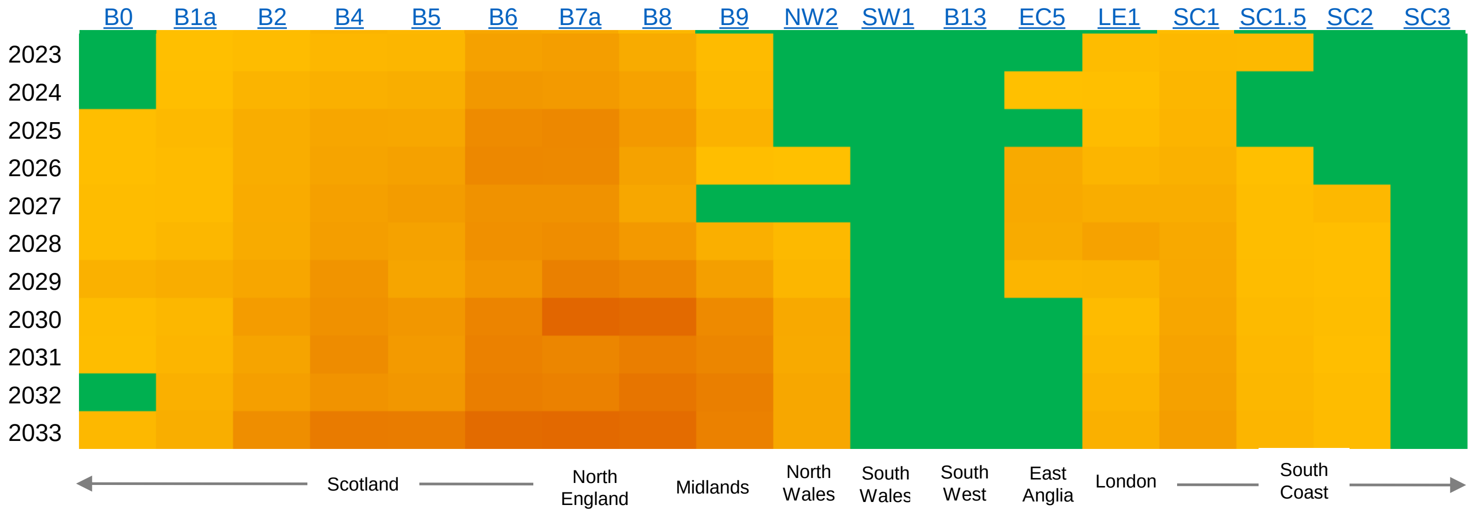


*Chart uses the 2021/22 NOA recommendations against *Leading the Way* scenario in 2022 FES flows

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Key Message 3

We are developing tools to expand our capability to assess a wider range of system conditions and scenarios

The past year has sparked recognition of the importance of a faster transition to net zero and an increasing focus on Great Britain's, as well as the rest of the world's, energy security. This highlights the need for the ESO and the wider industry to secure the network against a wider range of conditions.

Currently, the ETYS process focuses on securing the network against a winter-peak scenario for thermal or low-voltage constraints. With the ongoing rise in intermittent and converter-based technology on the transmission system we need to expand our view of system needs to a wider range of requirements including voltage and stability needs across a range of scenarios over the year.

We have continued to develop our year-round thermal analysis tool (POwer Uncertainty Year-round Analyser – POUYA) to help us evaluate year-round network flows. The ESO is developing new enduring processes to assist us in identifying and managing system needs relating to voltage and stability. We are also working with our transmission and distribution partners to determine how system needs across the transmission-distribution interface could be communicated.

We will value your feedback on our latest ideas and would like to hear your thoughts on how we can continue to enhance ETYS to communicate a wider range of year-round system needs. Read more in our chapter Improving the ETYS to integrate a wider range of system needs.

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ETYS and the Network Planning Process

Introduction

The *ETYS* is the ESO's view of future transmission requirements and the capability of Great Britain's National Electricity Transmission System (NETS) over the next 10 years.

The *ETYS* is important in helping us to understand where investment and development is needed to help us achieve our zero-carbon ambition. *ETYS* 2022's key messages explain some of the most pressing issues we see on the NETS as we drive towards net-zero.

Since the last publication of the ETYS, the world has fundamentally changed. Both the devastating war in Ukraine and the ongoing cost-living-crisis has underlined the importance of reaching Net Zero. A fast transition to Net Zero will bolster our energy security and reduce our exposure to volatile international fossil fuel prices, by harnessing abundant renewable and low carbon resources. This transition will ultimately minimise the costs for consumers in both the near and future term.

About the *ETYS*

The *ETYS* sits at the heart of our network planning process. Using the data from our Future Energy Scenarios (*FES*), we identify points on the transmission network where more transfer capacity is needed to continue to deliver electricity reliably.

Once we have assessed the network requirements, we invite stakeholders to propose solutions to these requirements.

These proposals are assessed through our Network Options Assessment (*NOA*) process, where the most economic and efficient solution is given a recommendation to proceed, and others put on hold or stop.

We are currently transitioning from the NOA to a new Centralised Strategic Network Plan (CSNP), you can find out more about what this means for the ETYS in this chapter.

What's new in *ETYS* 2022

We are continuing to develop our tools to allow us to expand our view of system needs. This year, using our in-house year-round thermal probabilistic tool, we have prepared some examples of how year-round thermal system needs could be communicated. These examples can be found in our new chapter 'Improving the ETYS to integrate a wider range of system needs', and we welcome your feedback.

As we continue to work towards integrating voltage system needs into the ETYS publication we have presented a roadmap to show how the development of an enduring process for assessing voltage needs will be integrated into the network planning cycle.

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Transitioning to the CSNP

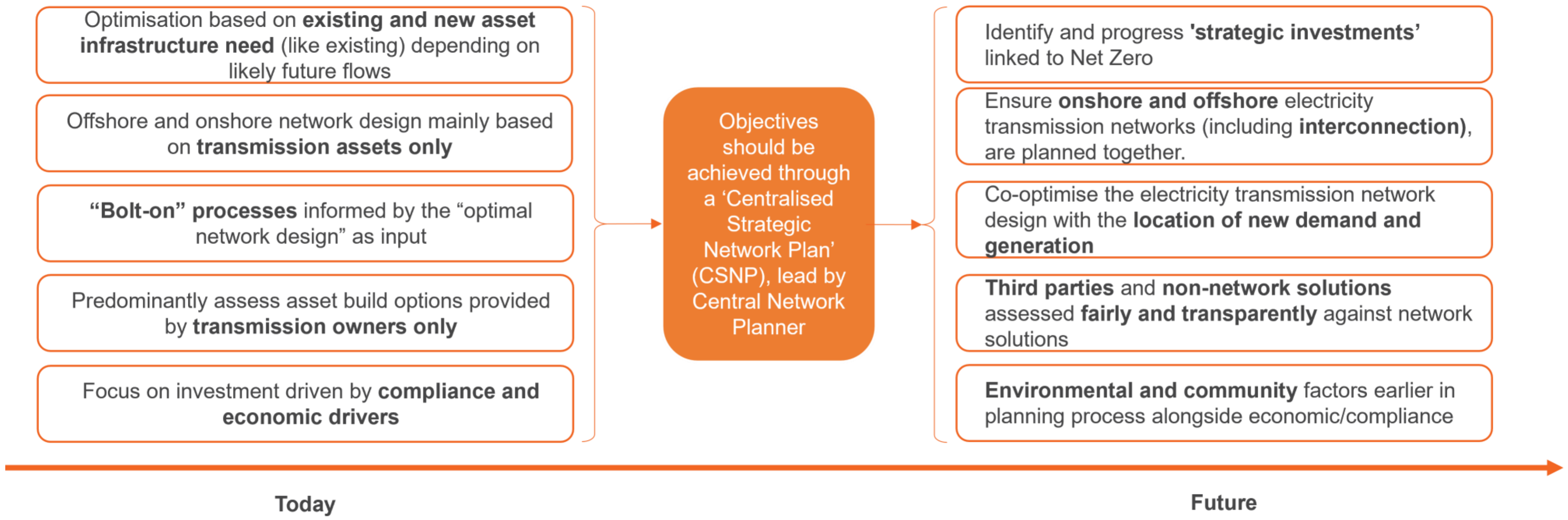
Our network planning process is undergoing major transformation as we transition to the Centralised Strategic Network Plan.

The ESO is working in collaboration with Ofgem on the Electricity Transmission Network Planning Review (ETNPR) to review our network planning processes to ensure that the network design and investment processes in Great Britain are fit for the future. In order to meet our ambitious decarbonisation targets, the pace and scale of our Electricity Network planning processes must change. We are therefore moving away from an annual network planning assessment cycle to a new Centralised Strategic Network Plan (CSNP).

The objectives of the CSNP are displayed in the figure below. The CSNP will proactively identify, design and progress investments in the network and will ensure that the transmission network is planned holistically, onshore, offshore, and across vectors.

There will be a shift away from focusing predominately on winter peak thermal flows moving closer to a year-round system needs assessment which includes voltage and stability requirements.

The options assessment will be adapted as part of the CSNP to create a level playing field whereby network options are assessed against third party and innovative solutions. In addition to economic assessment, the CSNP will also consider environmental and community factors earlier in the planning cycle.



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Transitioning to the CSNP

As we prepare for these changes, our network planning activities will look very different from previous network planning cycles.

We are in a state of evolution from the NOA to the CSNP and during this transition there will be some iterations of a transitional CSNP to continue informing network planning and investment decisions whilst we develop the enduring CSNP process.

The *first transitional Centralised Strategic Network Plan* (tCSNP1) was published in July 2022. This included the Holistic Network Design (HND) and the NOA 2021/22 Refresh. These publications together provided network designs and onshore network investment recommendations required to deliver the UK Government's ambition for 50GW of offshore wind by 2030.

As we prepare the framework and methodology for the enduring CSNP we will continue to adapt our planning processes in order to meet our ambitious objectives. To find out more about the CSNP or the Network Planning Review contact us at: box.NPR@nationalgrid.com

The second transitional Centralised Strategic Network Plan (tCSNP2) will be delivered in 2023 and will include:

Future view of supply and demand
Across a range of scenarios illustrating credible pathways to Net Zero (FES).

Offshore Transmission Network Review designs through HNDFUE
These build on the HND by connecting a further 20.7 GW of offshore wind in Scotland and a revised total capacity of 4.2GW in the Celtic Sea.

Future System Needs (ETYS)
This will include a wider range of system analysis, starting with year-round thermal analysis and expanding to include voltage and then stability needs in line with our ongoing tools development.

Transitional Centralised Strategic Network Plan 2 (published in December 2023)
tCSNP2 will build on the foundations of the existing NOA process providing recommendations on which onshore reinforcements should receive investment. This will also include any new network needs identified through HNDFUE.

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The work behind the *ETYS*

To identify the future transmission requirements of the GB NETS there are several inputs that are fed into the planning process and at various stages.

Using *FES* to Determine Demand and Generation

The process starts with the *FES*. These are a credible range of scenarios for how energy will be produced and consumed up to 2050. These scenarios form the foundation of our studies and analysis, and we use them to determine the peak demand and generation capacity regionally.

Apply Dispatch and SQSS Planning Criteria

We determine the winter-peak network flows of the GB NETS by dispatching the generation from the *FES* to balance with peak demand. Network behaviour is simulated according to the NETS SQSS planning conditions to determine network conditions such as circuit loading and voltage levels.

Determine Boundary Capabilities

We work with the transmission owners to undertake power system analysis to determine the boundary capability limitations in accordance with the SQSS limitations.

Determine Network Requirements

Finally, looking at the capability of the different boundaries on the network and the future boundary flows we expect, we identify the points on the transmission network where more transfer capacity is needed to help us continue to deliver electricity reliably.

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National Electricity Transmission System (NETS)

As the ESO, we are responsible for the system operation of the transmission networks in England, Wales, Scotland and offshore.

The NETS is mainly made up of 400kV, 275kV and 132kV assets connecting separately owned generators, interconnectors, large demands and distribution systems.

Here, ‘transmission’ generally means assets at 132kV or above in Scotland or offshore, but in some cases includes other lower voltage assets.

In England and Wales, it relates mainly to assets at 275kV and above. There are three onshore transmission owners (TOs) in GB:

- Scottish Hydro Electric Transmission owning the network in the north of Scotland.
- Scottish Power Transmission owning the network in the south of Scotland.
- National Grid Electricity Transmission owns the transmission network in England and Wales.

The offshore transmission systems are also separately owned.

There are 24 licenced offshore transmission owners (OFTOs) appointed through Ofgem’s competitive tendering process.

They connect operational offshore wind farms given Crown Estate seabed leases in allocation rounds.

The TOs and ESO work together to reflect real world changes in network modelling to accurately assess network behaviour under differing conditions.

1 Scottish & Southern Electricity Networks

2 SP ENERGY NETWORKS

3 nationalgrid

Together with the transmission owners, the ESO works to make sure the assumptions made in the analysis are acceptable and any changes in their networks are reflected correctly in the network models.

This ensures the *ETYS* portrays an accurate representation of the current transmission capabilities and identifies future requirements.

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What is a boundary?

A boundary splits the system into two parts, crossing critical circuit paths that carry power between the areas where power flow limitations may be encountered.

A boundary splits the system into two parts, crossing critical circuit paths that carry power between the areas where power flow limitations may be encountered.

Defining the boundaries has evolved over many years of planning and operating the transmission system. When significant changes occur, new boundaries may be defined and some boundaries either removed or amended and we communicate any changes with our stakeholders.

We do not study all boundaries, specifically those where no significant changes are identified in the FES generation and demand data compared to previous years. We assume the same capability as the previous year for these boundaries.

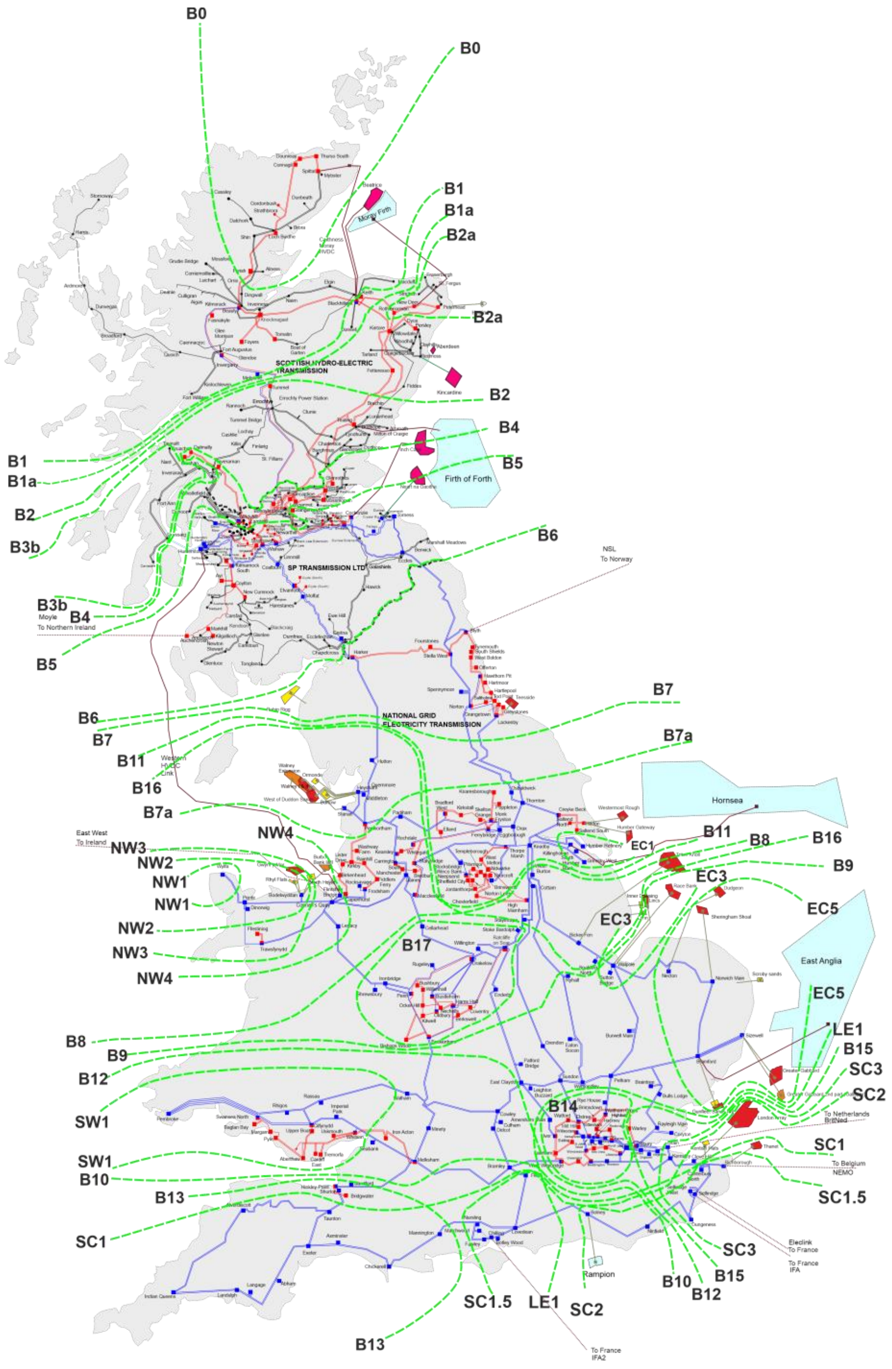
The boundaries used by ETYS and NOA can be split into two different types:

Local boundaries

Small areas of the NETS with a high concentration of generation. These small power export areas can give high probability of overloading the local transmission network due to too much generation operating simultaneously.

Wider boundaries

Large areas containing significant amounts of both generation and demand. The SQSS boundary scaling methodologies assess the capability of the wider boundaries. These consider both the geographical and technological effects of generation, allowing for a consistent capability and requirements assessment.



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Analysing the NETS boundaries

How do we determine requirements across Boundaries?

When we assess future requirements, we bear in mind that we have many signed contracts for new generation, demand and interconnectors seeking to connect to the NETS.

We do not know precisely how much new capacity there will be, when it will connect, or when existing generation will shut down. Our FES provides four credible scenario pathways to 2050 and we use these to identify expected future boundary flows as required by the NETS Security and Quality of Supply Standard (NETS SQSS).

For each boundary, we work with the transmission owners to undertake power system analysis to determine the boundary capability which is the maximum MW flow that can be transferred across a boundary while maintaining compliance with the NETS SQSS.

Limiting factors on transmission capacity include:

- Thermal circuit rating
- Voltage constraints
- Dynamic stability

For the ETYS network assessment, contingencies are applied, and the most severe limitation is used to determine the network boundary capability.

The base capability of each boundary can be seen in the Electricity Transmission Network section.

What planning criteria do we use?

The NETS SQSS defines the methodology to assess boundary planning requirements, based on:

The security criterion

The boundary transfer requirements needed to satisfy demand without relying on intermittent generators or imports from interconnectors.

The methodology for determining the security needs and capability is set out in SQSS Appendices C and D.

The economy criterion

The boundary transfer requirements when demand is met with high output from intermittent and low-carbon generators and imports from interconnectors.

This ensures capacity is adequate to transmit power from highly variable generation without any network constraint.

The methodology for determining the economy needs and capability are found in SQSS Appendices E and F.

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Electricity Transmission Network Requirements

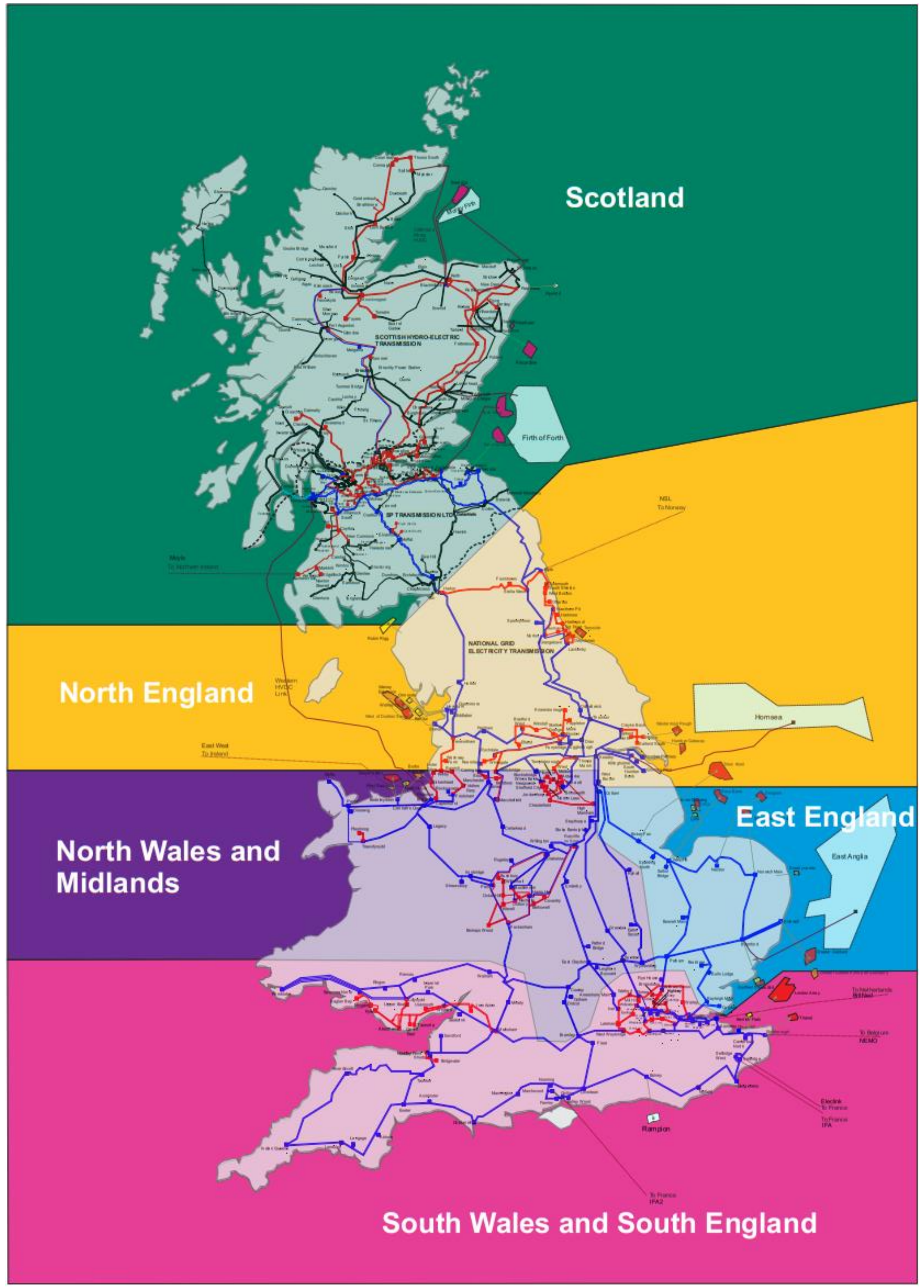
Introduction

Great Britain's National Electricity Transmission System (NETS) must continue to adapt and be developed so power can be transported from source to demand, reliably and efficiently.

In this chapter, we:

- Describe the NETS characteristics.
- Discuss each of the NETS boundaries, grouped by region, to help you gain an overview of requirements by boundary and regionally.
- Provide analysis to show how and when, in the years to come, the NETS will potentially face growing future networks needs in a number of regions.

This chapter is broken into regions as shown on the map to the right.



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How to interpret the boundary graphs?

The graphs show a distribution of power flows for each of our Future Energy Scenarios, in addition to the boundary power transfer capability and NETS SQSS requirements for the next twenty years.

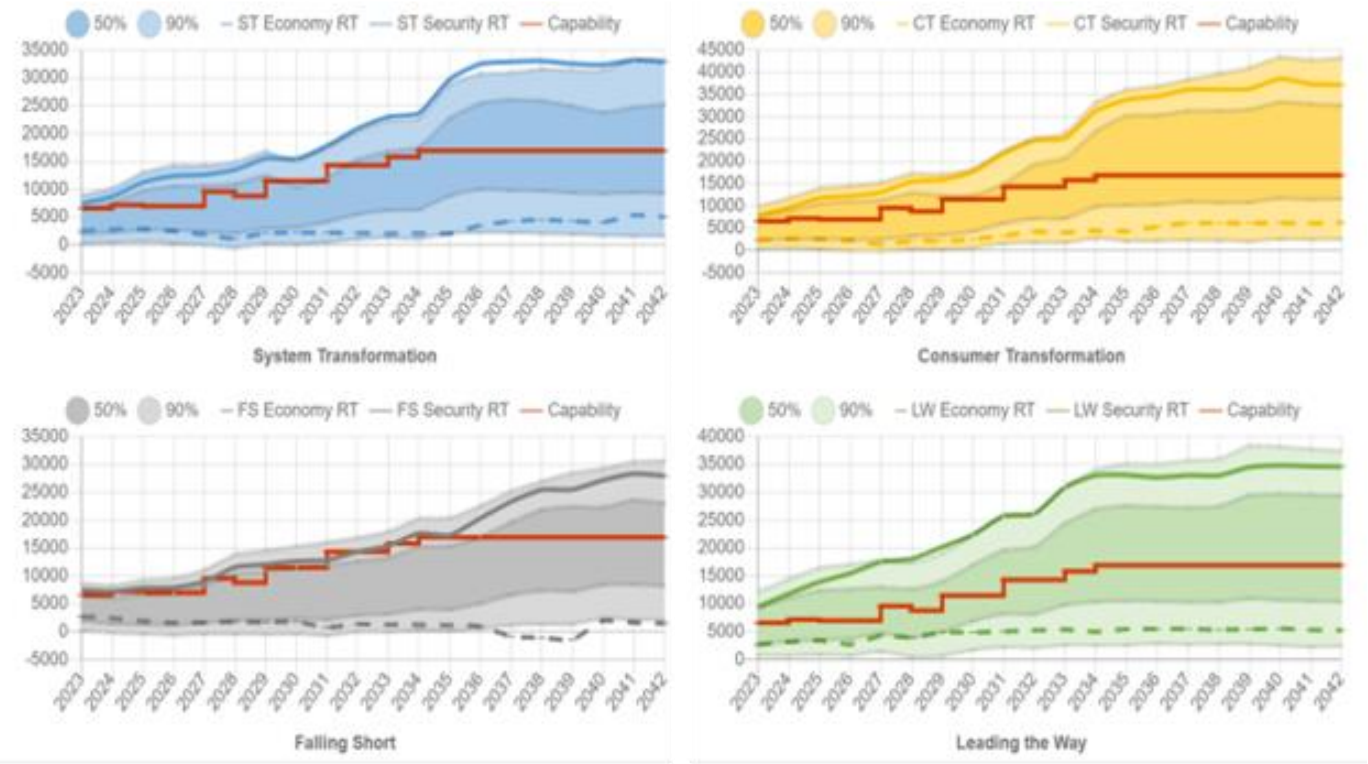
Each scenario has different generation and demand so produces different boundary power flow expectations. From applying the methodology in the NETS SQSS for wider boundary planning requirements (as discussed in the previous chapter), we determine for each scenario:

- The economy criteria - solid coloured line
- Security criteria - dashed coloured line
- Current boundary capability - solid black line

Due to the NOA being published after the ETYS, the boundary capability line (**red line**) is prepared from the 2021/22 NOA optimal path released in July 2022 which uses the 2021 FES and ETYS data. This is the best information available at the time of publication and will change annually and over time as the network, generation, demand and more importantly the NOA optimal path changes. More information about the NOA methodology can be found here. The 50%, 90%, Economy required transfer (RT) and Security RT are calculated from the 2022 FES and ETYS processes. Where the NOA transfer capability is not available, there is a **black line** that provides the current ETYS 2022 transfer capability

Note: Boundary capability line is affected by the generation and demand profiles within each FES background. Therefore, the graphs are provided for indicative purposes only and cannot be directly compared.

The calculations of the annual boundary flow are based on unconstrained market operation, meaning network restrictions are not applied. This way, the minimum cost generation output profile can be found. We can see where the expected future growing needs could be by looking at the power flows in comparison with boundary capability.



On each graph, the two shaded areas provide confidence as to what the power flows would be across each boundary:

- The darker region shows 50% of the annual power flows
- The lighter region shows 90% of the annual power flows

From the regions, we can show how often the power flows expected in the region split by the boundary are within its capability (red line). If the capability of the boundary is lower than the two regions over the next 20 years, there might be a need for reinforcements to increase the capability. However, if the line is above the shaded regions, it shows that there should be sufficient capability here and that potentially no reinforcements are needed from a free market power flow perspective until the shaded regions exceed the capability (red line).

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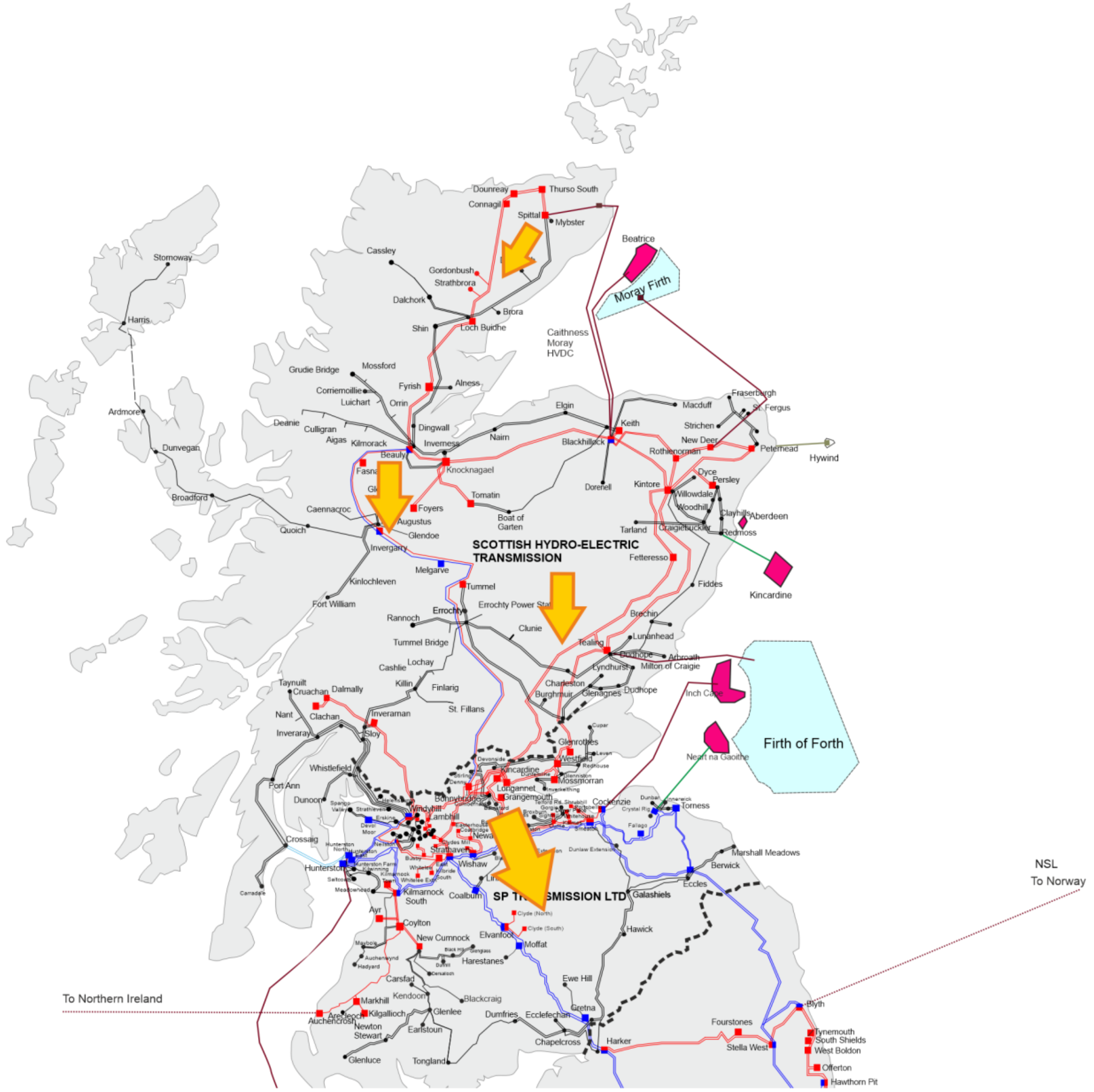
Scotland

The onshore transmission network in Scotland is owned by SSEN Transmission and SP Transmission.

The Scottish NETS is divided into 7 boundaries –

- B0 – Upper North SSEN Transmission
- B1a – North West SSEN Transmission
- B2 – North to South SSEN Transmission
- B3b – Kintyre and Argyll SSEN Transmission
- B4 – SSEN Transmission to SP Transmission boundary (shared by SSEN Transmission and SP Transmission)
- B5 – North to South SP Transmission
- B6 – SP Transmission to NGET (shared by SP Transmission and National Grid Electricity Transmission)

The map on the right shows the general pattern of power flow directions expected to occur most of the time in the years to come up to 2031, i.e. power will generally flow from north to south. The arrows in the diagram illustrate power flow directions and are approximately scaled relative to the winter peak flows.



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Regional Drivers - Scotland

Scotland is experiencing large growth in renewable generation capacity, often in areas where the electricity network is limited.

Due to Scotland's abundant availability of natural resources, both on and offshore, they are experiencing a large growth in renewable generation capacity, however this is often in areas where the current electricity network is limited.

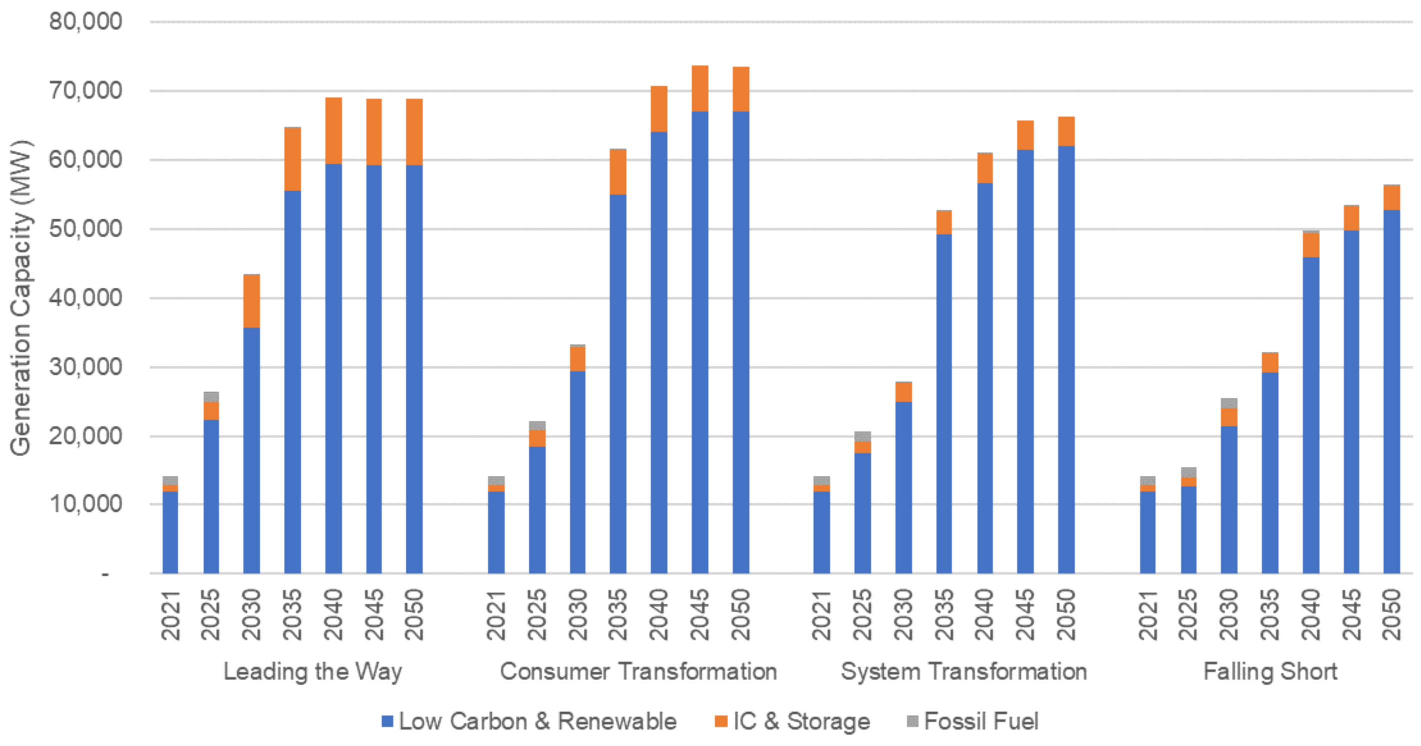
Over the next 10 years, this rapid growth in renewable generation capacity, mainly from offshore wind will contribute significantly to higher power transfer requirements in Scotland. This will increase the network reinforcement needs in some areas.

Across all the scenarios in the FES, the fossil fuel generation capacity in Scotland reaches almost zero between 2030 - 2035. By 2030, all scenarios show an increase in wind generation capacity between 11 – 25 GW, the development of further wind generation in Scotland is key to reaching the UK & Scottish governments' targets for 50GW of offshore wind and 20GW of onshore wind by 2030 respectively.

With the closure of Hunterston B nuclear power station in January 2022, Torness power station is the last remaining nuclear plant in Scotland and is itself scheduled for closure by 2028. There will be no significant fossil fuel generation remaining in Scotland following the closure of Peterhead CCGT, though there are plans to possibly develop a 910MW carbon capture and storage equipped plant at the same site in the future.

The reduction in synchronous generation could lead to system operability challenges with reduced short circuit levels and inertia. This potentially leads to increasingly dynamic network behaviour depending on factors such as weather conditions and price of electricity. To overcome this challenge, the NOA Stability Pathfinder Phase 2 successfully procured cost-effective services which will meet our immediate and future short-circuit level and inertia needs in the Scottish region, contracts were awarded mid-2022.

With gross demand in Scotland not expected to exceed 6GW by 2030 (with an average embedded generation output of 1.7GW), generation capacity in Scotland far exceeds demand. Scotland will be expected to export power into England most of the time.



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Regional Drivers - Scotland

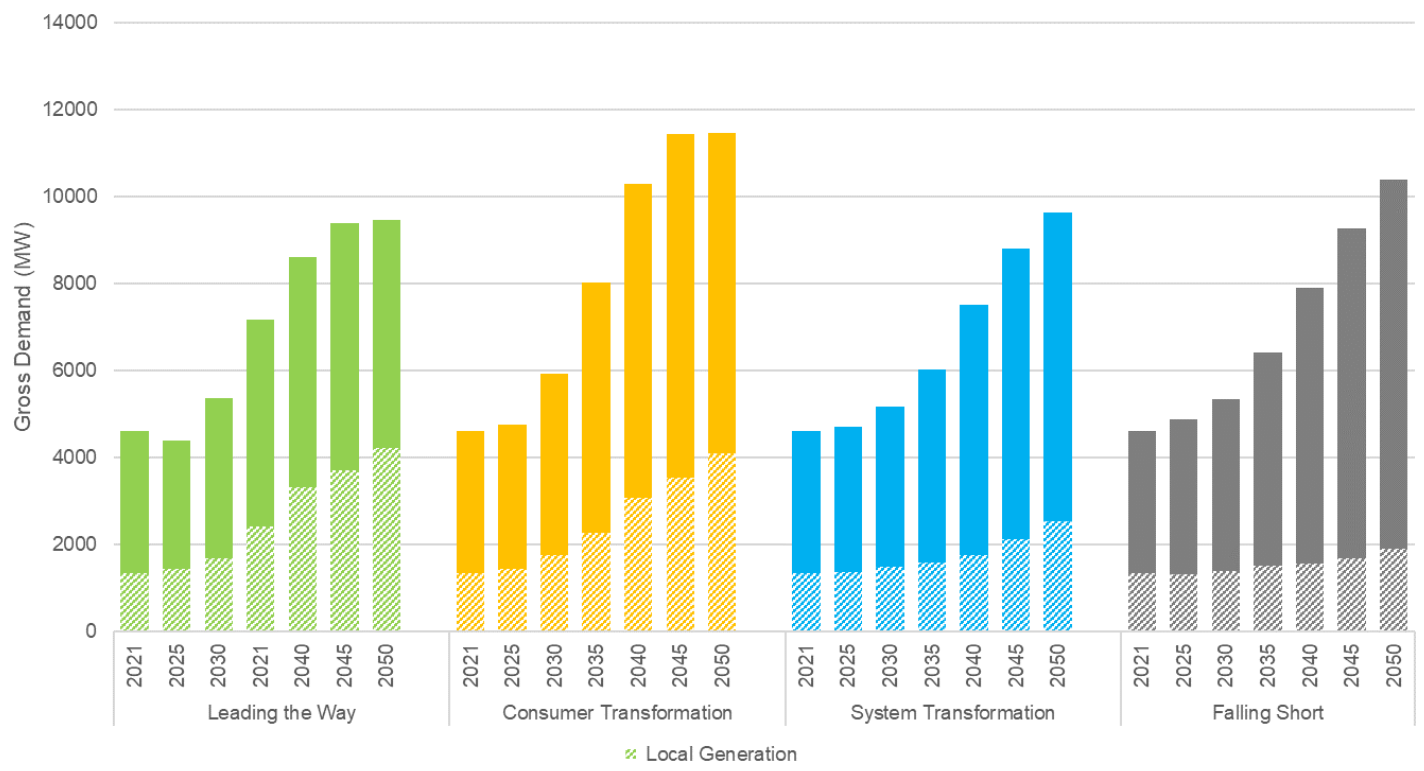
With such high capacities of renewable generation connected in Scotland, under prolonged periods of low wind it is also credible that Scotland may need to import power from England due to the low synchronous generation capacity in the region.

The anticipated increase in renewable generation in Scotland is increasing power transfer across the Scottish boundaries. On a local basis, with the anticipated generation development in the north of Scotland, including generation developments on the Western Isles, Orkney and the Shetland Islands, there may be limitations on power transfer from generation in the remote Scottish NETS locations to the main transmission routes (B0, B1a). The recent decision on Accelerating Strategic Transmission Investments (ASTI) by Ofgem included a 1.8GW Western Isles transmission link which will alleviate some of these limitations and facilitate the transfer of renewable generation to the mainland.

As generation within these areas increases over time, due to the high volume of new renewable generation seeking connection, boundary transfers across the Scottish NETS boundaries (B0, B1a, B2, B3b, B4 and B5 and B6) increase. There are significant constraints observed across the B6 boundary (Anglo-Scottish border) which the ESO is looking to address via a commercial solution, the B6 Constraint Management Intertrip Service (CMIS). This has contracted with generators (totalling 2GW in capacity) in the region to provide a more economical method of managing constraints than actions through the balancing mechanism.

Significant reinforcements are currently planned for the Scotland region, with some being actively accelerated following Ofgem's decision on the Accelerated Strategic Transmission Investment (ASTI) framework, in order to facilitate the connection of large volumes of offshore wind from the HND and the upcoming HNDFUE.

The need for any new network reinforcement to address the above-mentioned potential capability issues will be evaluated in the upcoming HNDFUE and tCSNP2 following input from Transmission Owners and other interested stakeholders. Following the evaluation, the preferred reinforcements for the Scotland region will be recommended.



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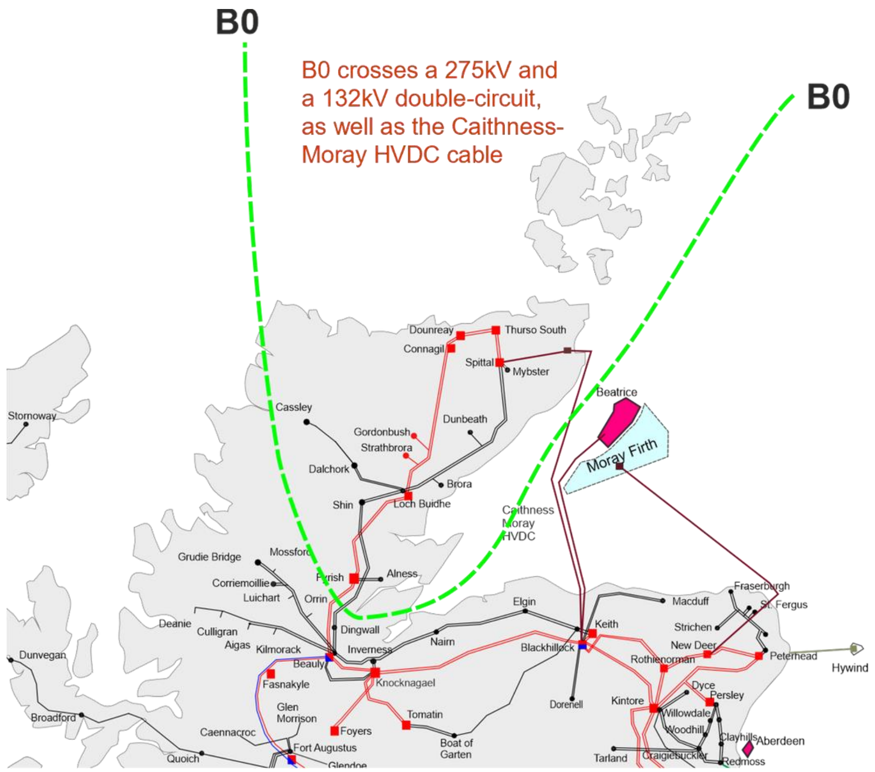
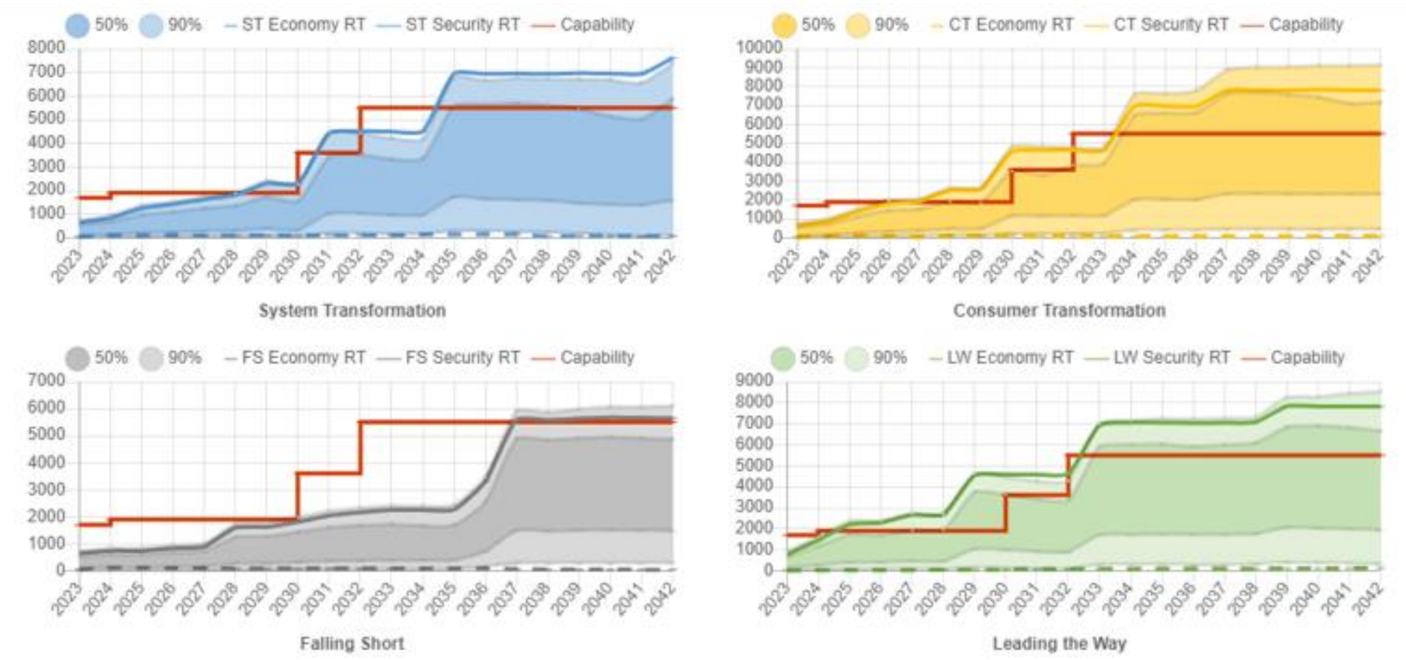
Boundary B0 – Upper North SSEN Transmission

Boundary B0 separates the area north of Beauly, comprising the north of the Highlands, Caithness, Sutherland and Orkney.





The power transfer through B0 is increasing due to the substantial growth of renewable generation north of the boundary. This generation is primarily centred around both onshore and offshore wind. There is also the prospect of new marine generation resource in the Pentland Firth and Orkney waters in the longer term.

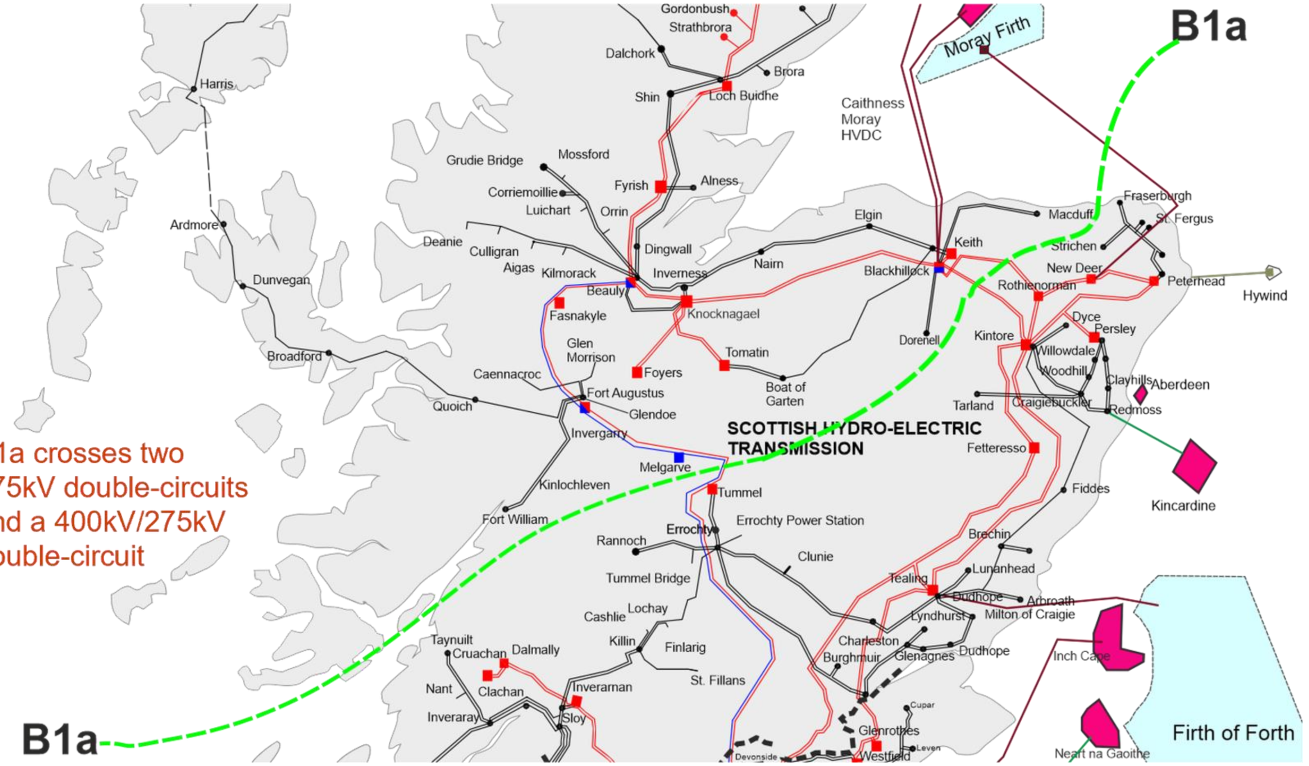
The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 1.15GW due to a thermal constraint on the Beauly - Shin 132kV circuit

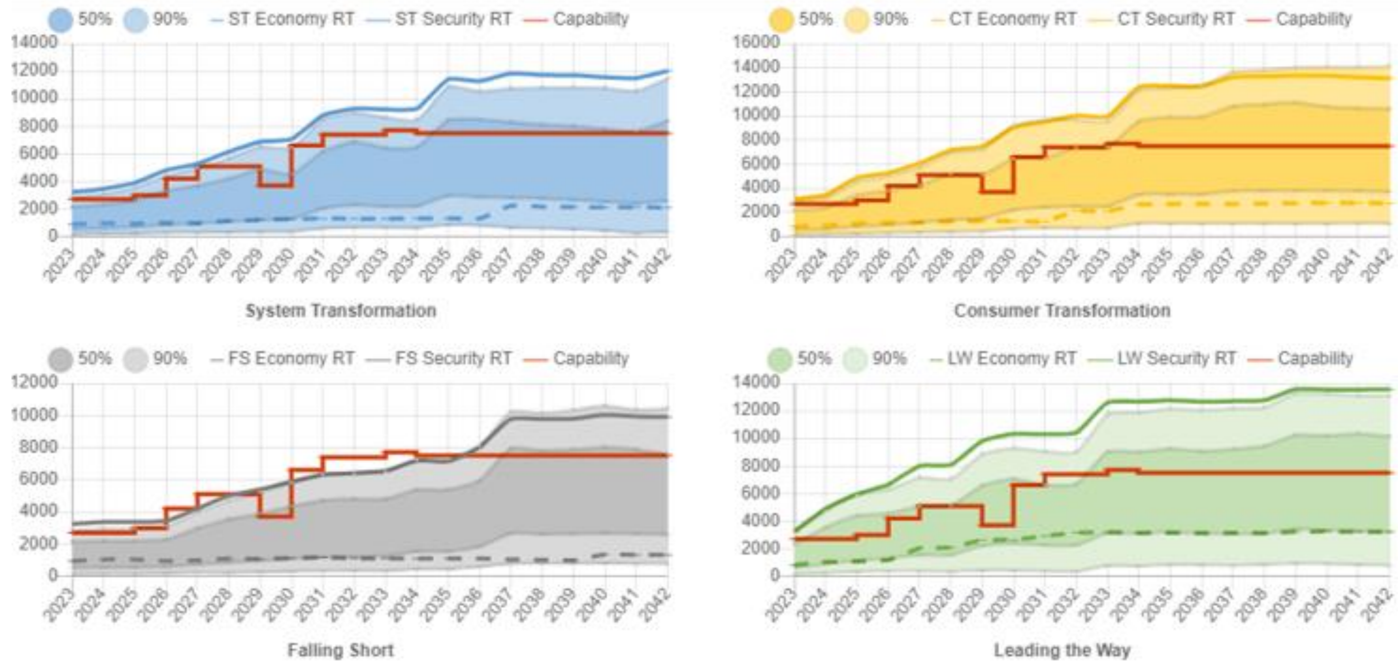
ETYS 2022 / Scotland 23

Boundary B1a – North West SSEN Transmission

Boundary B1a runs from the Moray coast near Macduff to the west coast near Oban, separating the north west of Scotland from the southern and eastern regions.



B1a crosses two 275kV double-circuits and a 400kV/275kV double-circuit



New renewable generation connections north of the boundary are expected to result in a significant increase in export requirements across the boundary, especially along the Beauly – Denny circuit. All generation north of boundary B0 also lies behind boundary B1a.

In all the future energy scenarios, there is an increase in the power transfer through B1a due to the large volume of renewable generation connecting to the north of this boundary. Although this is primarily onshore wind and hydro, there is the prospect of significant additional wind, wave and tidal generation resources being connected in the longer term. Contracted generation behind boundary B1a includes the renewable generation on the Western Isles, Orkney and the Shetland Isles with a considerable volume of large and small onshore wind developments. Future connection of several new pumped storage assets in the North-West of the country is planned.

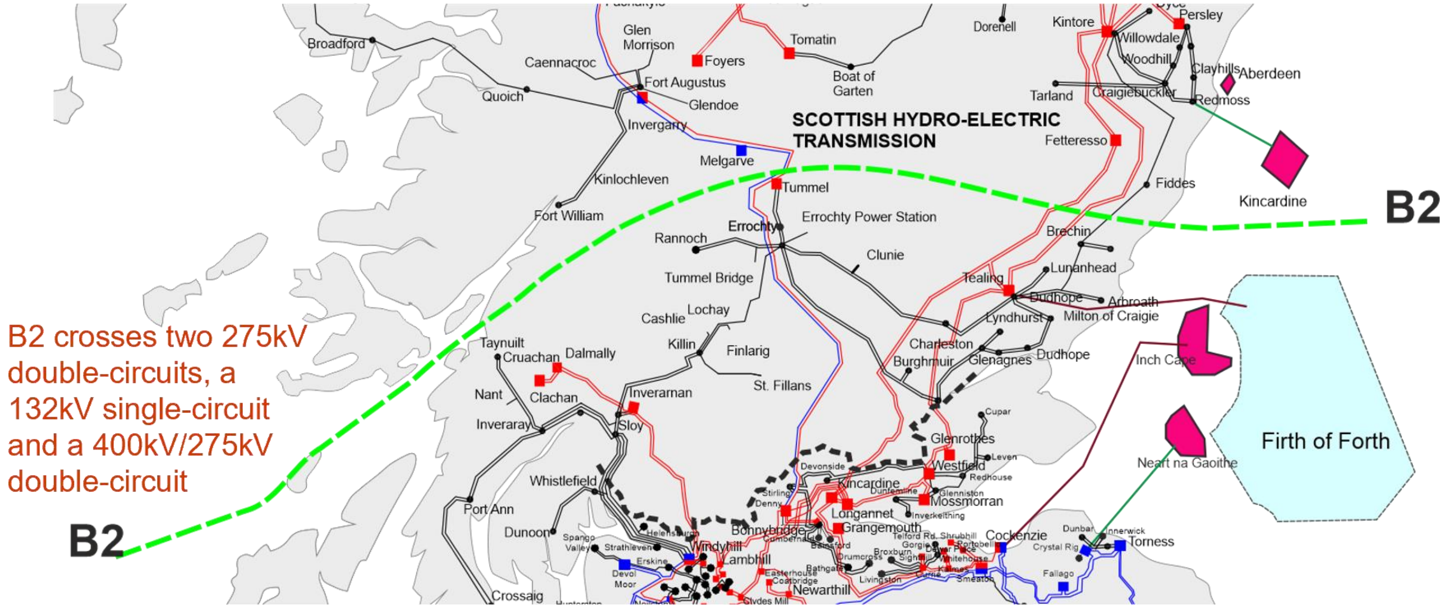
The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

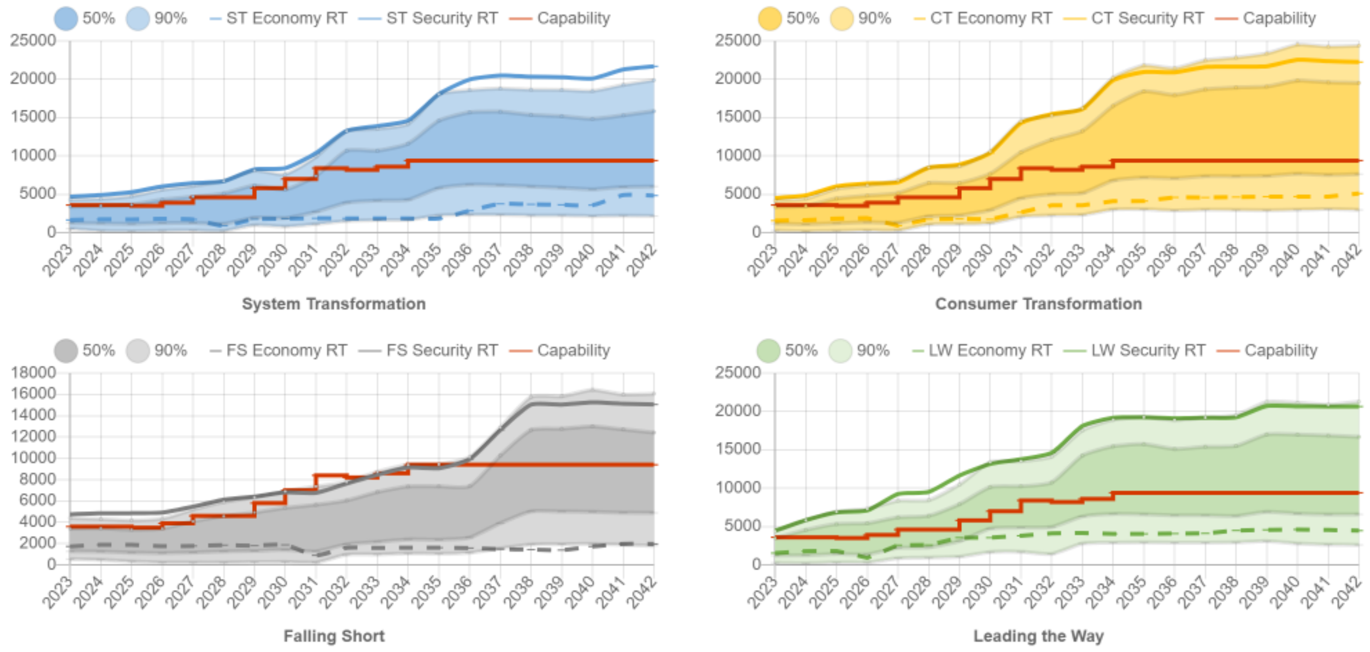
The current boundary capability is limited to 1.7GW due to a thermal constraint on the Errochty - Killin 132kV circuit

ETYS 2022 / Scotland 24

Boundary B2 – North to South SSEN Transmission

Boundary B2 cuts across the Scottish mainland from the east coast between Aberdeen and Dundee to near Oban on the west coast crossing the main north-south routes from the north of Scotland.





The potential future boundary transfers for boundary B2 are increasing at a significant rate because of the high volume of renewable generation to be connected to the north of the boundary. This increased generation capacity will drive increasing power flows down the east coast 275kV circuits.

The increase in the required transfer capability for this boundary across all generation scenarios indicates the strong potential need to reinforce the transmission system.

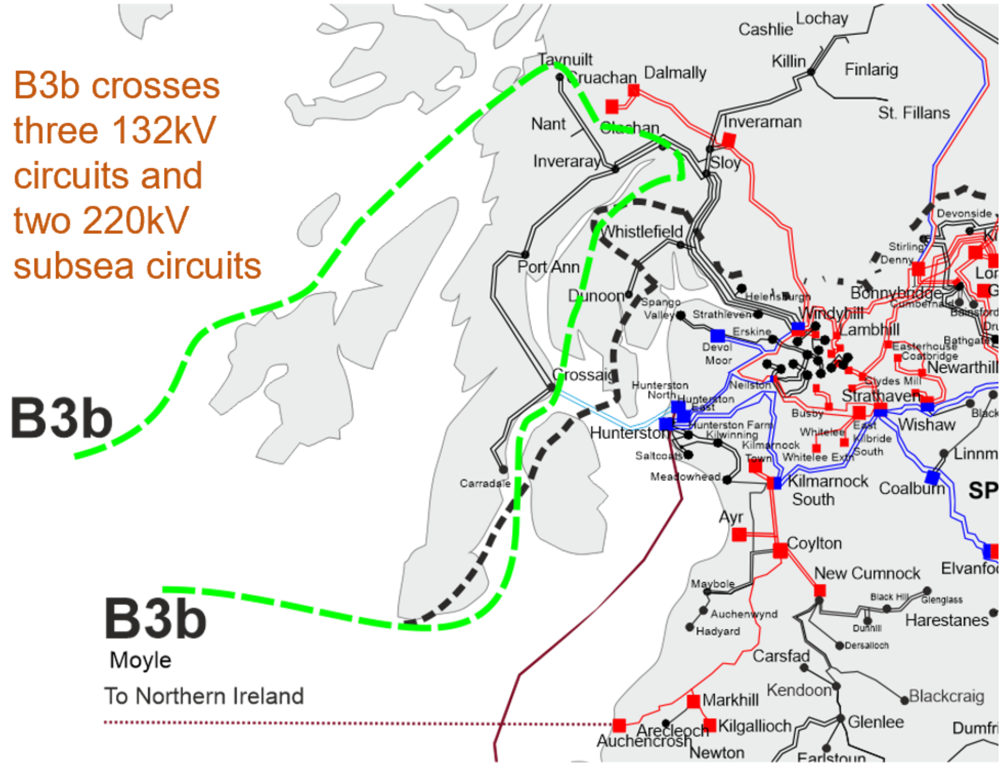
The generation behind boundary B2 includes both onshore and offshore wind, with the potential for additional pumped storage plant to be located in the Fort Augustus area. The thermal generation at Peterhead lies between boundaries B1a and B2, as do several offshore windfarms and the proposed future North Connect interconnector with Norway.

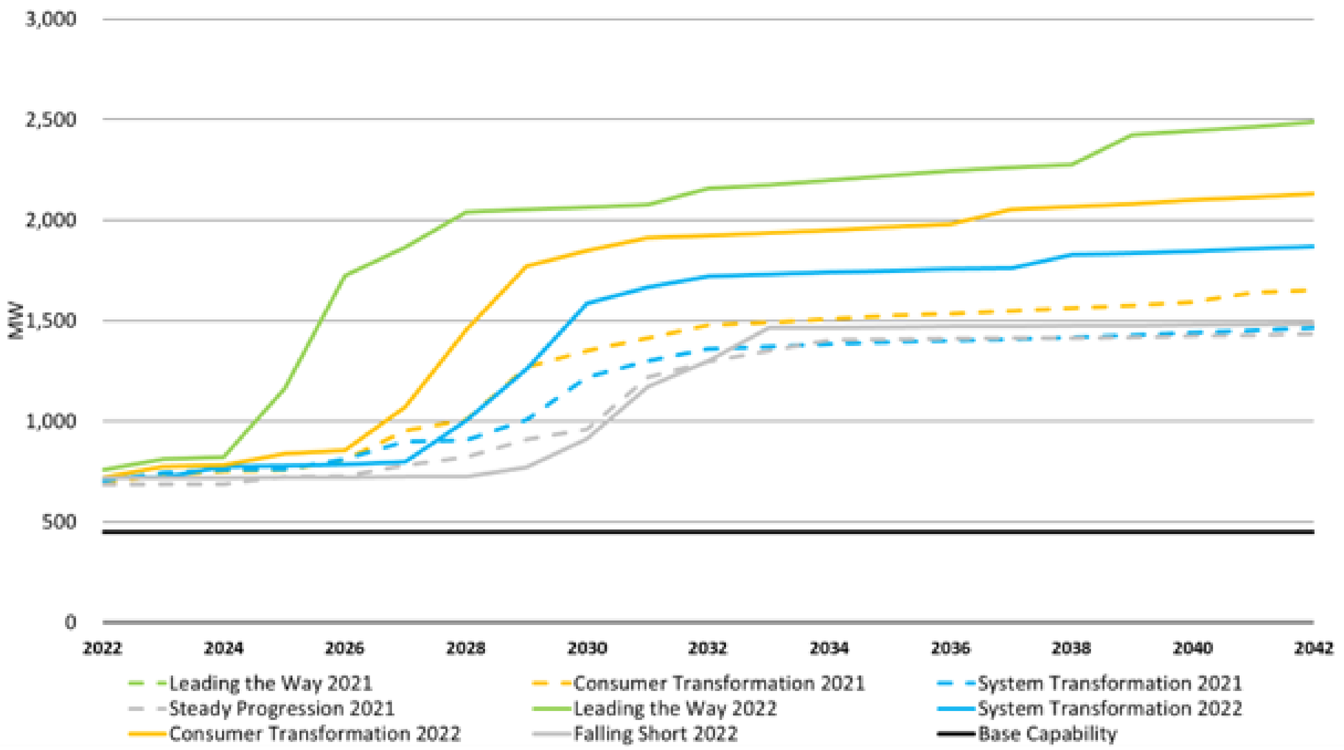
The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 2.6GW due to a thermal constraint on the Fetteresso - Kincardine 275kV circuit

Boundary B3b – Kintyre and Argyll SSEN Transmission

Boundary B3b encompasses the Argyll and Kintyre peninsula, and boundary assessments are used to show limitations on the generation power flow out of the peninsula.





The percentile power flows are not determined for the B3b boundary. The capability line (in black) is based on the ETYS transfer capability using FES 2022 data, shown below.

The generation within boundary B3b includes both onshore wind and hydro generation, with the prospect of further wind generation resource and the potential for marine generation being connected in B3b in the future, triggering the requirement for future reinforcement of this network.

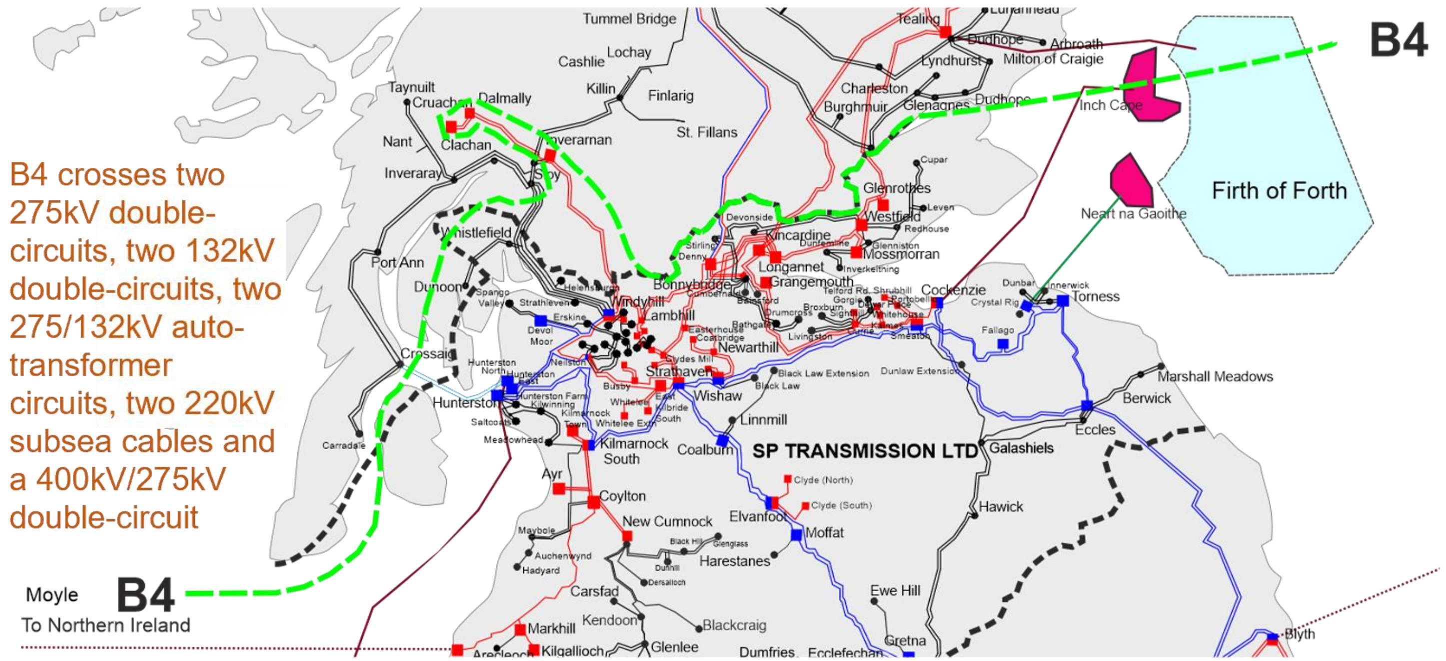
B3b is not currently subject to NOA reinforcement options as current contracted enabling works for customer connections will increase the ability to export power from this region, effectively splitting the network in the South West and altering the boundary.

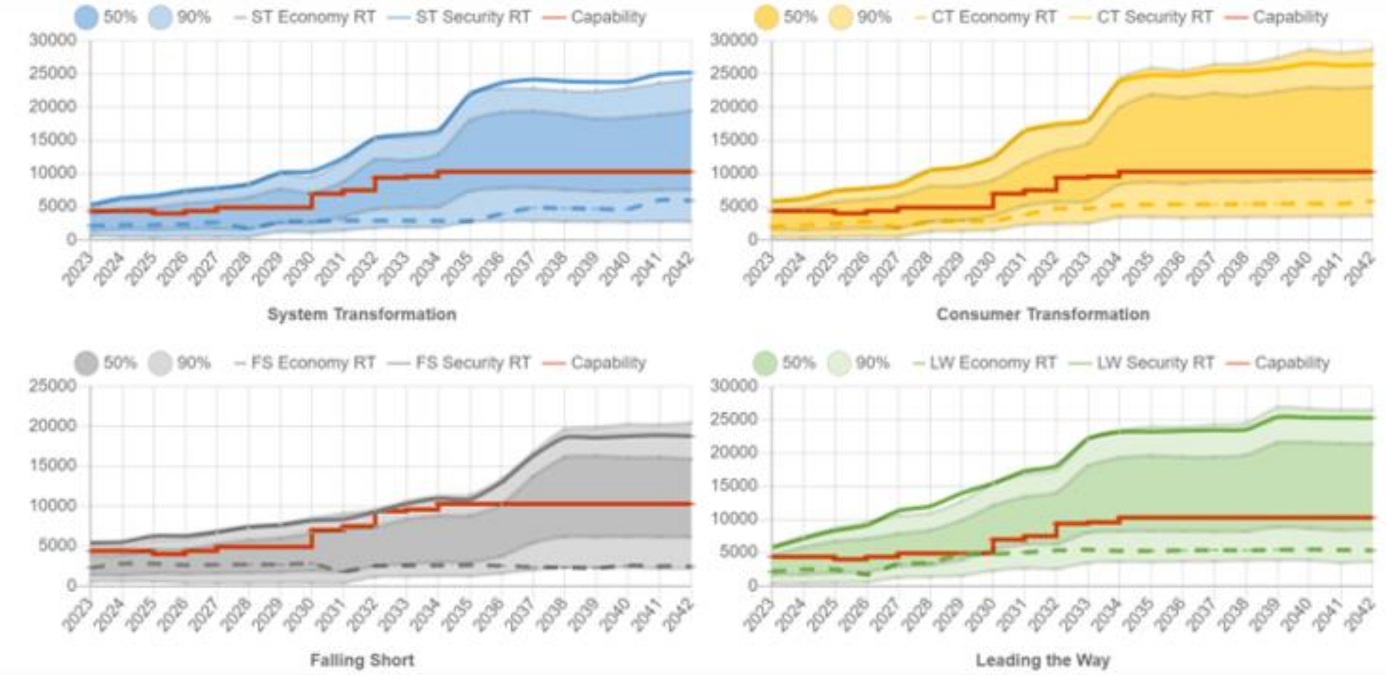
The current boundary capability is limited to 0.44GW due to a thermal constraint on the Inveraray - Sloy 132kV circuit

ETYS 2022 / Scotland 26

Boundary B4 – SSEN Transmission to SP Transmission

Boundary B4 separates the transmission network at the SP Transmission and SSEN Transmission interface running from the Firth of Tay in the east to the north of the Isle of Arran in the west.





With increasing generation and potential interconnectors in the SSEN Transmission area for all scenarios, the required transfer across boundary B4 is expected to increase significantly over the ETYS period. The prospective generation behind boundary B4 includes around 2.7GW from Rounds 1–3 and Scottish territorial waters offshore wind located off the coast of Scotland.

In all scenarios in the FES, the power transfer through boundary B4 increases because of the significant volumes of generation connecting north of the boundary, including all generation above boundaries B0, B1a, B2 and B3b. This is primarily onshore and offshore wind generation, with the prospect of significant further offshore wind and new marine generation resource being connected in the longer term.

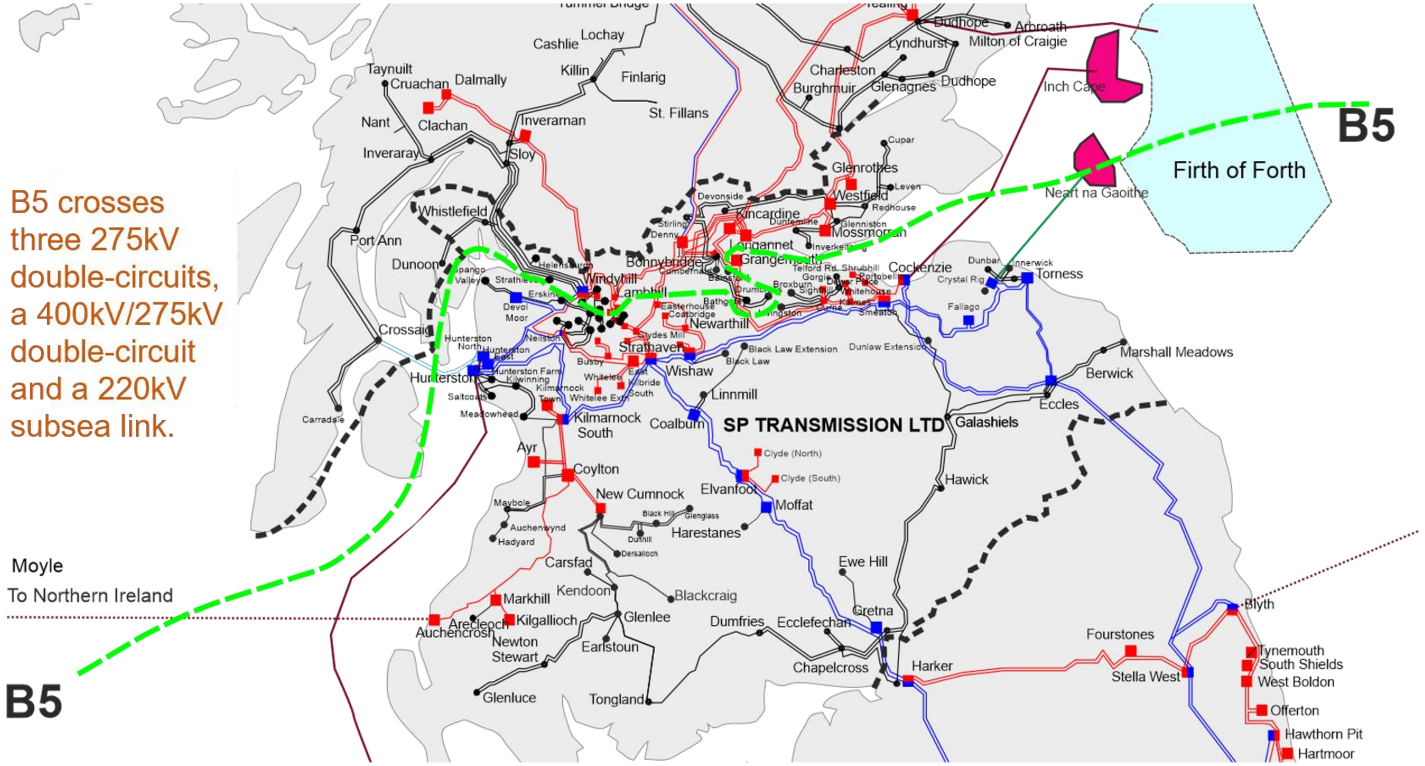
The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 3.4GW due to a thermal constraint on the Westfield - Longannet 275kV circuit

ETYS 2022 / Scotland 27

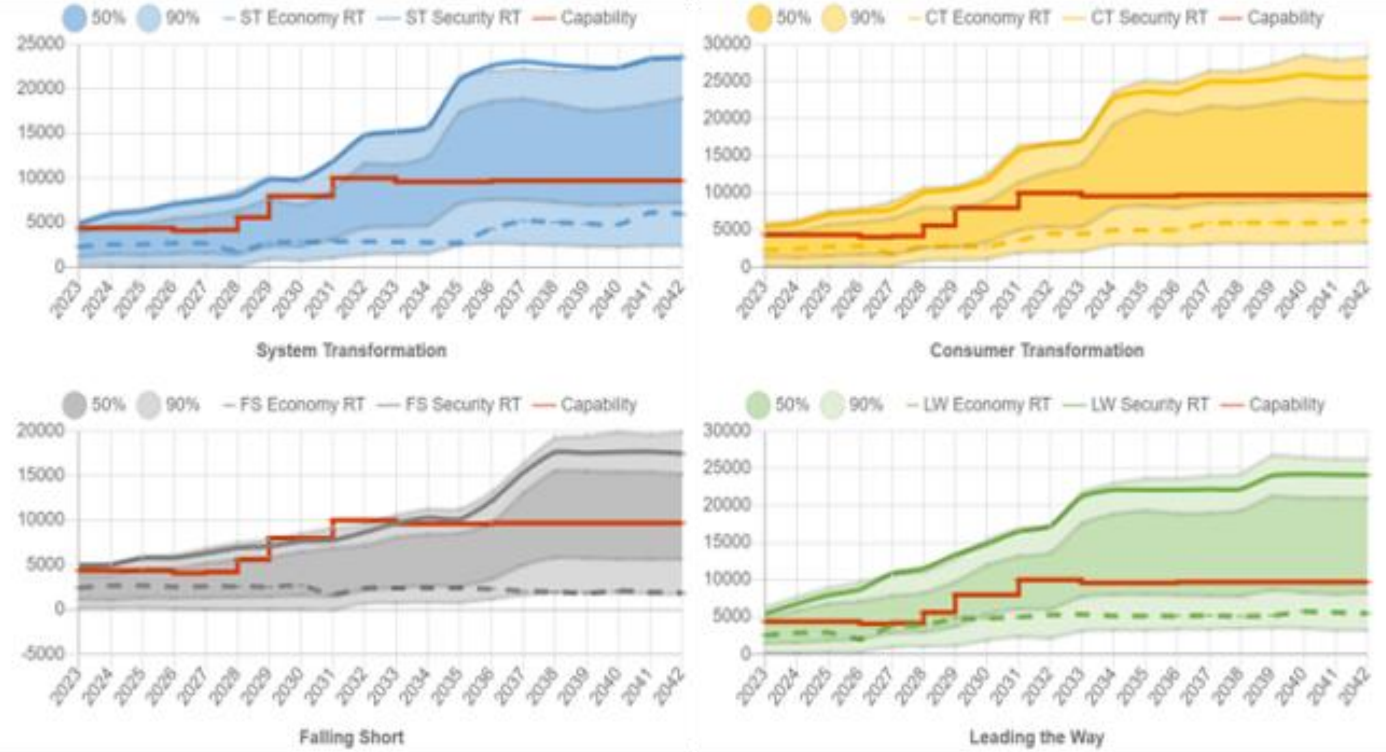
Boundary B5 – North to South SP Transmission

Boundary B5 is internal to the SP Transmission system and runs from the Firth of Clyde in the west to the Firth of Forth in the east.



The generating station at Cruachan, together with the demand groups served from Windyhill, Lambhill, Bonnybridge, Mossmorran and Westfield 275kV substations are located to the north of boundary B5.

In all the scenarios in the FES, the power transfer through boundary B5 increases because of the significant volumes of generation connecting north of the boundary, including all generation above boundaries B0, B1a, B2 and B4. This is primarily onshore and offshore wind generation.



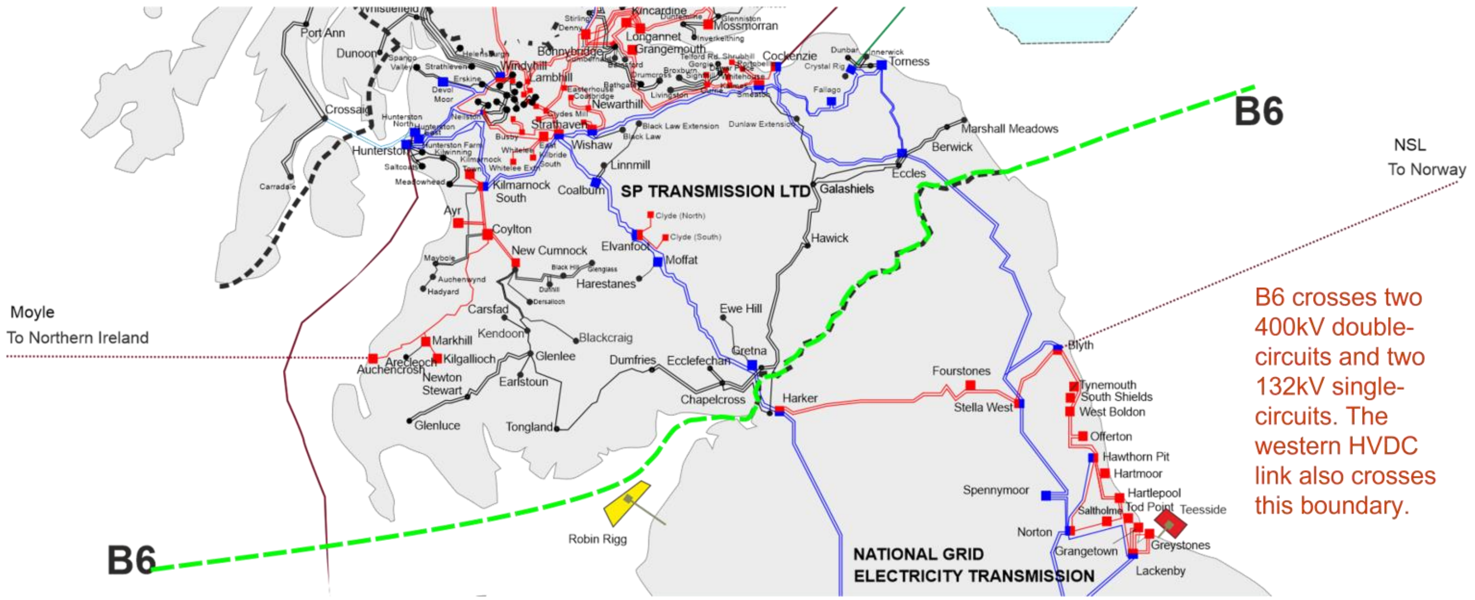
The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 3.9GW due to a thermal constraint on the Kincardine - Tealing 275kV circuit

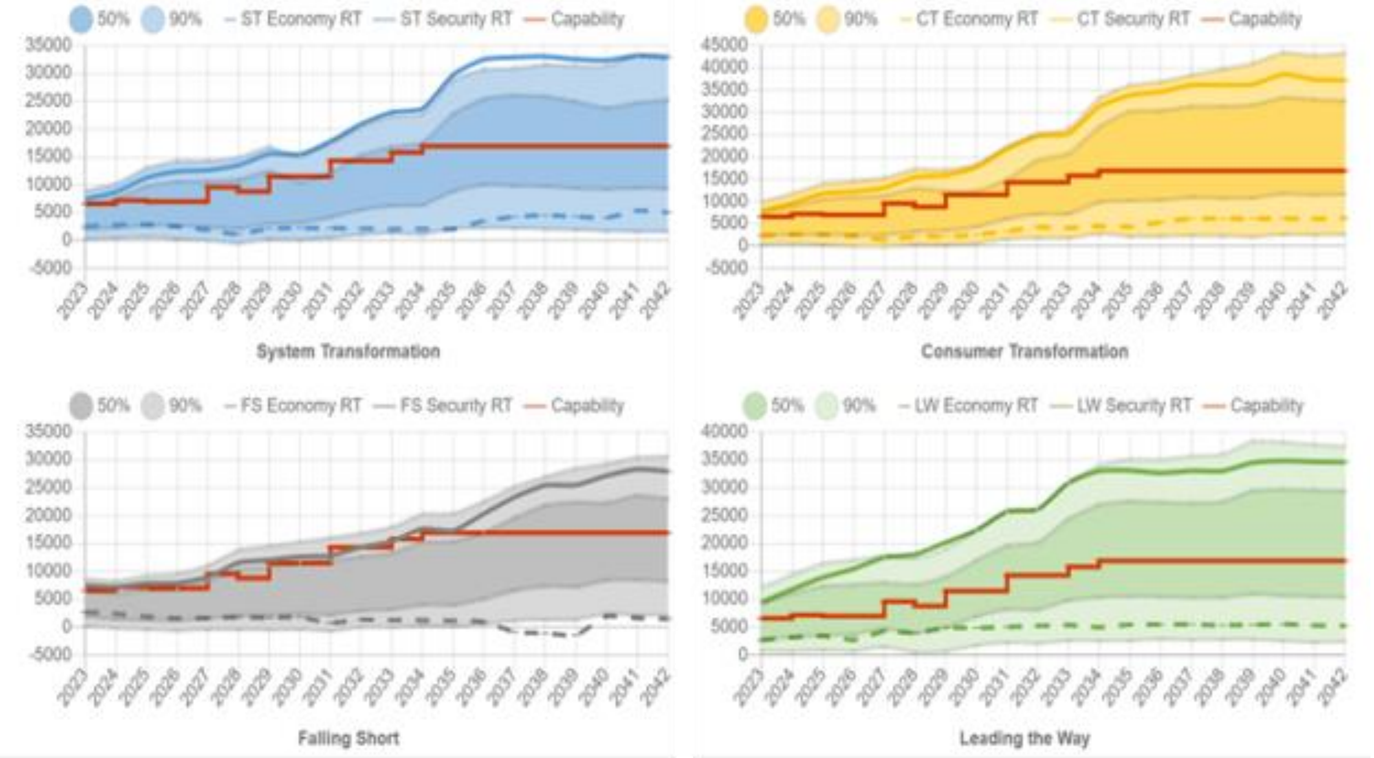
ETYS 2022 / Scotland 28

Boundary B6 – SP Transmission to NGET

Boundary B6 separates the transmission network at the SP Transmission and National Grid Transmission interface running roughly along the border between Scotland and England.



B6 crosses two 400kV double-circuits and two 132kV single-circuits. The western HVDC link also crosses this boundary.



Across all FES, there is an increase in the power transfer requirements from Scotland to England due to the connection of additional generation in Scotland, primarily onshore and offshore wind.

With the FES including many wind farms in Scotland, the spread of boundary power flows is very wide due to the intermittent nature of wind generation. With low generation output in Scotland, it is credible to have power flowing from south to north feeding Scottish demand, particularly on closure of the remaining nuclear plants north of the boundary such as Hunterston B which was decommissioned in 2022. The magnitude of the south to north power flows is low compared to those in the opposite direction so network capability is sufficient to support those conditions.

While the south to north transfer capability is enough to meet demand in Scotland, it is still necessary for conventional synchronous plant to remain in service in Scotland to maintain year-round secure system operation.

The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 6.3GW due to a thermal constraint on the Harker – Moffat 400kV circuit

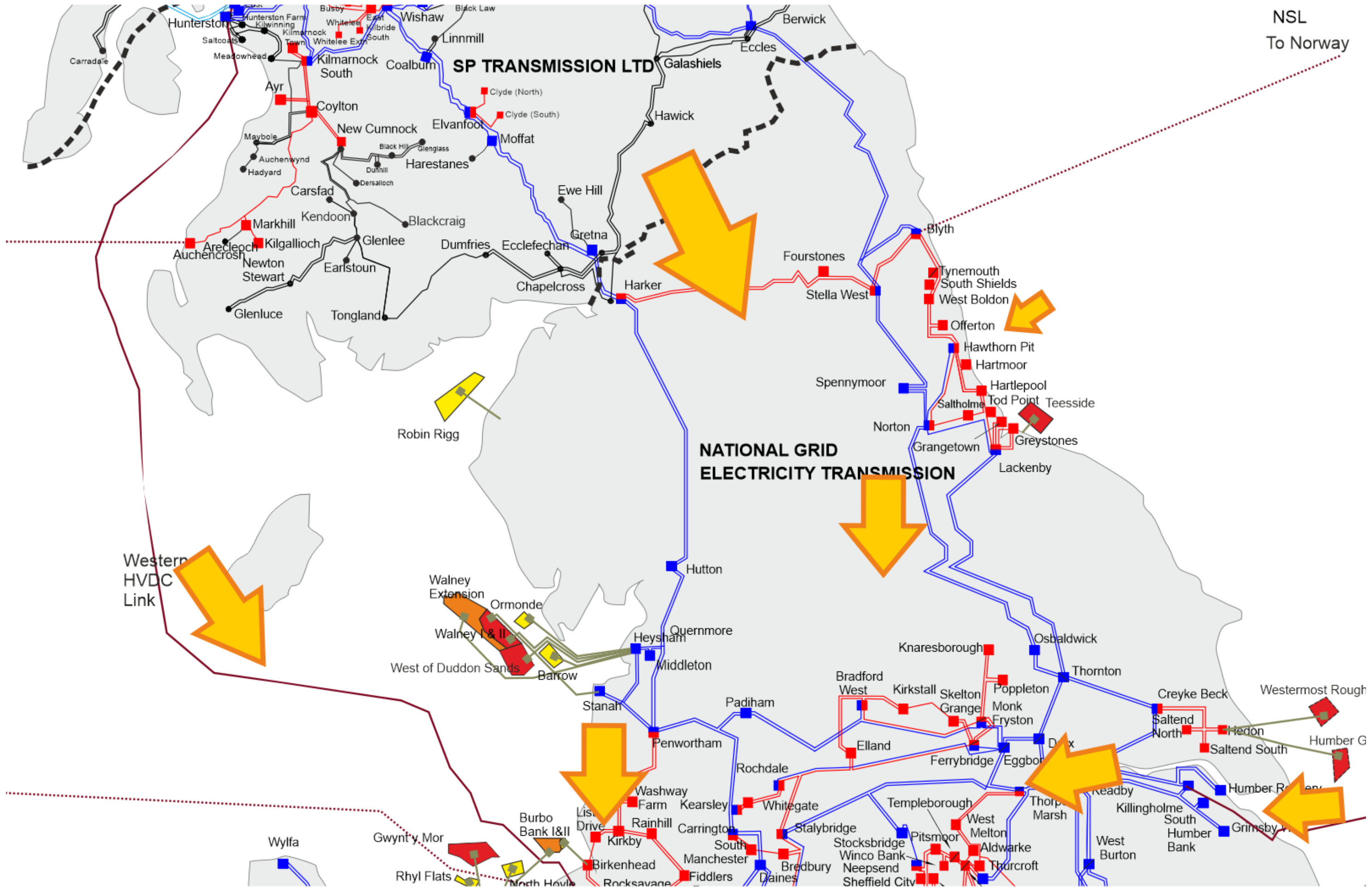
ETYS 2022 / Scotland 29

North of England

The North of England transmission region includes the transmission network between the Scottish border and the north Midlands.

This includes the upper north boundaries [B7a](#) and [B8](#). The figure below shows likely power flow directions at system winter peak.

The figure to the right shows the general pattern of power flow directions expected to occur most of the time in the years to come up to 2031, i.e. power will generally flow from north to south. The arrows in the diagram illustrate power flow directions and are approximately scaled relative to the winter peak flows.



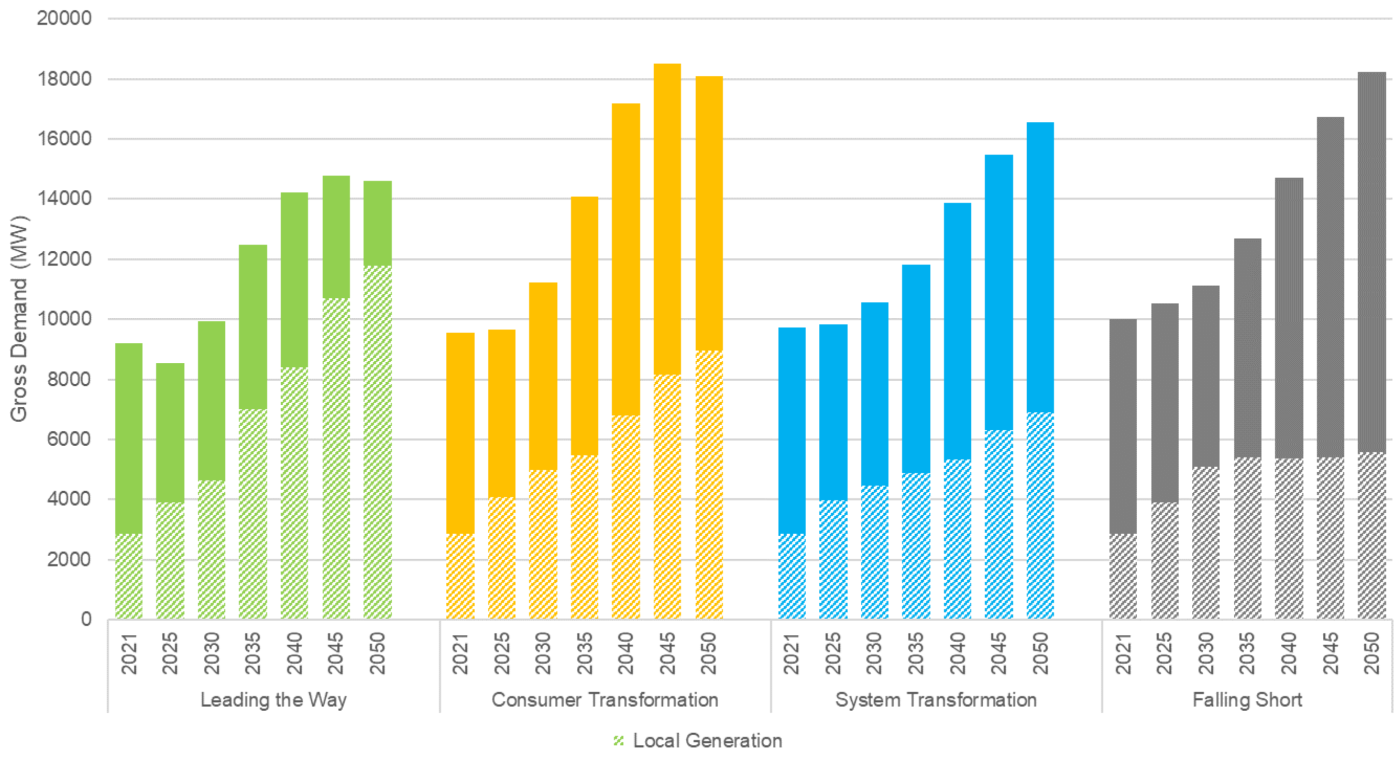
Regional Drivers – North of England

The connection of large amounts of new generation, most of which is intermittent renewables, in Scotland and the north will cause overloading in the northern transmission network unless appropriate reinforcements are in place. Future power transfer requirements could be more than double compared to what they are today in some scenarios.

Gross demand in the North of England is expected to increase to a total of up to 11GW by 2030, generation in the region is already double that figure today, and will increase by an additional 5GW by 2020. The North of England is a heavily power-exporting region and must also manage power flows from Scotland to the demand centres in the Midlands and South.

All four scenarios show a steady increase in the gross demand of the region that outstrips the increase in local generation for all but the Leading the Way scenario. There are stark differences seen in the range of local generation under the four scenarios, from 5 – 10 GW is expected by 2050, up from 2.8GW today. More local generation will mean that less of the North-South power flows that travel through this region will be absorbed by demand.

The highly variable nature of power flows in the north presents challenges for voltage management, and therefore automatic reactive power control switching is utilised. This helps to manage the significant voltage drop due to reactive power demands which arise at times of high levels of power flow on long circuits. Operational reactive switching solutions are also used to manage light loading conditions when the voltage can rise to unacceptable levels. The high concentration of large conventional generators around Humber and South Yorkshire means that system configuration can be limited by high fault levels. Therefore, some potential network capability restrictions in the north can be due to the inability to configure the network as desired due to fault level concerns.



ETYS 2022 / North of England 31

Regional Drivers – North of England

All four scenarios suggest growth in low-carbon and renewable generation, in addition to new storage and interconnector developments. The connected fossil fuel generation could see sustained decline in all but the Falling Short scenario, but would not be phased out in the region until at least 2040. Presently, most of the northern transmission network is oriented for north-south power flows with connections for demand and generation along the way.

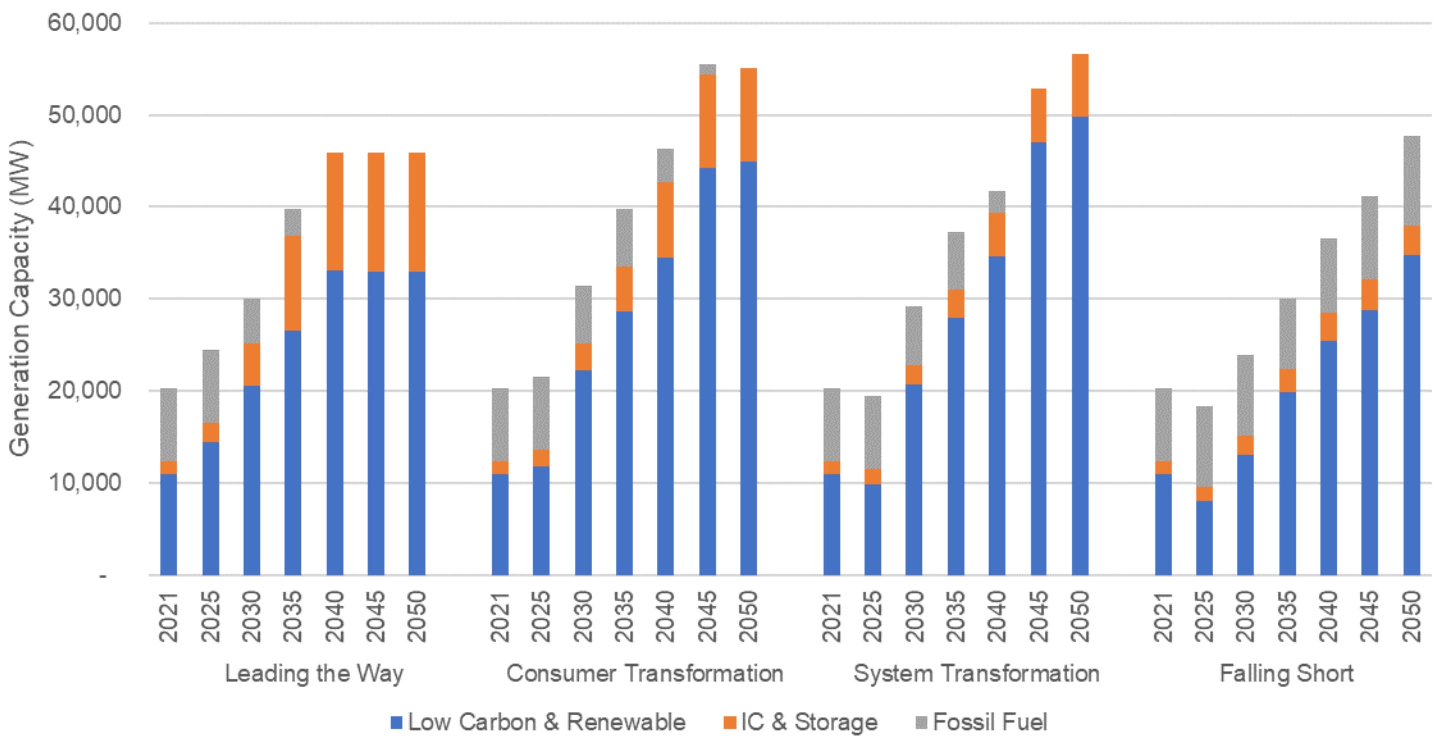
At times of high wind generation, the power flow will mostly be from north to south, with power coming from both internal boundary generation and generation further north in Scotland.

When most of this area and Scotland is generating power, the transmission network can be highly overloaded. The loss of one of the north-to-south routes can have a highly undesirable impact on the remaining circuits.

As the potential future requirement to transfer more power from Scotland to England increases, B7a is likely to reach its capability limit and needs network reinforcement. The potential future restrictions to be overcome across B7a are summarised:

- At high power transfer, thermal limitations occur on a number of circuits within the north east 275kV ring.
- Limitation on power transfer from Cumbria to Lancashire (boundary B7a) occurs due to thermal limitation at Padiham–Penwortham circuit.

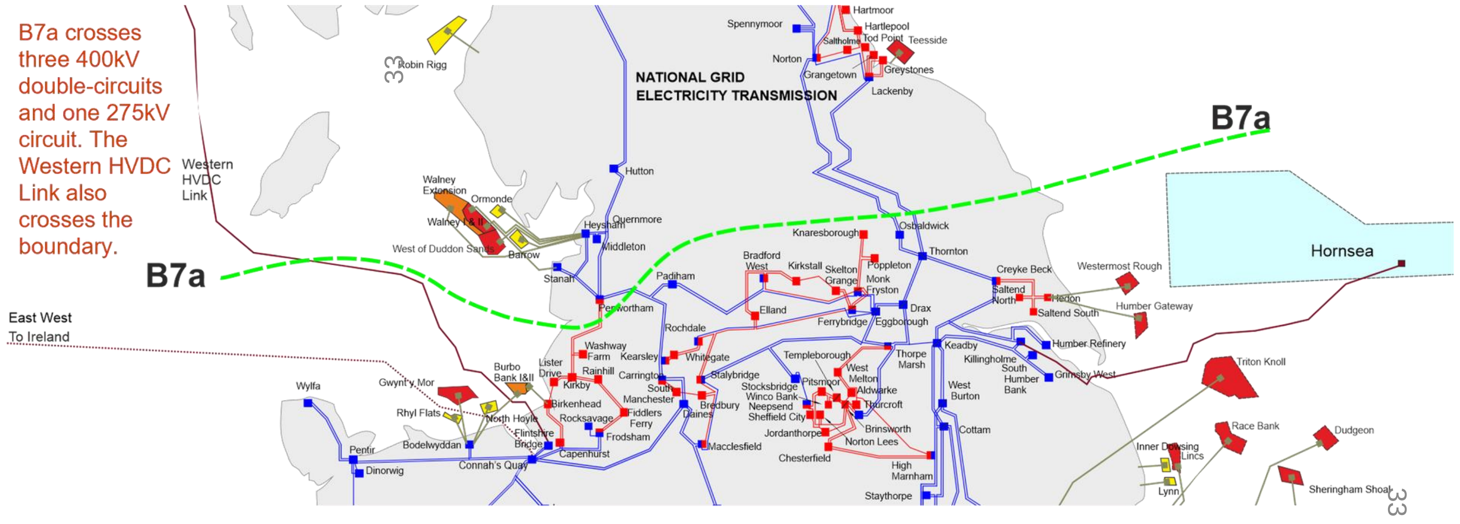
The need for any new network reinforcement to address potential capability issues will be evaluated in the upcoming HNDFUE and tCSNP2 following input from Transmission Owners and other interested stakeholders. Following the evaluation, the preferred reinforcements for the North of England region will be recommended.

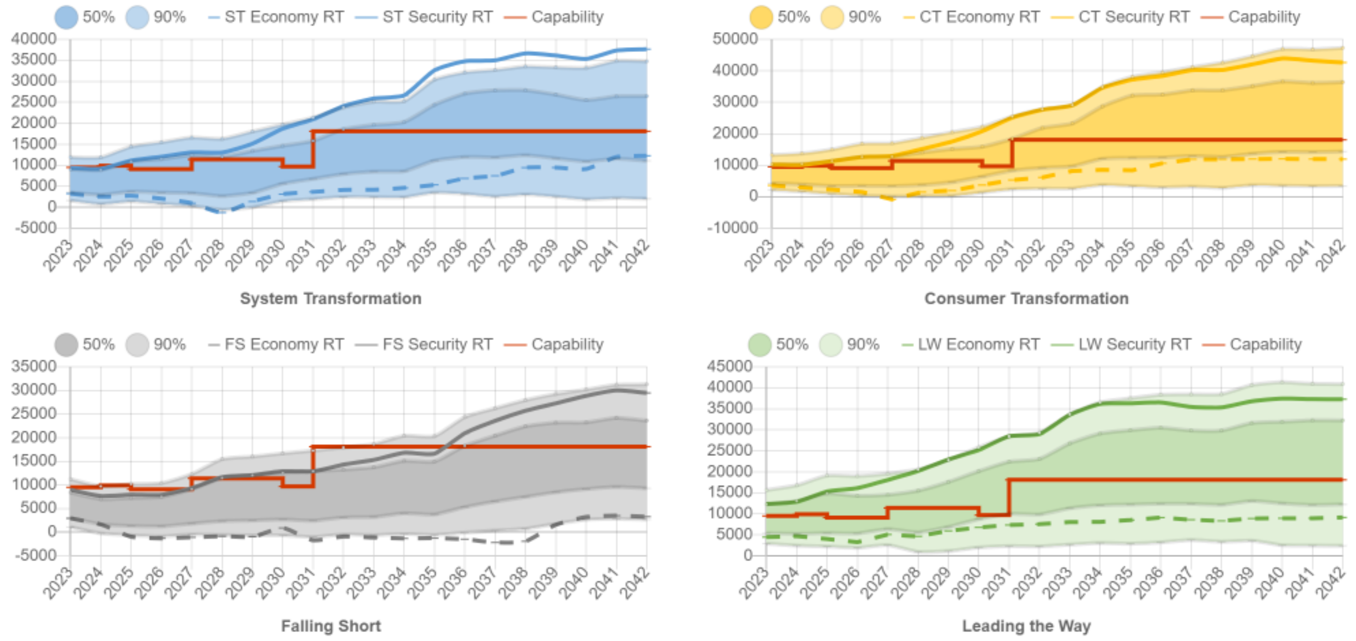


ETYS 2022 / North of England 32

Boundary B7a – Upper North of England

Boundary B7a bisects England south of Teesside and into the Mersey Ring area. It is used to capture network restrictions on the circuits feeding down through Liverpool, Manchester and Leeds.





For all scenarios in the FES except Falling Short, the SQSS economy required transfer and expected power flows quickly grow to beyond the present boundary capability. Falling Short will exceed this by 2027. This suggests a strong need for network development to manage the increasing power flows.

The FES show a lot of intermittent renewable generation in the north, meaning the spread of boundary power flows is very wide. With low northern generation output in it is credible to have power flowing from south to north feeding northern demand.

The magnitude of the south to north power flows is low compared to those in the opposite direction so network capability should be sufficient to support those conditions.

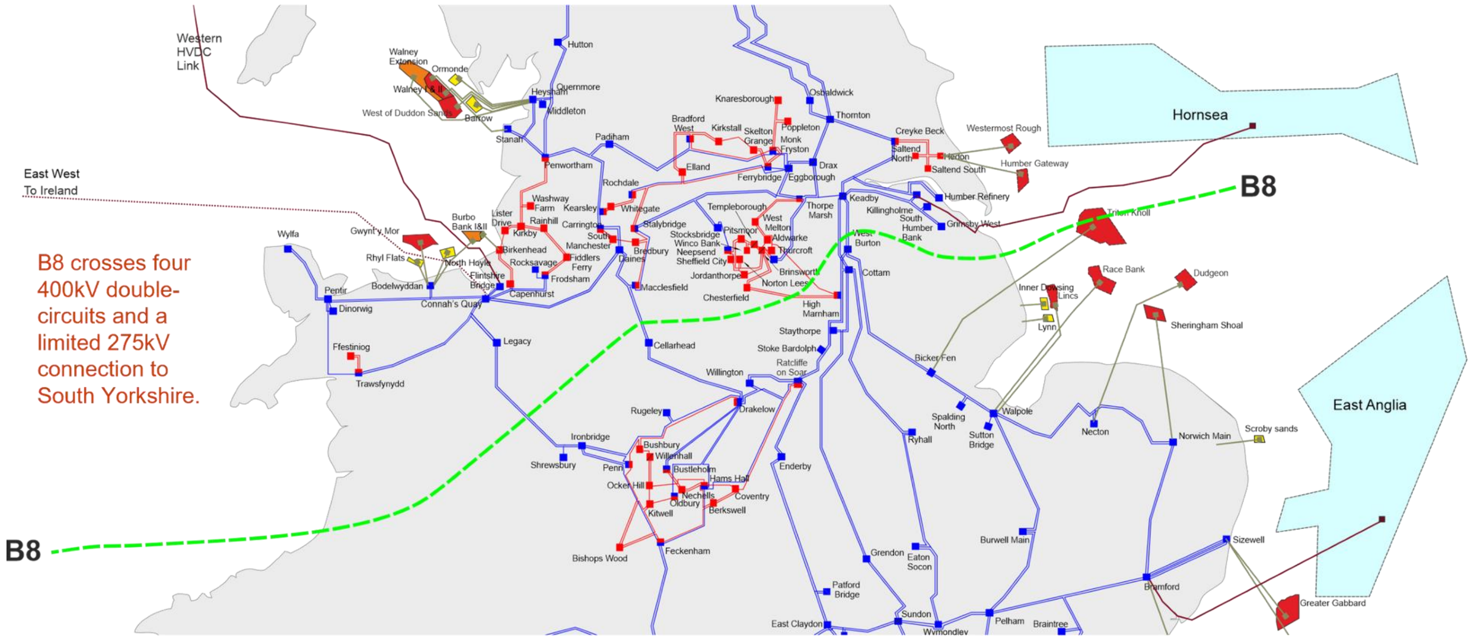
The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

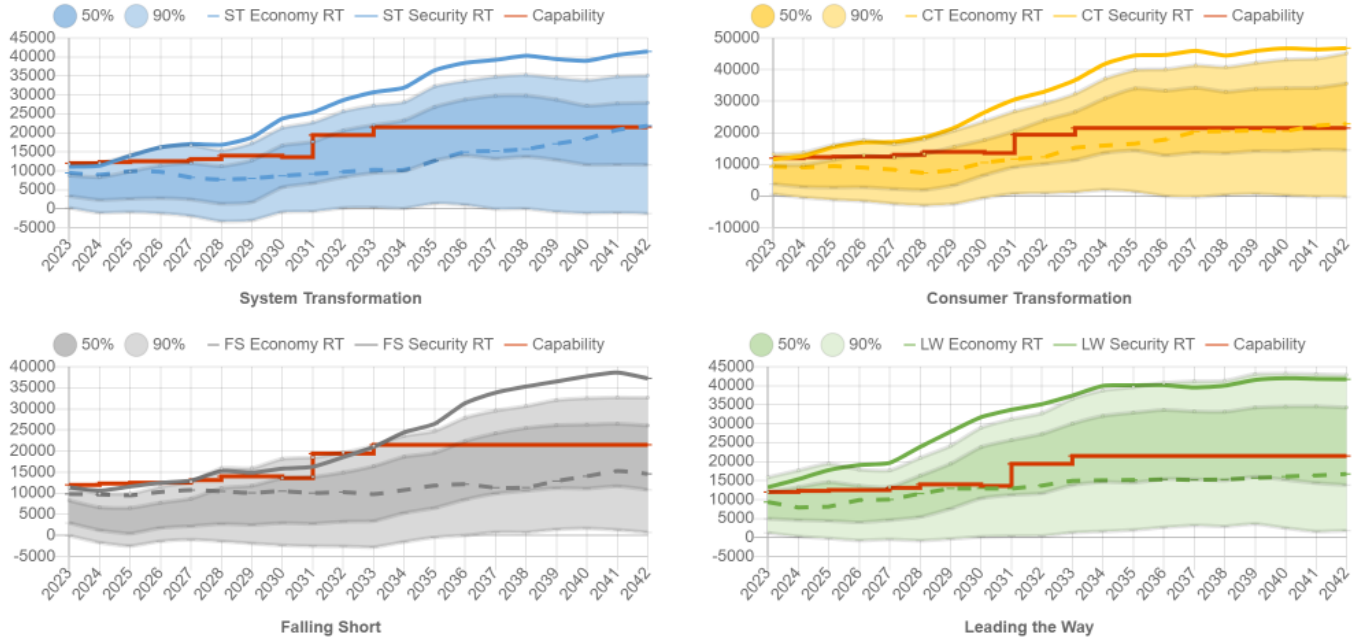
The current boundary capability is limited to 9.4GW due to a thermal constraint on the Penwortham – Washway Farm 275kV circuit

ETYS 2022 / North of England 33

Boundary B8 – North of England to Midlands

Boundary B8 is one of the wider boundaries that intersects the centre of GB, separating the northern generation zones including Scotland, Northern England and North Wales from the Midlands and southern demand centres.





For all scenarios in the FES, the SQSS economy required transfer and expected power flows quickly grow to beyond the present boundary capability. This suggests a strong need for network development to manage the increasing power flows.

The FES show a lot of intermittent renewable generation in the north, meaning the spread of boundary power flows is very wide. With low northern generation output in it is credible to have power flowing from south to north feeding northern demand.

The magnitude of the south to north power flows is low compared to those in the opposite direction so network capability should be sufficient to support those conditions.

The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 11.6GW due to a thermal constraint on the Keadby – West Burton 400kV circuit

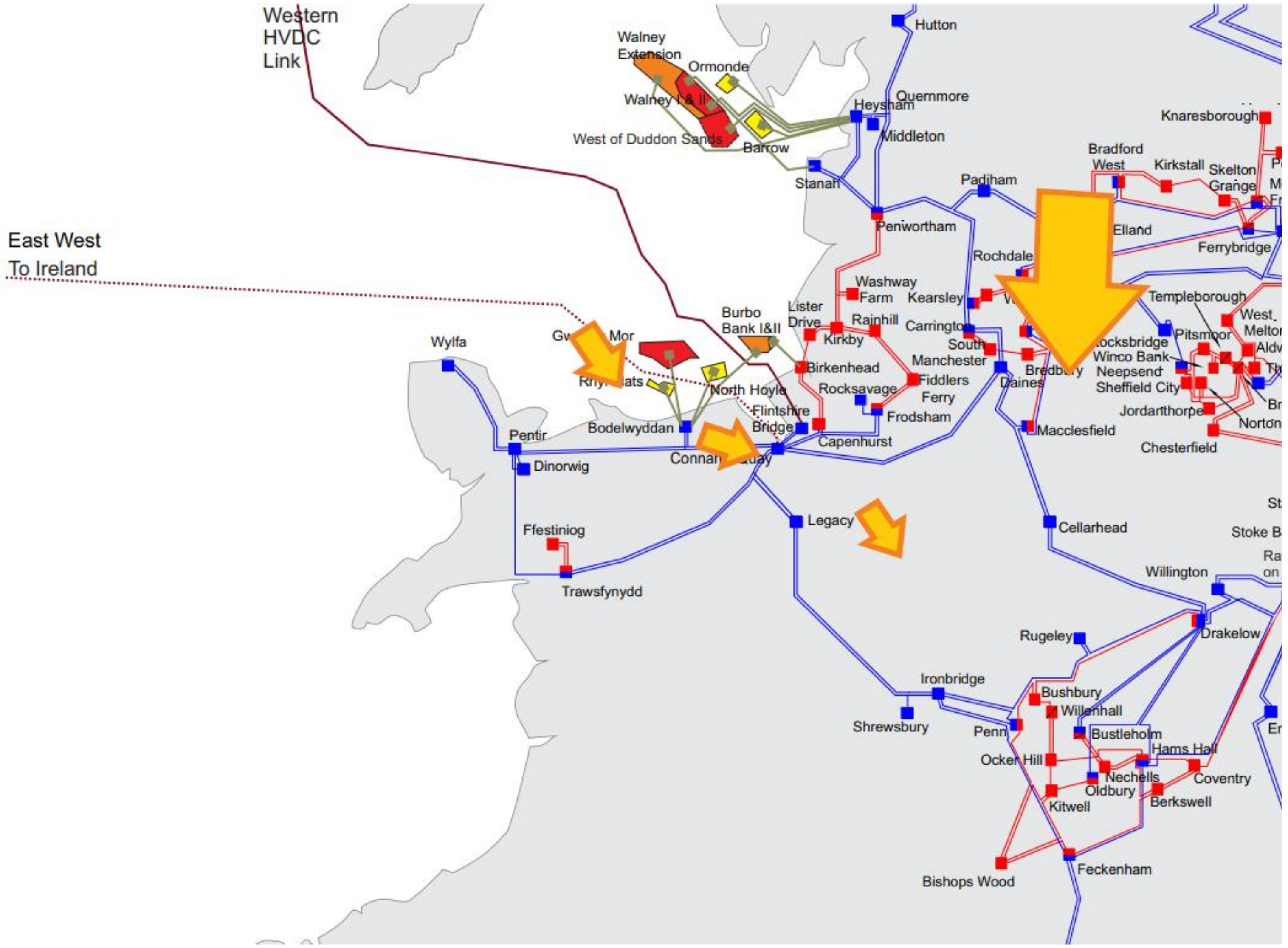
ETYS 2022 / North of England 34

North Wales and the Midlands

The Western transmission region includes boundaries in the Midlands and the north of Wales.

This includes the lower midlands boundary B9 and the north Wales boundaries NW1, NW2 and NW3.

The figure to the right shows the general pattern of power flow directions expected to occur most of the time in the years to come up to 2031, i.e. power will generally flow from north to south. The arrows in the diagram illustrate power flow directions and are approximately scaled relative to the winter peak flows.



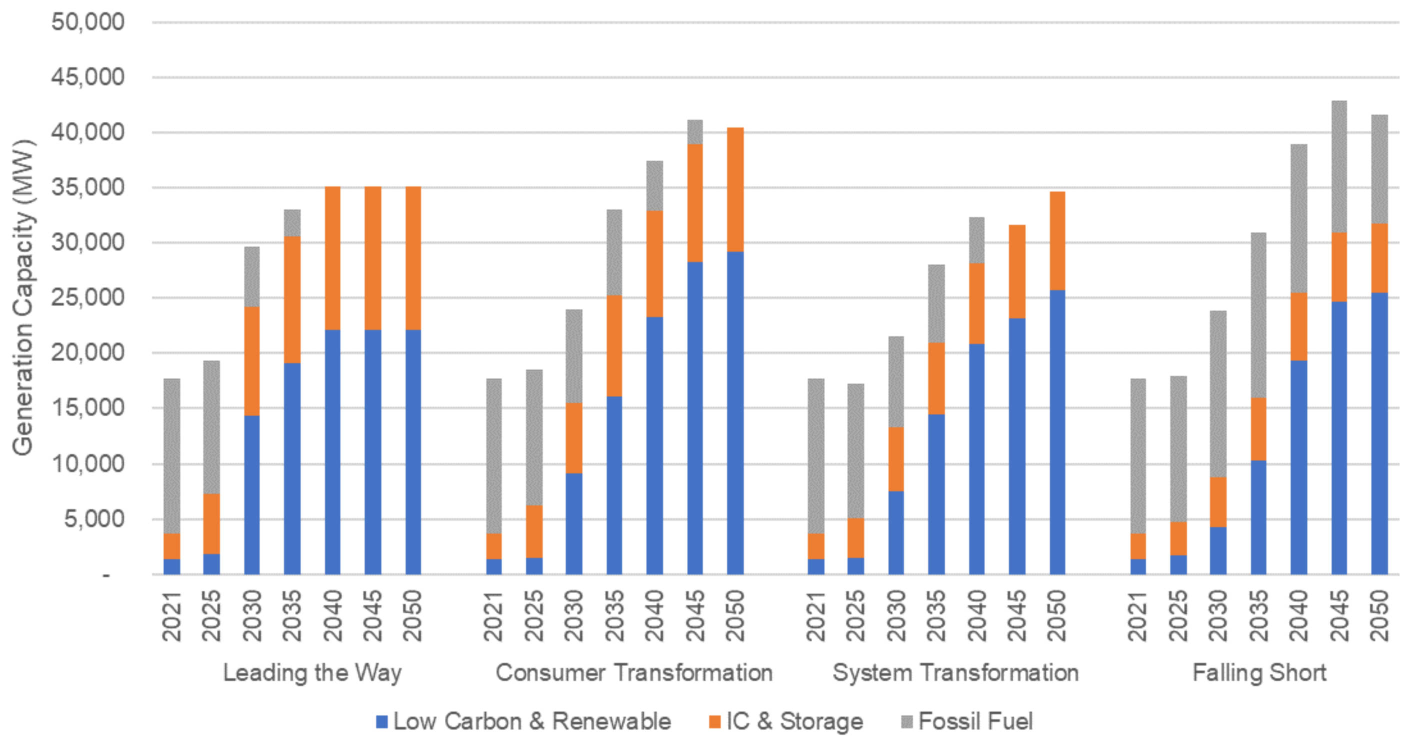
ETYS 2022 / North Wales & Midlands 35

Regional Drivers – North Wales & Midlands

Future offshore wind and biomass generation connecting in North Wales have the potential to drive increased power flows eastward into the Midlands where power plant closures are set to occur, and demand is set to remain fairly high.

Future offshore wind and biomass generation connecting in North Wales have the potential to drive increased power flows eastward into the Midlands where power plant closures are set to occur, and demand is set to remain fairly high.

By 2030, the FES scenarios suggest a total amount of transmission-connected generation capacity of between 22GW to 30GW, from the current 17GW. At present, this region has significant levels of fossil fuel (about 14GW). All scenarios show a decline in fossil fuel generation capacity with slight growth in interconnectors and storage and a significant growth in low-carbon technologies, especially offshore wind and carbon capture and storage (CCS) generation. For all scenarios other than Falling Short, fossil fuel generation is not present in the region by 2050.



ETYS 2022 / North Wales & Midlands 36

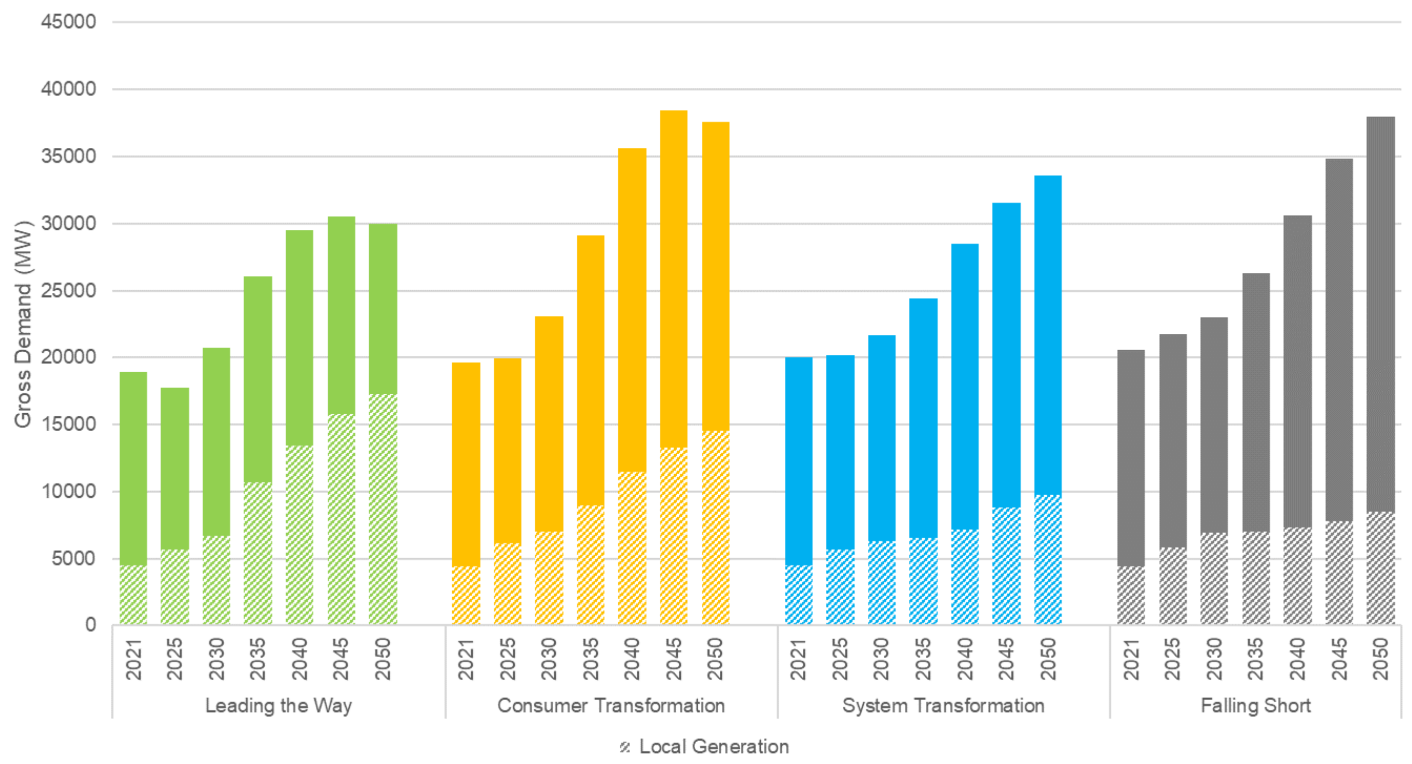
Regional Drivers – North Wales & Midlands

The graph shows that the gross demand as seen from the transmission network in the region will increase across all scenarios. As with other regions, this is driven by the adoption of technologies such as electric vehicles, heat pumps and embedded storage.

Across all scenarios, this region maintains a relative balance between its growth in both gross demand and transmission connected generation capacity up to 2030. Following 2030 North Wales and the Midlands is expected to become a generally exporting region due to the connection of offshore wind projects facilitated by the HND.

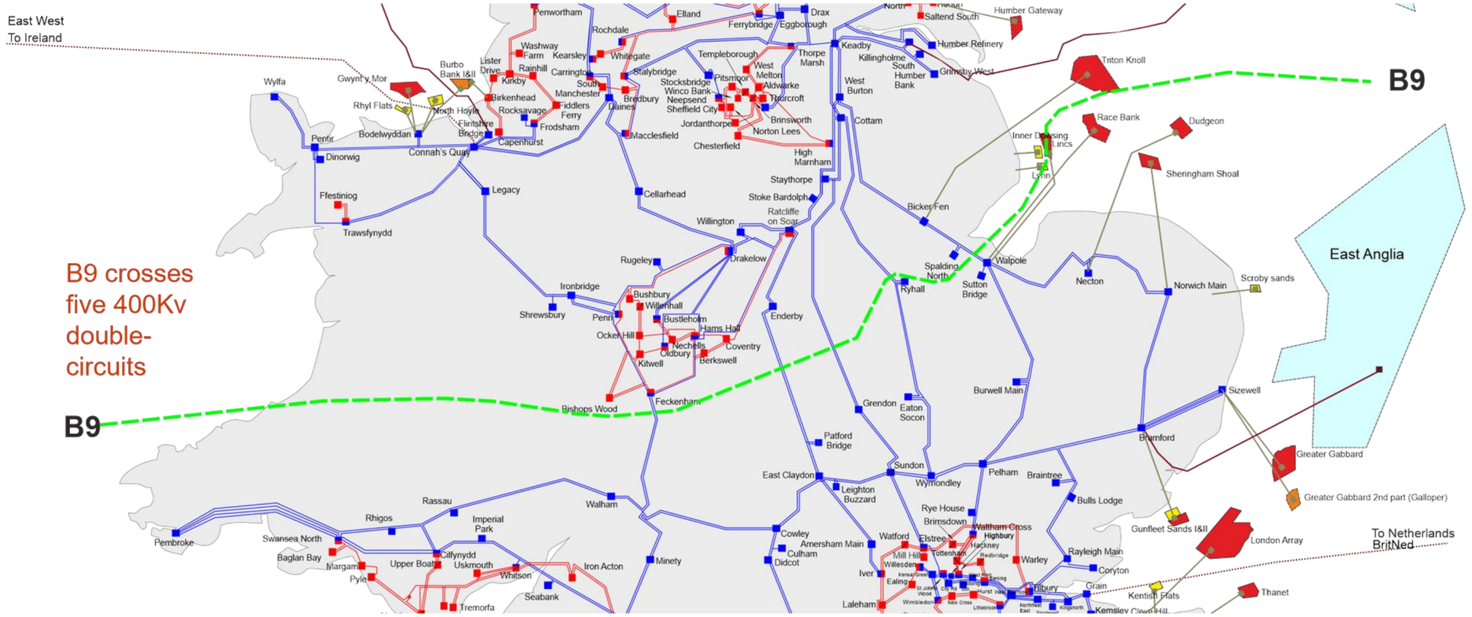
Significant reinforcements, as suggested in previous ETYS/NOA iterations are currently planned for the Wales region, with some being actively accelerated, in order to facilitate the connection of large volumes of offshore wind from the HND and the upcoming HNDFUE.

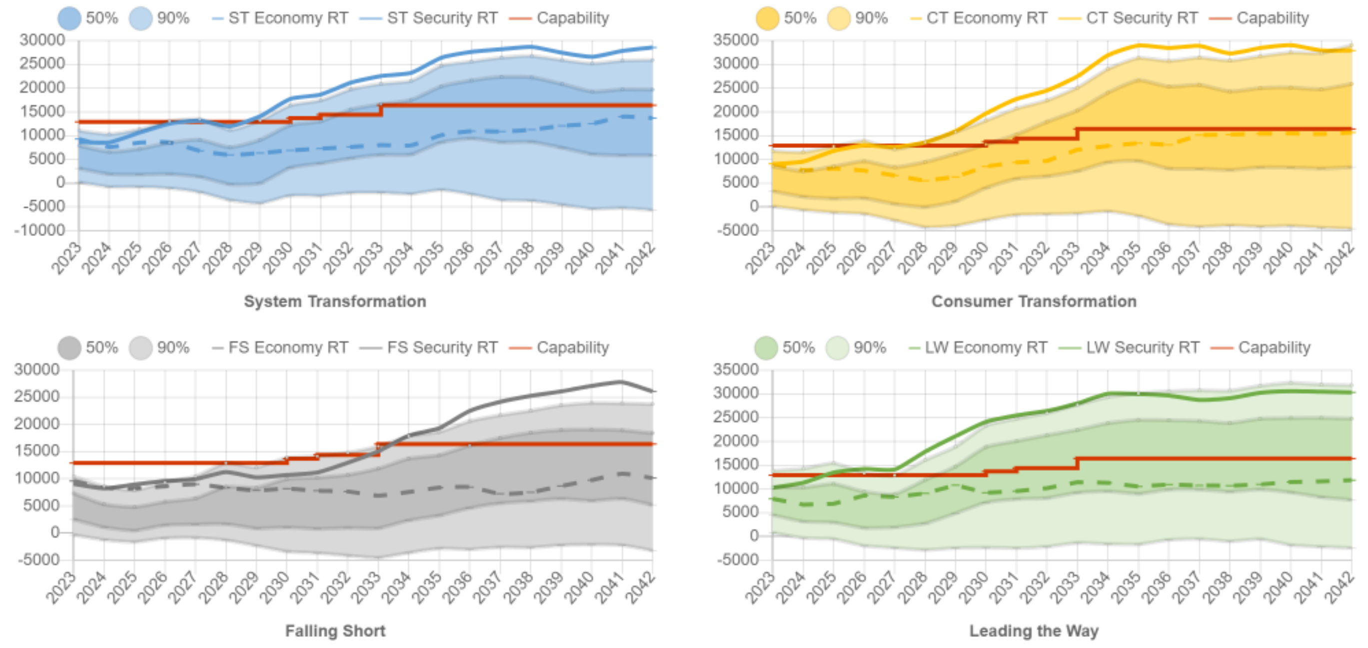
The need for any new network reinforcement to address the above-mentioned potential capability issues will be evaluated in the upcoming HNDFUE and tCSNP2 following input from Transmission Owners and other interested stakeholders. Following the evaluation, the preferred reinforcements for the North Wales & Midlands region will be recommended.



Boundary B9 – Midlands to South of England

Boundary B9 separates the northern generation zones and the southern demand centres.





Developments in the east coast and the East Anglia regions, such as the locations of offshore wind generation connection and the network infrastructure requirements, will affect the transfer requirements and capability of boundary B9.

In all four scenarios, the requirements gradually increase to above the boundary capability for B9. The increase is more than last year showing a need for additional boundary capability in the future for three out of the four scenarios.

The generation expected behind B9 is a combination of offshore wind generation and biomass generation.

The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 12.5GW due to a voltage constraint for a fault on the Enderby-Ratcliffe on Soar double-circuit

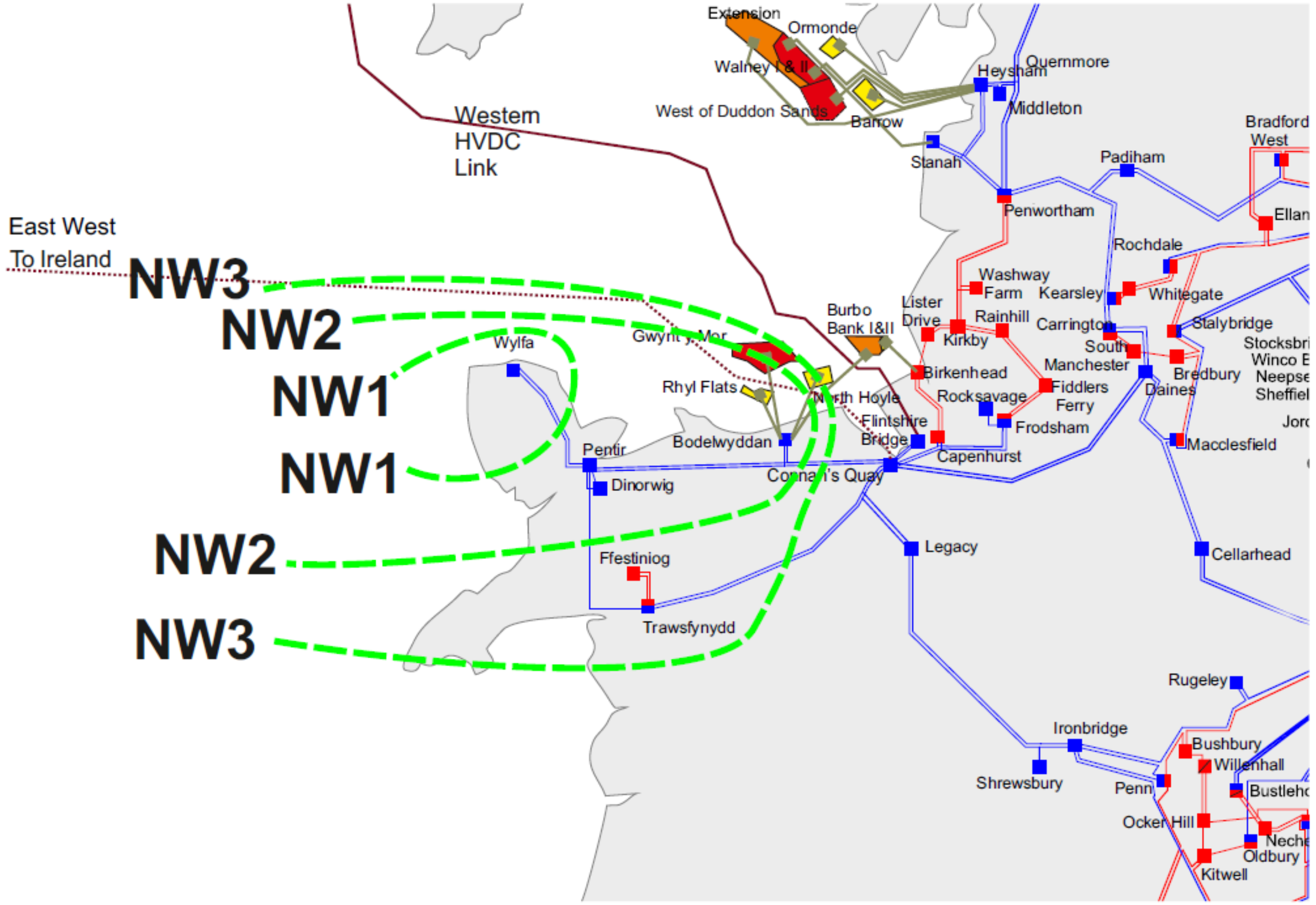
ETYS 2022 / North Wales & Midlands 38

North Wales

The onshore network in North Wales comprises a 400kV circuit ring that connects Pentir, Connah's Quay and Trawsfynydd substations.

A 400kV double-circuit spur crossing the Menai Strait and running the length of Anglesey connects the now decommissioned nuclear power station at Wylfa to Pentir. A short 400kV double-circuit cable spur from Pentir connects Dinorwig pumped storage power station. In addition, a 275kV spur traverses north of Trawsfynydd to Ffestiniog pumped storage power station.

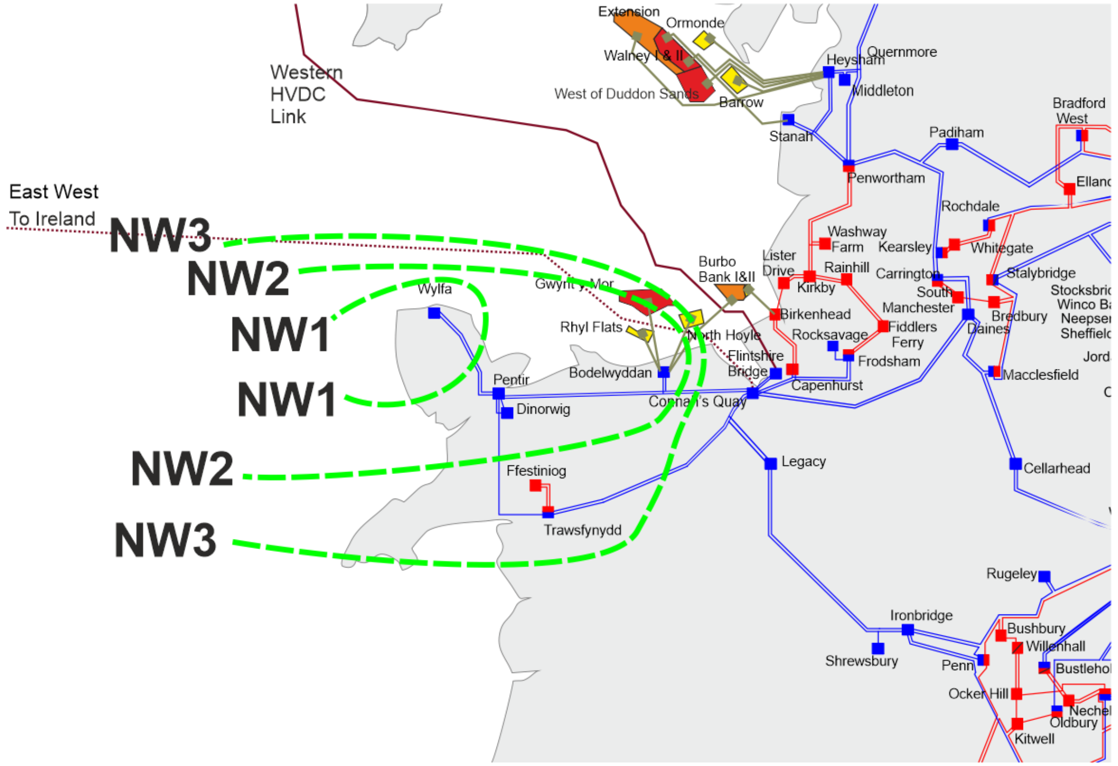
Most of these circuits are of double circuit tower construction. However, Pentir and Trawsfynydd within the Snowdonia National Park are connected by a single 400kV circuit, which is the main limiting factor for capacity in this area. The area is studied by analysing the local boundaries NW (North Wales) 1 to 3.

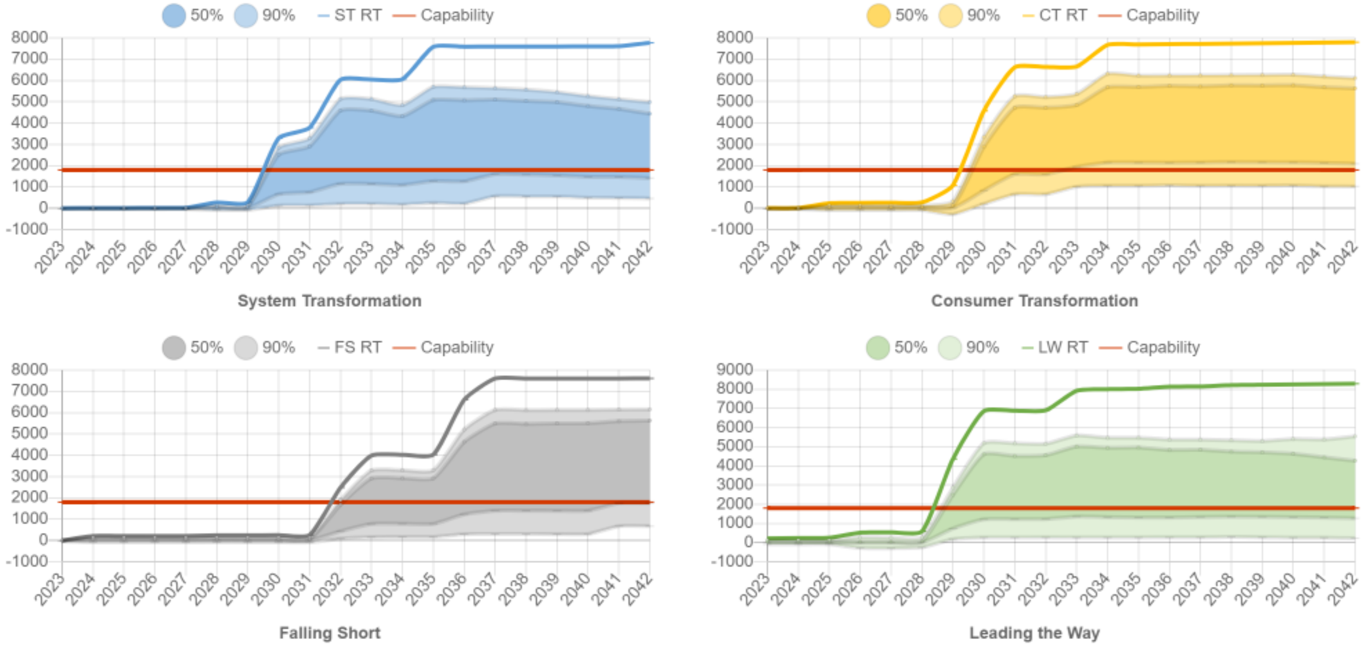


ETYS 2022 / North Wales & Midlands 39

Boundary NW1 - Anglesey

Boundary NW1 encloses the Wylfa 400kV substation





There is currently very low amounts of transmission-connected generation behind NW1 following the closure of Wylfa power station in 2015.

For all scenarios in the FES, between 2029 and 2031 a sharp rise in required transfers are expected over NW1 as large volumes of generation connect at Wylfa substation, including over 6GW of offshore wind and solar generation. This increase suggests a need for additional boundary capability in the near future for NW1 to support the increasing amounts of generation behind it.

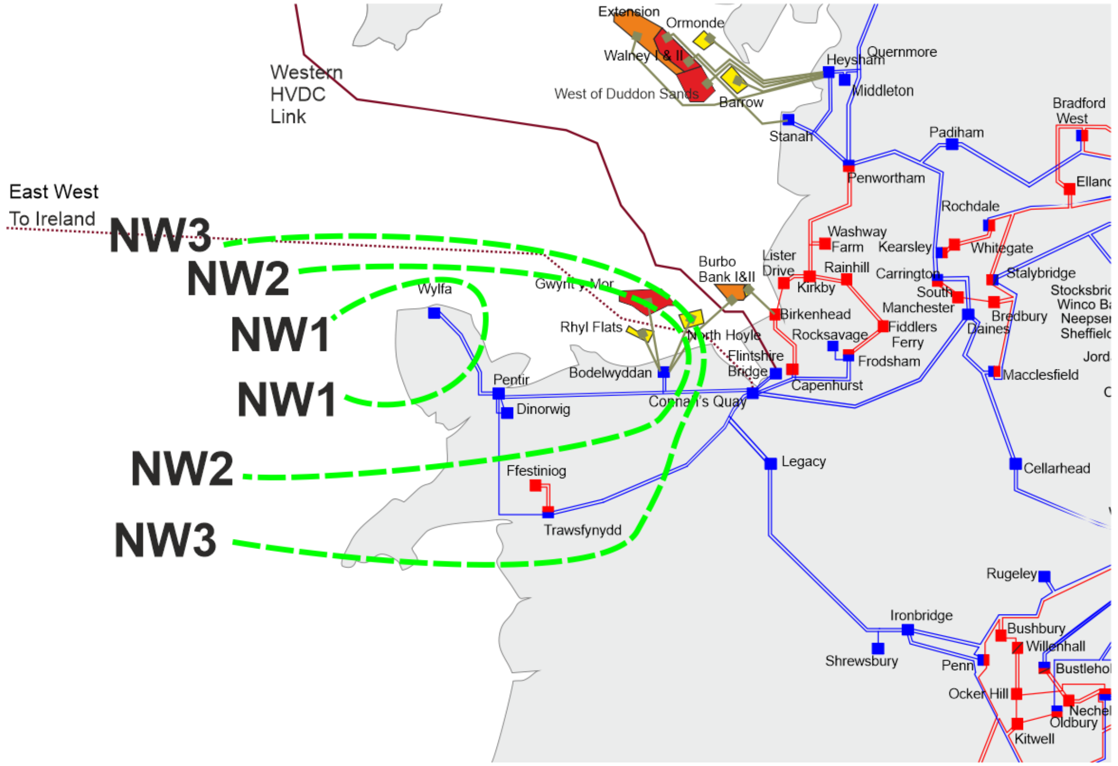
The capability line (in red) is based on the ETYS transfer capability using FES 2022 data, shown below. The 50%, 90% Economy RT and Security RT lines are based on FES 2022.

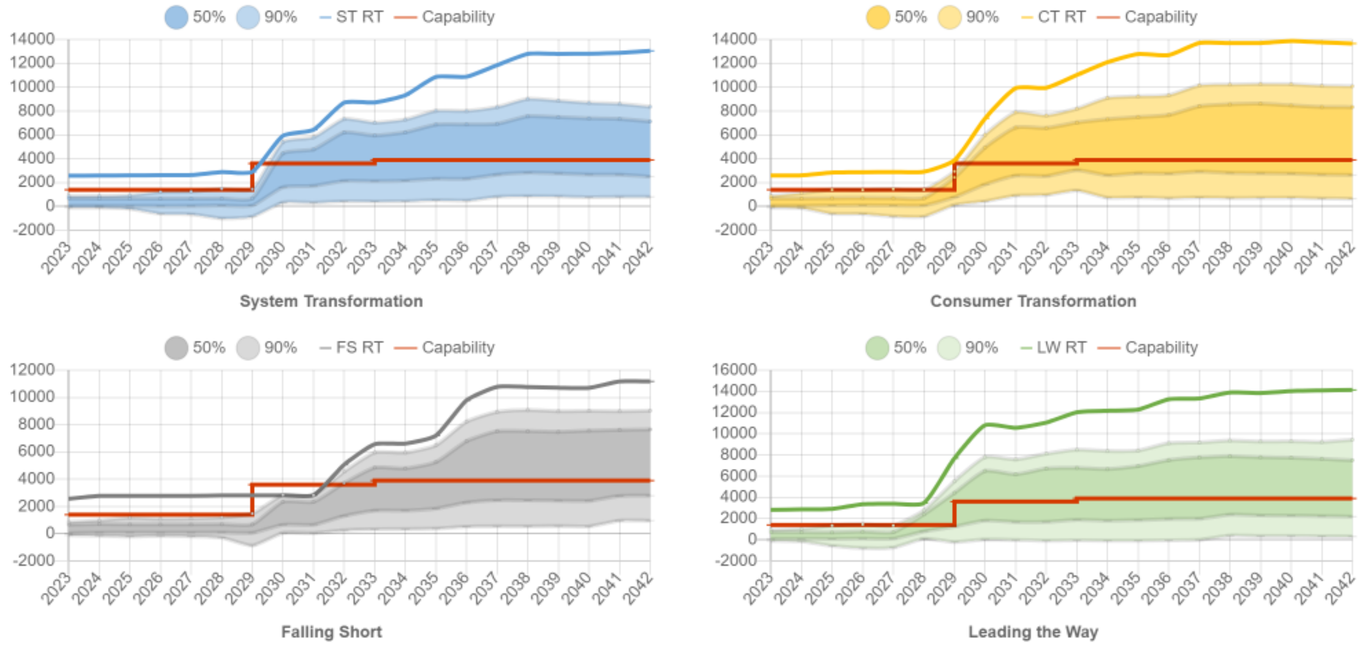
The current boundary capability is limited by the infrequent infeed loss risk criterion set in the SQSS, currently 1.8GW

ETYS 2022 / North Wales & Midlands 40

Boundary NW2 – Anglesey and Caernarvonshire

Boundary NW2 encloses NW1 and the Pentir, Dinorwig, and Bodelwyddan 400kV substations





Currently, there is not a significant amount of generation behind NW2, mainly Dinorwig pumped storage and offshore wind projects connecting to Bodelwyddan. The expected transfers only see significant changes from around 2029 onward when they increase very sharply as large new offshore wind projects come online and an intra GB DC link connecting to Scotland lands at Pentir. This will mean that in future transfers across the NW2 boundary will be heavily dependent on wind conditions.

The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 1.4GW due to a thermal constraint on the Pentir - Trawsfynydd 400kV circuit

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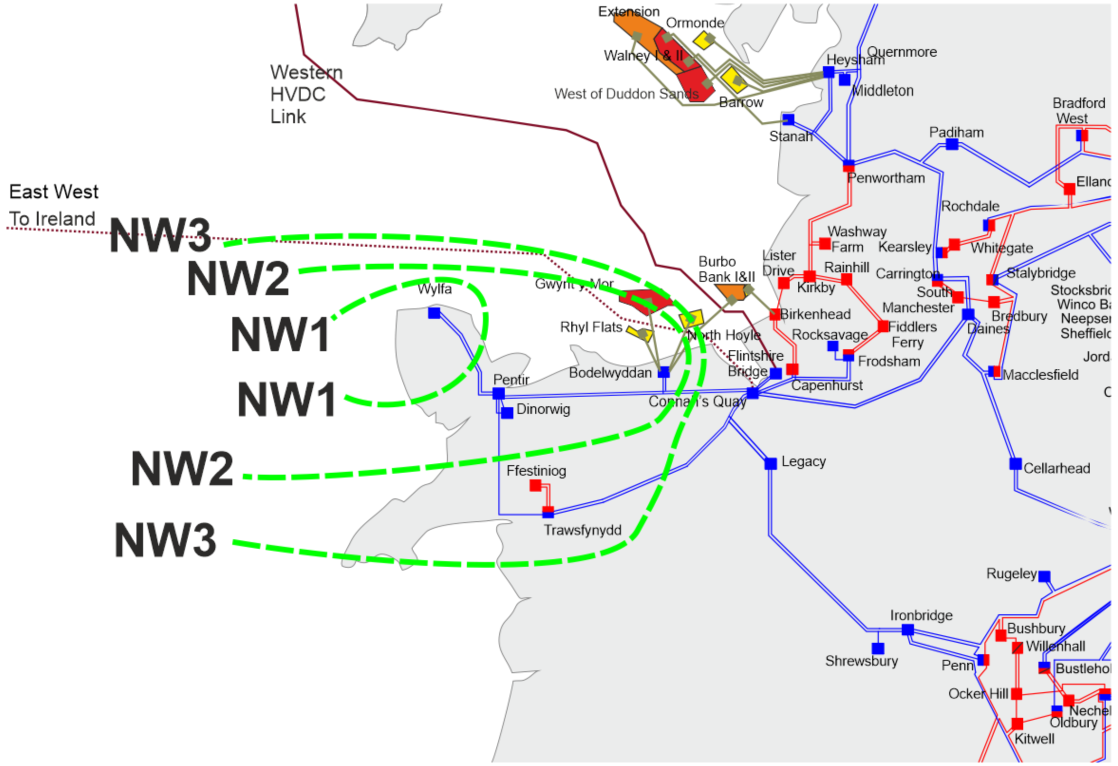
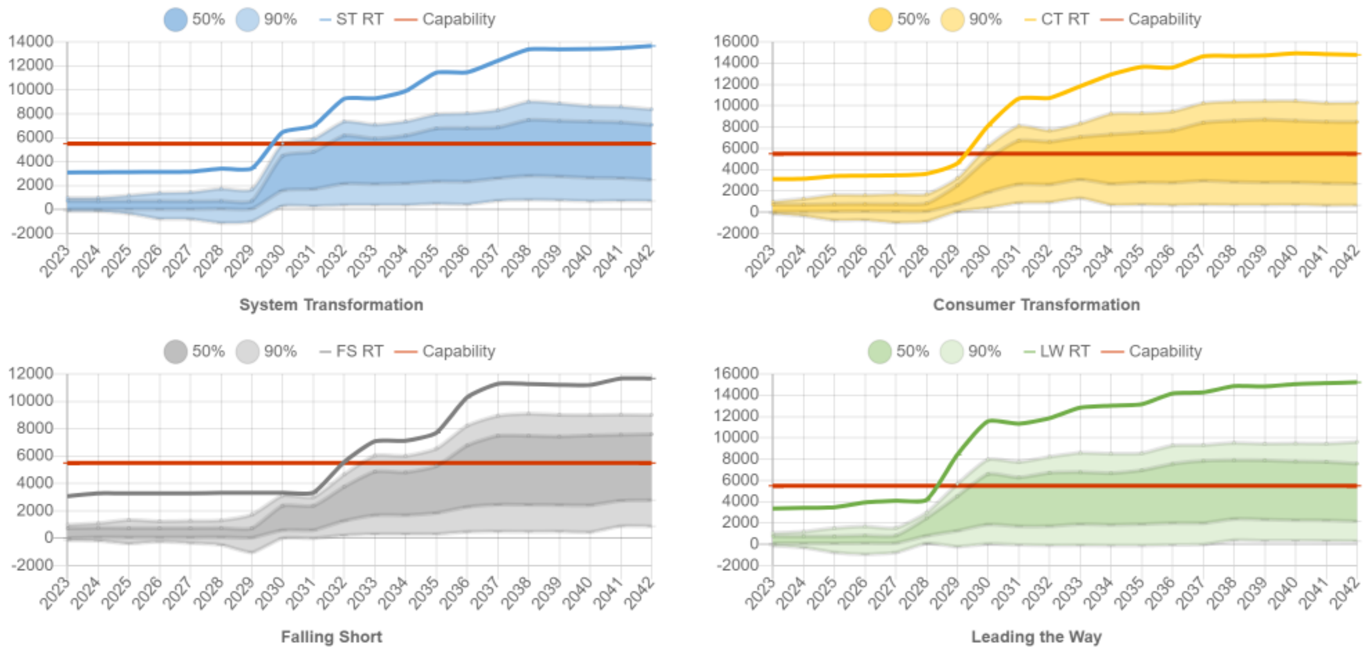
NW3 – Anglesey, Caernarvonshire and Merionethshire

Boundary NW3 encloses NW2, Trawsfynydd 400kV substation, and the Ffestiniog 275kV substation.



Across all four FES scenarios, the SQSS economy required transfer grows beyond the present boundary capability from between 2029 to 2032 onwards. Generation behind NW3 is largely similar to that behind NW2, with no significant volumes of generation currently anticipated to connect at Ffestiniog or Trawsfynydd substations in the future.



The capability line (in red) is based on the ETYS transfer capability using FES 2022 data, described below. The 50%, 90% Economy RT and Security RT lines are based on FES 2022.

The current boundary capability is limited to 5.5GW due to a thermal constraint on the Connah's Quay - Bodelwyddan - Pentir 400kV circuit

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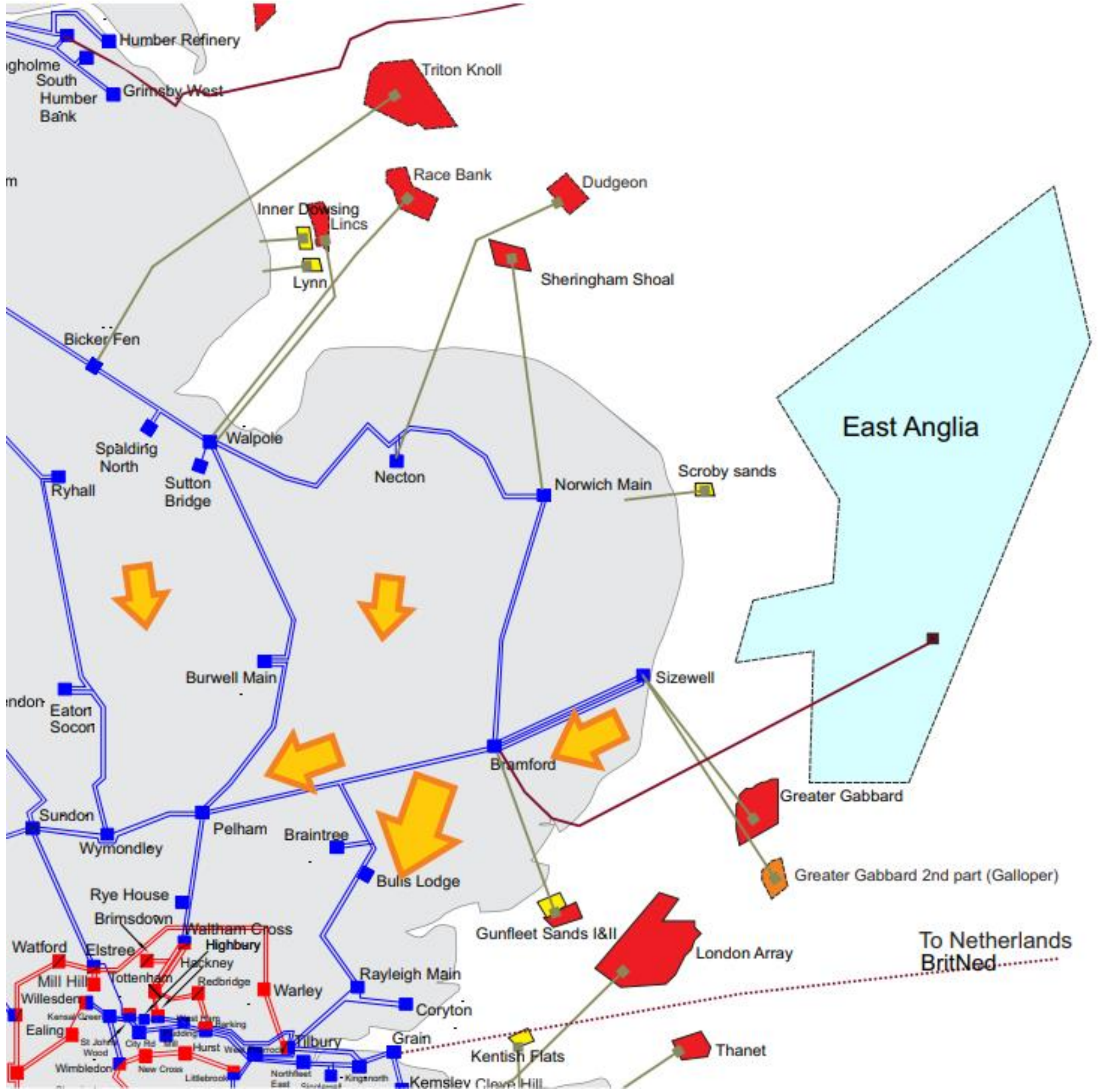
East of England

The East of England region includes the counties of Norfolk and Suffolk.

The figure to the right shows the general pattern of power flow directions expected to occur most of the time in the years to come up to 2031, i.e. power will generally flow from north to south. The arrows in the diagram illustrate power flow directions and are approximately scaled relative to the winter peak flows.



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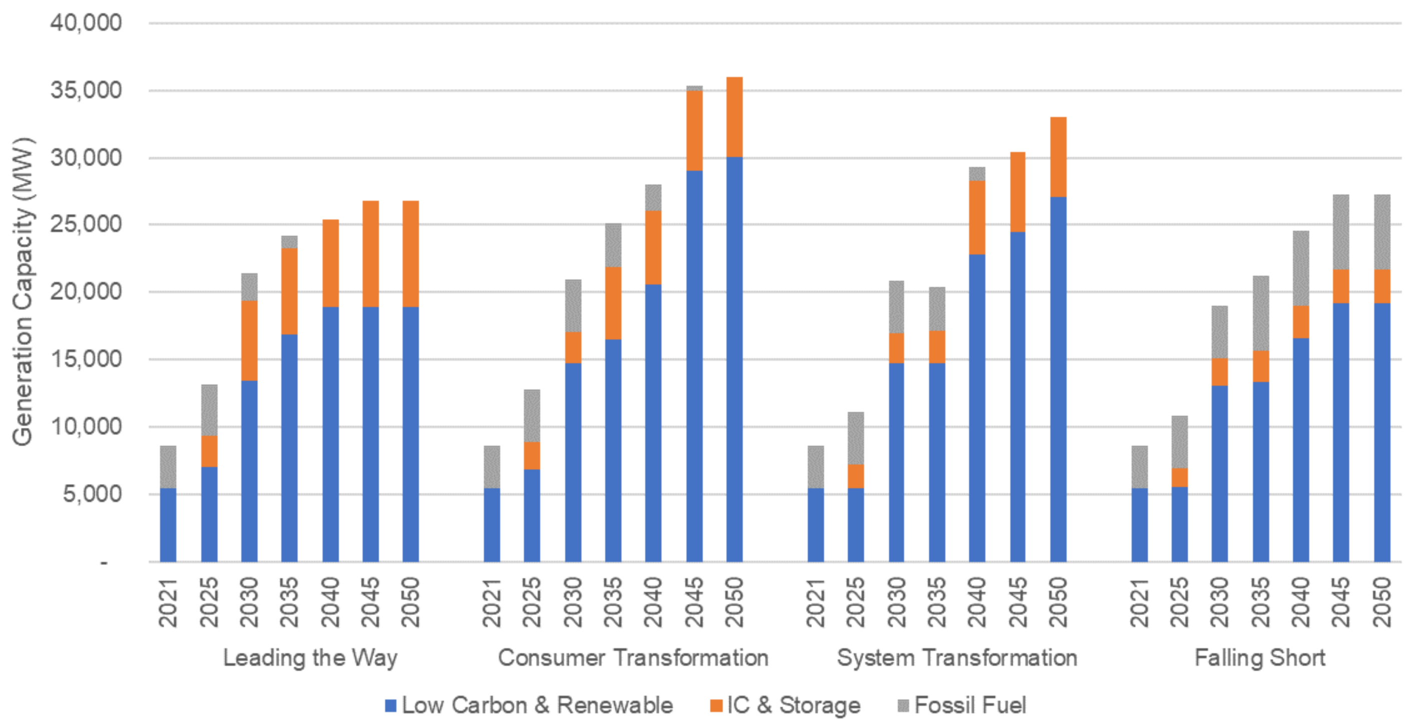
Regional Drivers – East of England

The future energy scenarios highlight that generation between 8-18GW could be expected to connect within this region by 2030. Peak gross demand in the East of England region is expected to be remain steady or potentially rise by up to 1GW.

Currently, there is a total of 8GW transmission-connected generation in the region, across all of our FES scenarios this is forecast to increase to between 18-21GW by 2030. A majority of this increase in total generation capacity is driven by growth in low carbon generation projects (mainly offshore wind) connecting across the region by 2030, which is expected to increase from 5.5GW today to over 13GW by 2030 across all FES scenarios

Fossil fuel generation is expected to remain steady within this region and interconnector capacity is expected to rise. The total generation in all the scenarios will exceed the local demand; thus, the East of England will be a power exporting region. Peak gross demand in the East of England region is expected to remain steady or potentially rise by up to 1GW.The graph on the following page shows snapshots of the peak gross demand and local embedded generation for the East of England across the four different scenarios.



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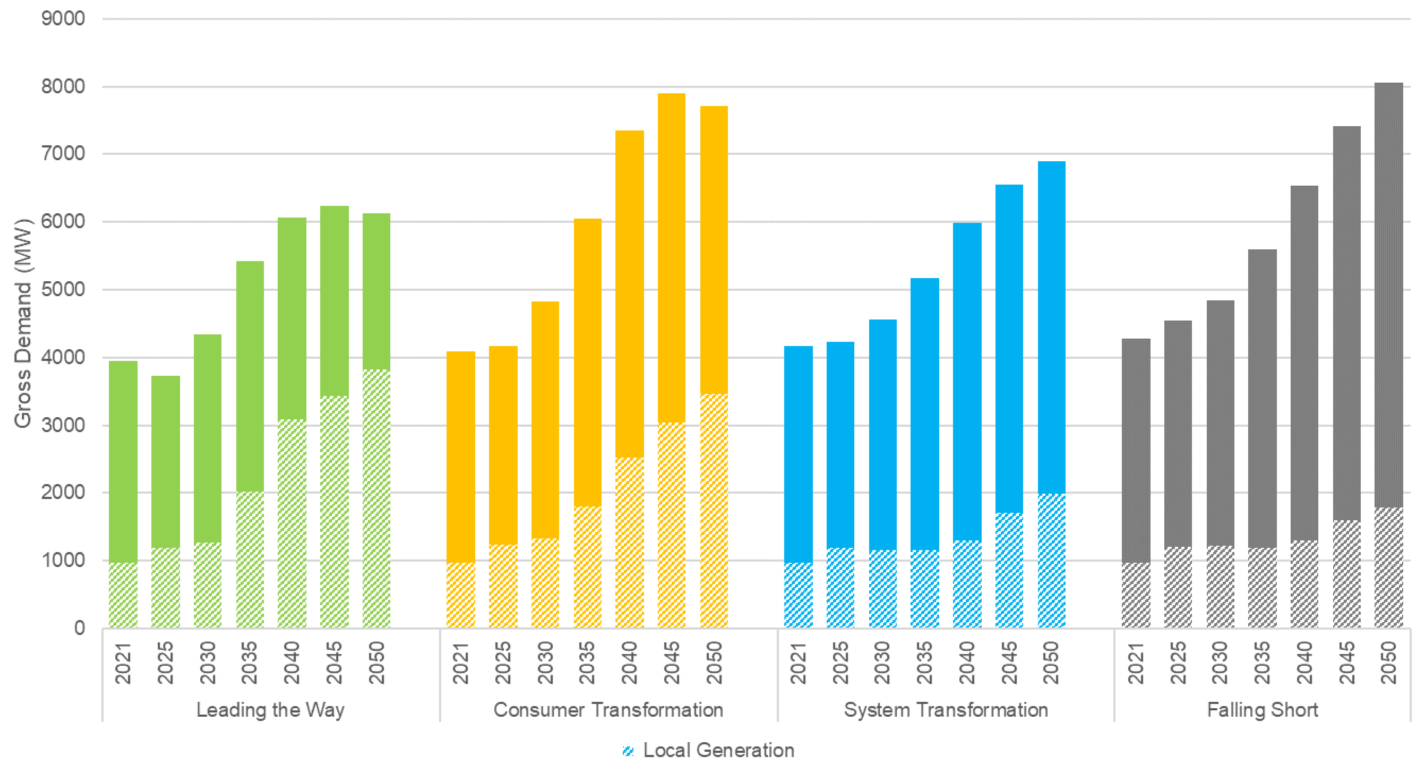
Regional Drivers – East of England

The East Anglia transmission network to which the future generation will connect has eight 400kV double circuits. The potential future increase in generation within this region could result in very heavy circuit loadings, stability issues and voltage depressions – for power transfer scenarios from East Anglia to London and South East England. This is explained as follows:

- The East of England region is connected by several sets of long 400kV double circuits, including Bramford-Pelham/Braintree, Walpole–Spalding North/Bicker Fenn and Walpole–Burwell Main. During a fault on any one set of these circuits, power exported from this region is forced to reroute. This causes some of the power to flow through a much longer distance to reach the rest of the system, predominantly the Greater London and South East England networks via the East Anglia region.
- Stability becomes of additional interest when some of the large generators connect, further increasing the size of the generation group in the area connected to the network. Losing a set of double circuits to a fault will lead to significant exposure to a risk of instability as power transfer increases.

There are multiple energy infrastructure projects in development, at various stages across the region. The analysis put forward in this ETYS is based upon our 2022 future energy scenarios and previous iterations of the NOA. Our view of future transmission requirement and system capability in this ETYS does not consider potential coordination implications from the early opportunities work stream of the Offshore Transmission Network Review as it is still ongoing.



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Regional Drivers – East of England

The coastline and waters around East Anglia are seeing a large increase in the connection of offshore wind projects, including the East Anglia Round 3 offshore zone that lies directly to the east.

The existing nuclear generation site at Sizewell is one of the approved sites selected for new nuclear generation development. A new interconnector project is also contracted to connect within this boundary.

The growth in offshore wind, nuclear generation and interconnector capacities connecting behind this boundary greatly increase the power transfer requirements. The present boundary capability is sufficient for today's needs but could be significantly short of the future capability requirements.

To mitigate the effects of the delta between expected flows and boundary capability from 2025 – 2030 and reduce constraint costs for this region the ESO has developed a commercial non-build solution, the EC5 Constraint Management Intertrip Service (CMIS). This is contracting with generators in the region to provide a more economical method of managing constraints than actions through the balancing mechanism, following the success of the CMIS now in operation across the B6 boundary.

The need for any new network reinforcement to address potential capability issues will be evaluated in the upcoming HNDFUE and tCSNP2 following input from Transmission Owners and other interested stakeholders. Following the evaluation, the preferred reinforcements for the East of England region will be recommended.

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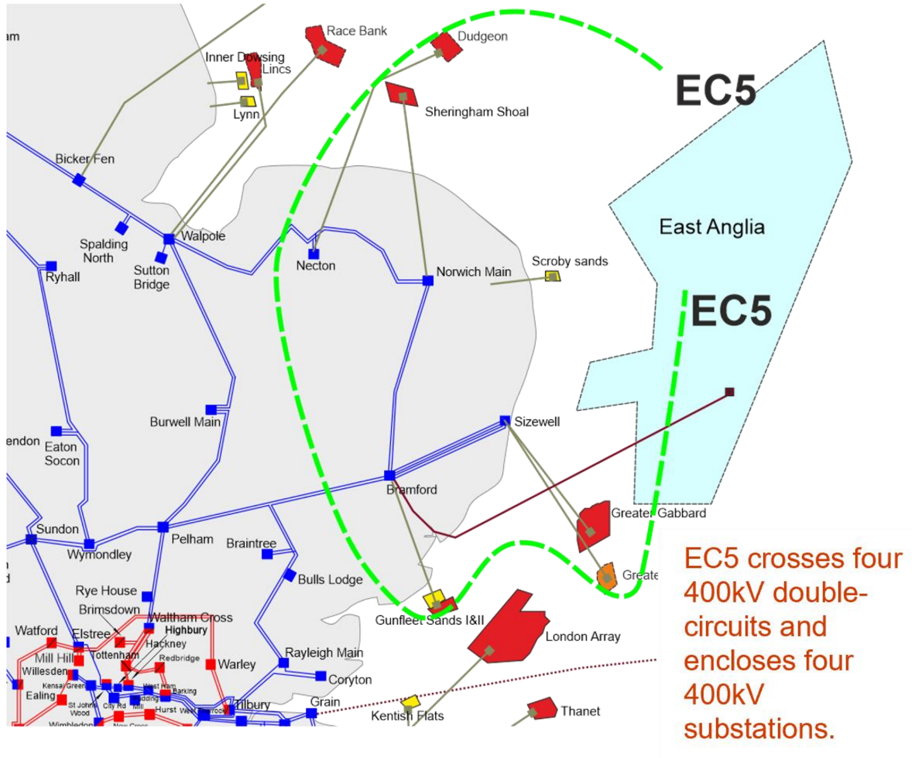
Boundary EC5 – East Anglia

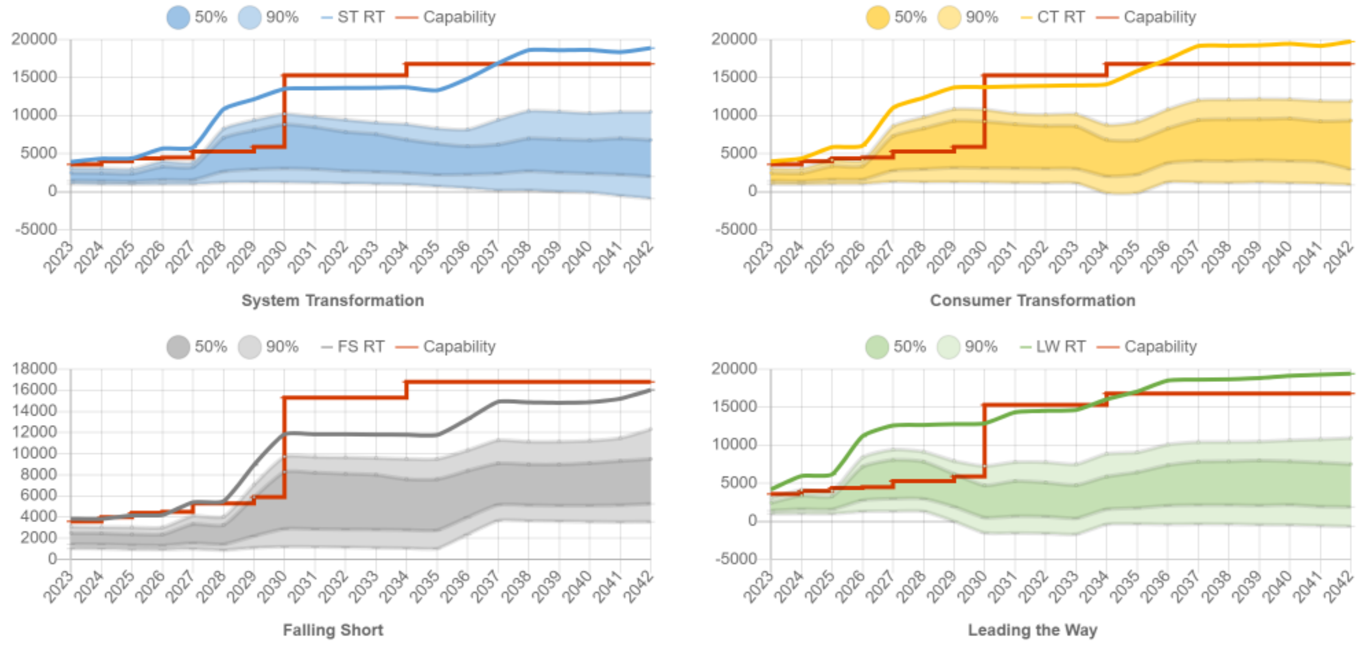
Boundary EC5 is a local boundary enclosing most of East Anglia.



The coastline and waters around East Anglia are attractive for the connection of offshore wind projects, including the large East Anglia Round 3 offshore zone that lies directly to the east.

The existing nuclear generation site at Sizewell is one of the approved sites selected for new nuclear generation development. A new interconnector project is also contracted to connect within this boundary.

The growth in offshore wind, nuclear generation and interconnector capacities connecting behind this boundary greatly increase the power transfer requirements. The present boundary capability is sufficient for today's needs but could be significantly short of the future capability requirements.



We have updated the boundary charts for EC5 boundary. Between 30/01/2023 and 17/04/2023 the required transfer values for the EC5 boundary were calculated based on our wider boundary methodology rather than the local boundary (as EC5 is designated as a local boundary). This has now been corrected and the appropriate values are now shown in the updated charts.

To mitigate the effects of the delta between expected flows and boundary capability from 2025 – 2030 and reduce constraint costs for this region the ESO has developed a commercial solution, the EC5 Constraint Management Intertrip Service (CMIS). This is contracting with generators in the region to provide a more economical method of managing constraints than actions through the balancing mechanism, following the success of the CMIS now in operation across the B6 boundary.

The current boundary capability is limited to 3.85GW due to a thermal constraint on the Bramford – Norwich Main double-circuit

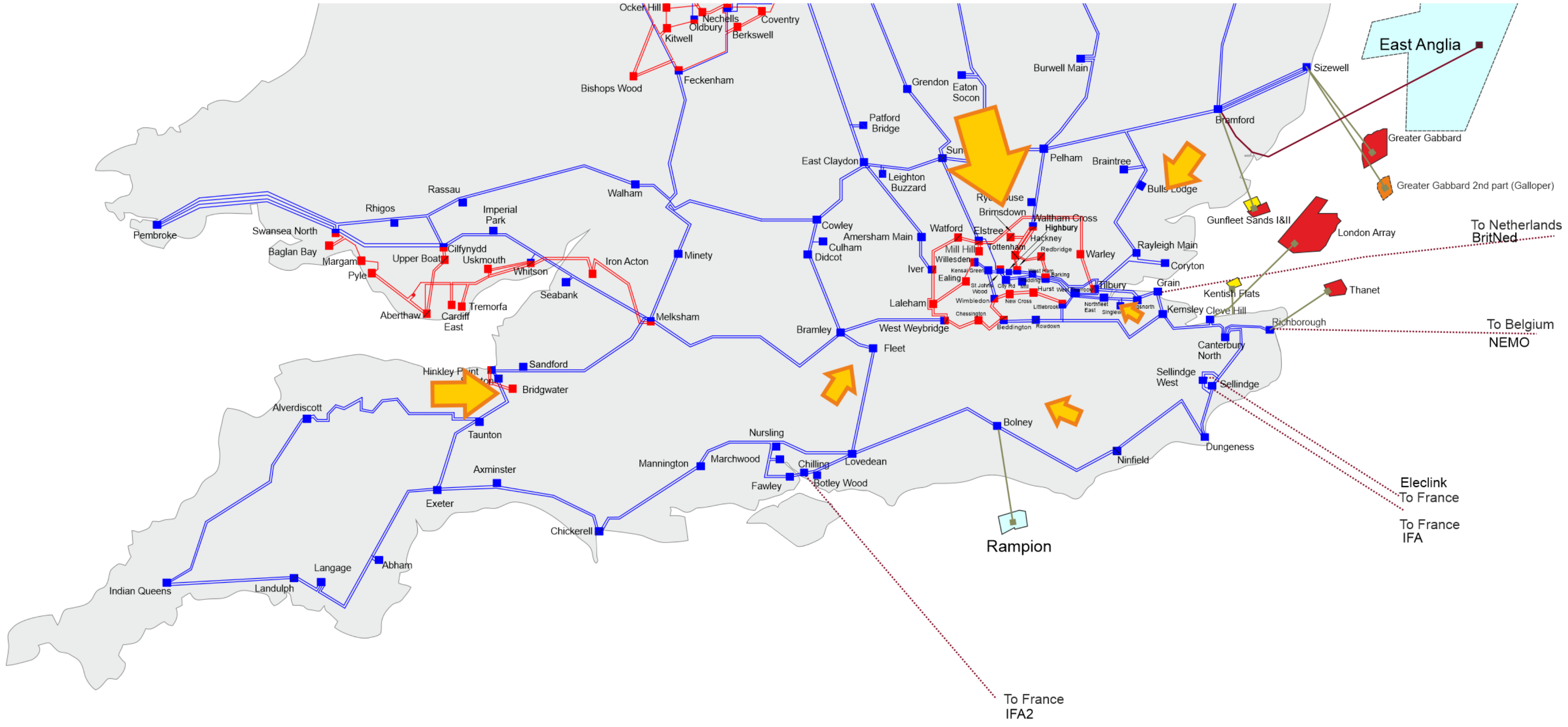
South Wales and South of England

The region includes the high demand area of London, generation around the Thames estuary and the long set of circuits that run around the south coast and South Wales.

Interconnection to Central Europe is connected along the south east coast and this interconnection has significant influence on power flows in the region by being able to both import and export power with Europe.

The South of England transmission region includes boundaries B13, B14, LE1, SC1, SC1.5, SC2, SC3 and SW1.

The figure to the right shows the general pattern of power flow directions expected to occur most of the time in the years to come up to 2031, i.e. power will generally flow from north to south. The arrows in the diagram illustrate power flow directions and are approximately scaled relative to the winter peak flows.



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Regional Drivers – South Wales & South England

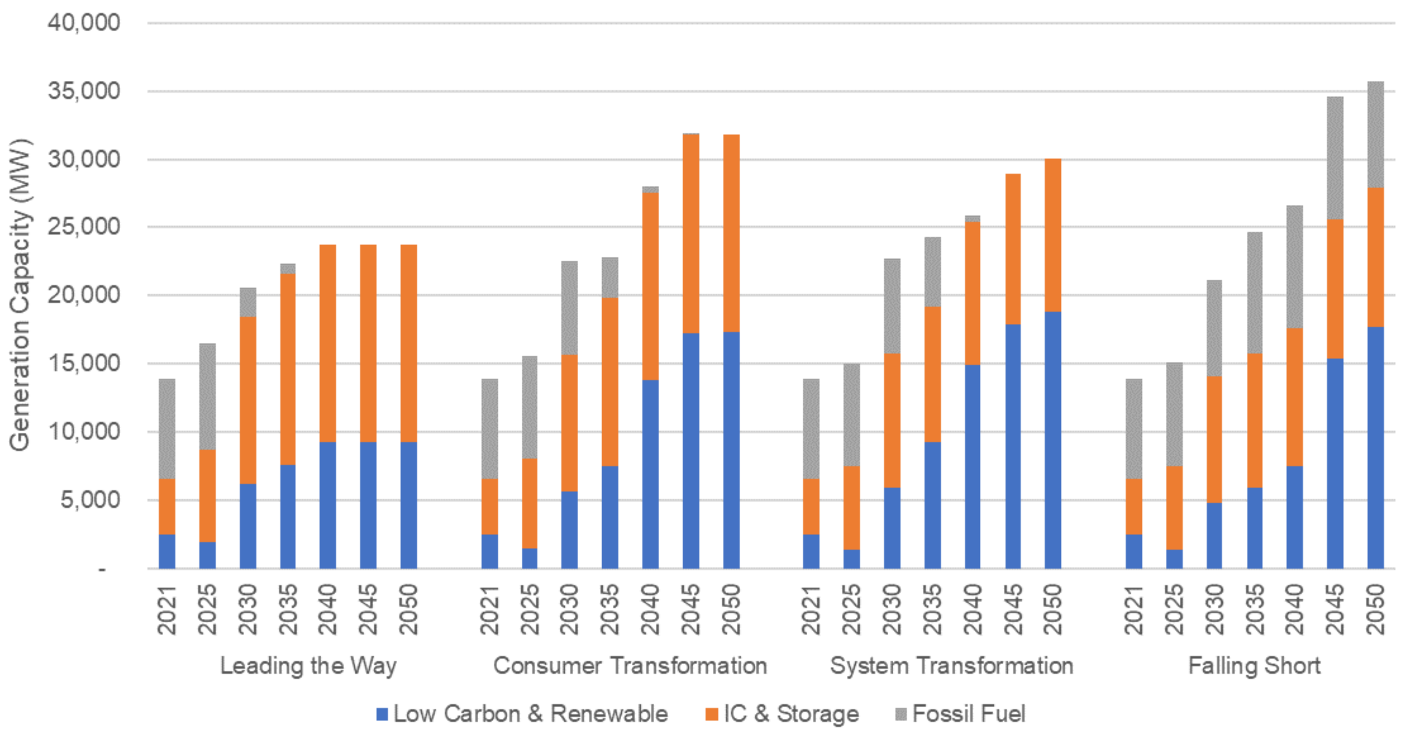
European interconnector developments along the south coast could potentially drive very high circuit flows causing circuit overloads, voltage management and stability issues.

The Leading the Way scenario suggests that over 10GW of additional interconnectors and energy storage capacity may connect in the south by 2030, for a total of over 14GW. European interconnector developments along the south coast could potentially drive very high circuit flows causing circuit overloads, voltage management and stability issues.

As interconnectors and storage are bi-directional, the south could therefore see their capacity provide up to 14GW power injection or 14GW increased demand. This variation could place a very heavy burden on the transmission network. Most of the interconnectors will be connected south of boundary SC1 so the impact can be seen later in the chapter in the SC1, SC1.5 and SC2 requirements.

With future additional interconnector connections, the south region will potentially be unable to support all interconnectors importing or exporting simultaneously without network reinforcement. Overloading can be expected on many of the southern circuits.

The connection of the new nuclear generating units at Hinkley may also require reinforcing the areas surrounding Hinkley. With new interconnector and generation connections, boundaries SC1, SC1.5, SC2, SC3, LE1 and B13 will need to be able to support large power flows in both directions. Wales has seen some generation closures recently, freeing some transmission capacity, but the power export capacity out of the area remains tight. If there is growth in generation capacity in the area, the transmission capacity could be limiting.



Regional Drivers – South Wales & South England

In a highly decentralised scenario like Leading the Way, local generation capacity connected at the distribution level in this region could reach over 15GW by 2030. Of that capacity, a typical embedded generation output on average might be around 4GW. The South is expected to fulfil a smaller portion of its demand from local embedded generation than other regions are.

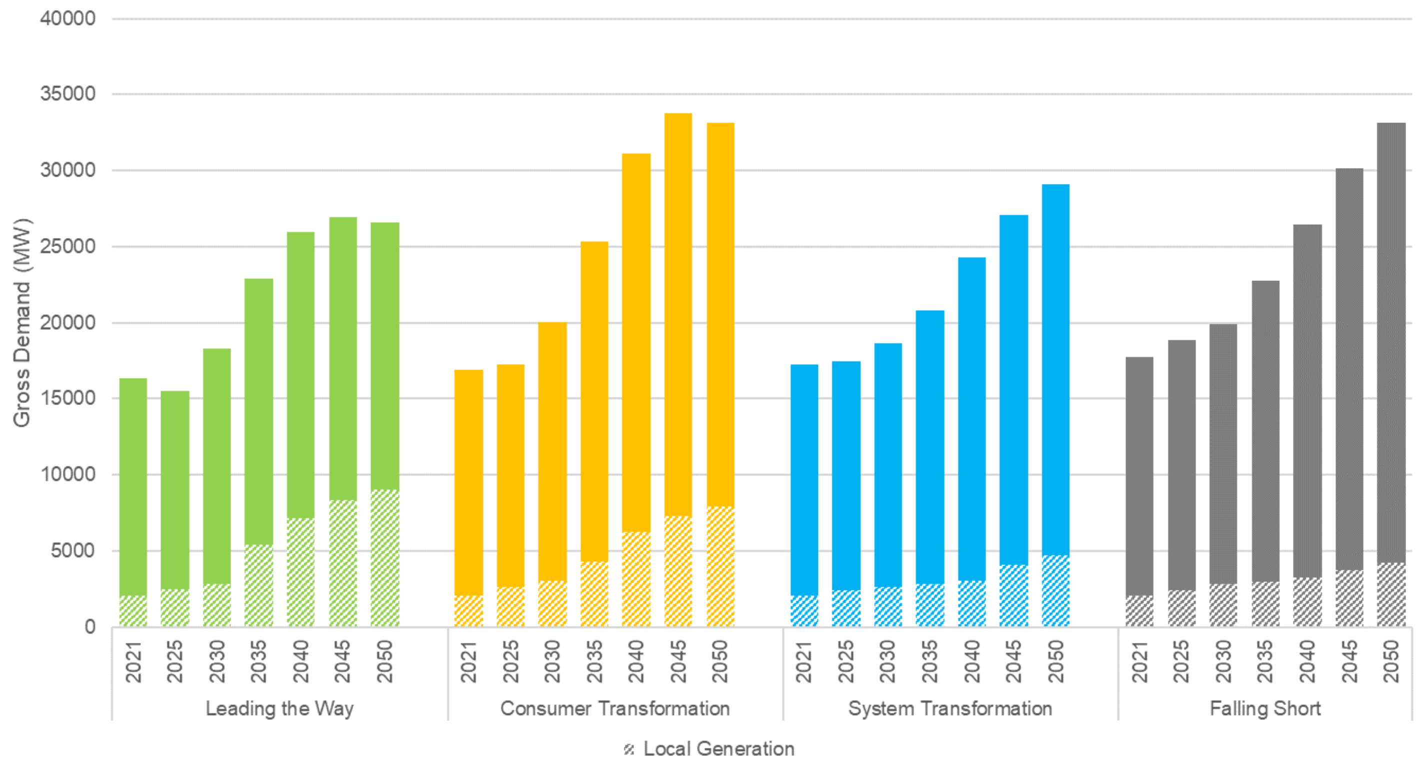
The transmission network in the south is heavily meshed in and around the London boundary B14 and the Thames estuary, but below there and towards the west the network becomes more radial with relatively long distances between substations.

In the future, the southern network could potentially see a number of issues driven by future connections. If the interconnectors export power to Europe at the same time that high demand power is drawn both into and through London, then the northern circuits feeding London will be thermally overloaded.

If the south-east interconnectors are importing from the continent and there is a double-circuit fault south of Kemsley, then the south–east circuits may overload and there could be significant voltage depression along the circuits to Lovedean.

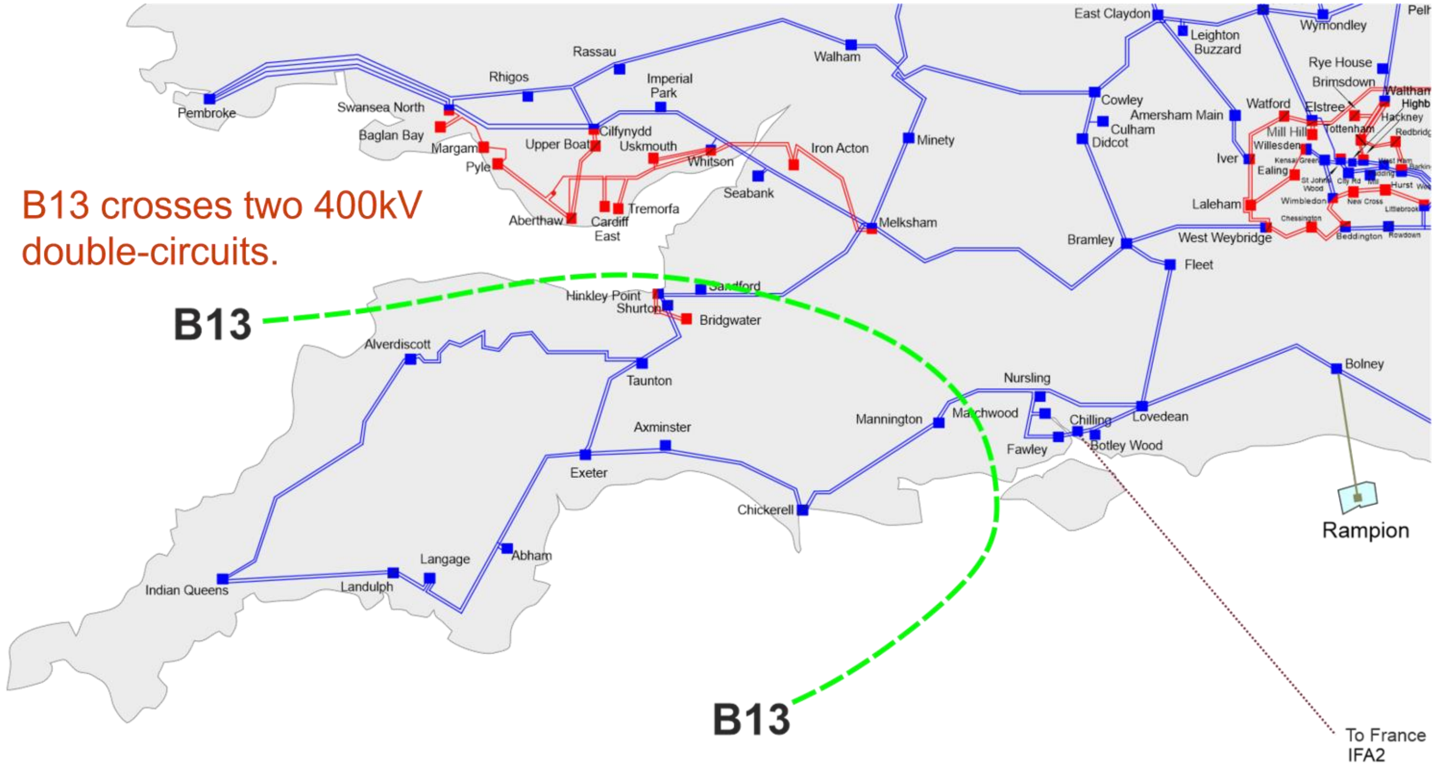
The high demand and power flows may also lead to voltage depression in London and the south-east. The closure of conventional generation within the region will present added stability and voltage depression concerns which may need to be solved through reinforcements.

The need for any new network reinforcement to address potential capability issues will be evaluated in the upcoming HNDFUE and tCSNP2 following input from Transmission Owners and other interested stakeholders. Following the evaluation, the preferred reinforcements for the South Wales & South of England region will be recommended.



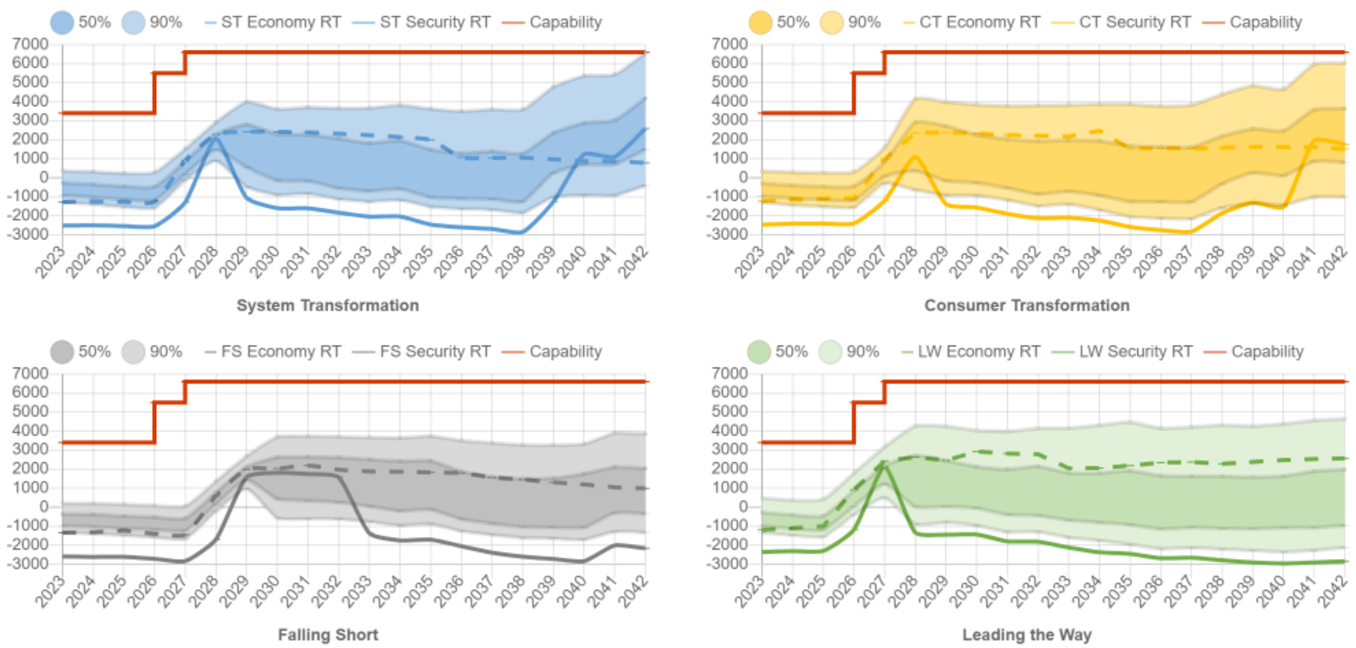
Boundary B13 – South West

Wider boundary B13 is defined as the southernmost tip of the UK below the Severn Estuary, encompassing Hinkley Point in the south west and stretching as far east as Mannington. The southwest peninsula is a region with a high level of localised generation and demand.



It can be seen that until new generation or interconnectors connect there is very little variation in boundary requirements, and that the current importing boundary capability is sufficient to meet the short-term needs.

The large size of the potential new generators wishing to connect close to boundary B13 is likely to push it to large exports and require additional boundary capacity.



The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 3.4GW* due to a voltage compliance constraint at the Indian Queens substation

* ETYS Transfer capability calculated using the 2021 FES data

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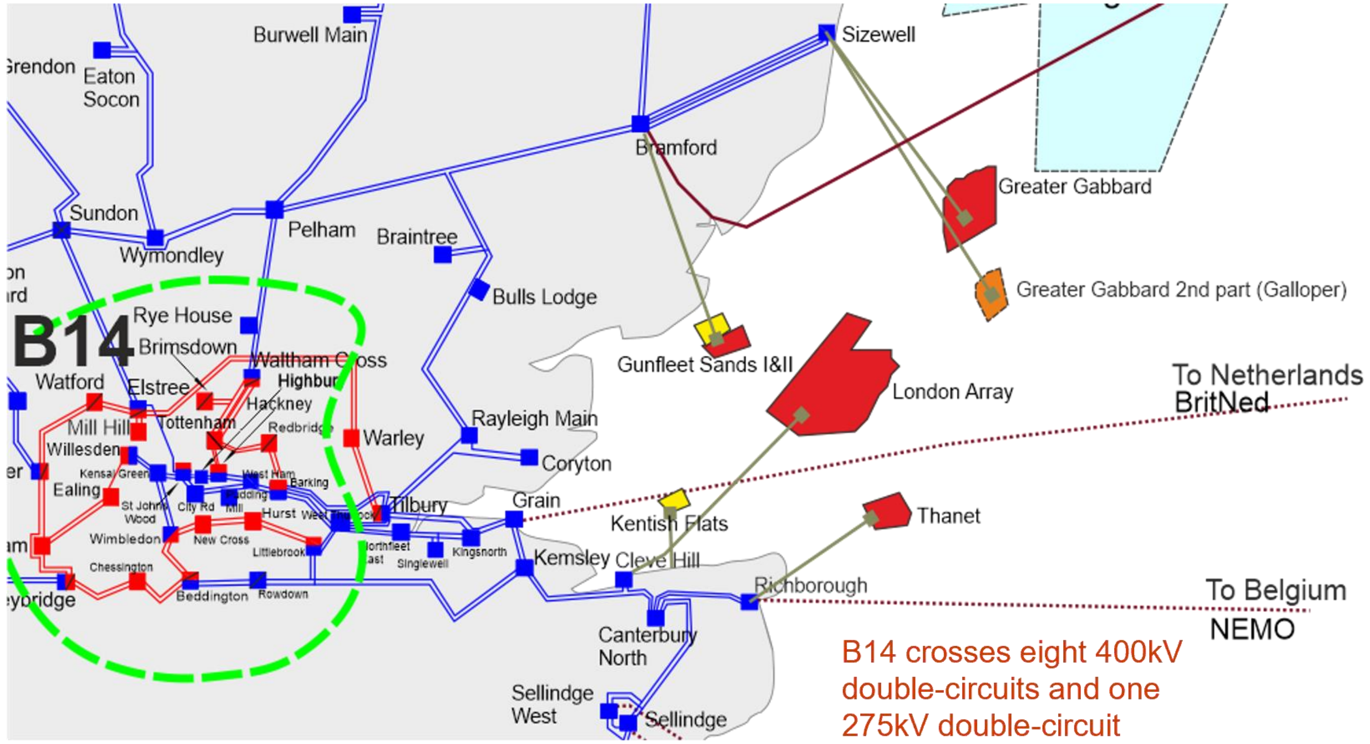
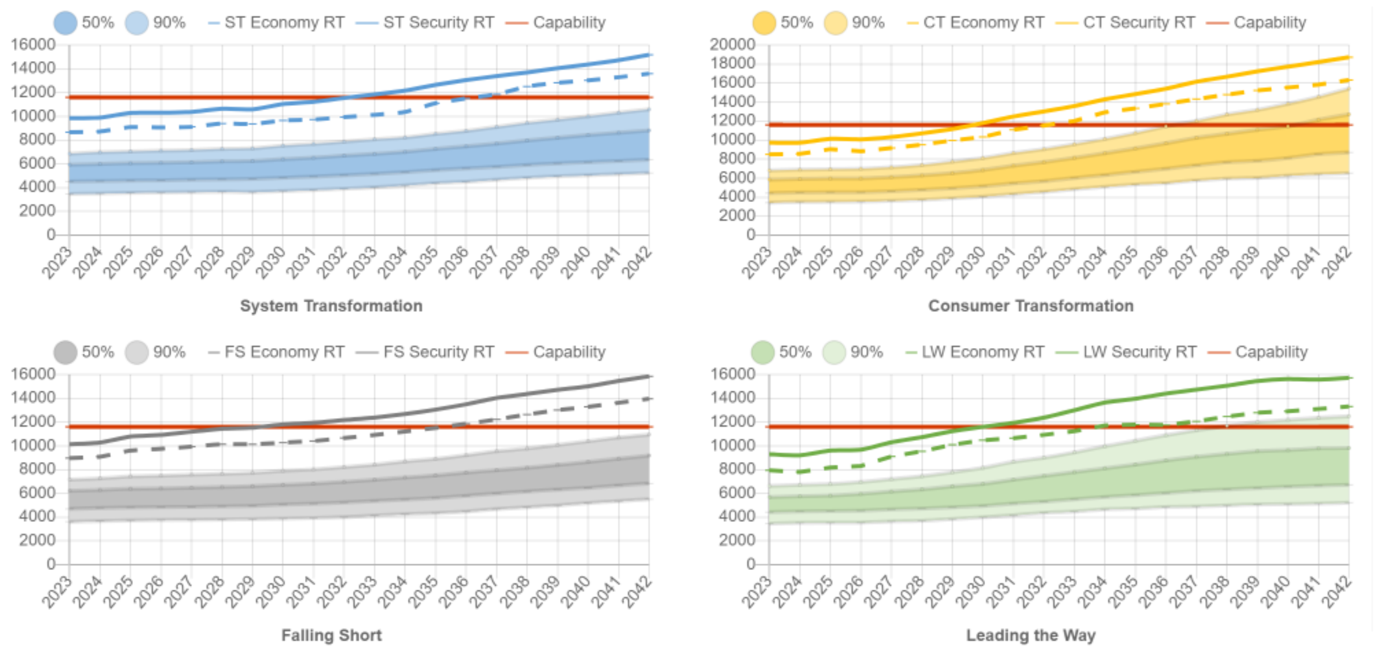
Boundary B14 – London

Boundary B14 encloses London and is characterised by high local demand and a small amount of generation. London’s energy import relies heavily on surrounding 400kV and 275kV circuits.





The circuits entering from the north can be particularly heavily loaded at winter peak conditions. The circuits are further overloaded when the European interconnectors export to mainland Europe as power is transported via London to feed the interconnectors along the south coast.

As the transfer across this boundary is mostly dictated by the contained demand, the scenario requirements mostly follow the demand with little deviation due to generation changes.

The boundary requirements are close to each other across all four scenarios for security and economy required transfer. In both criteria, the required transfer is above 90% flows, meaning planning for these values covers all possible flows.

The capability line (in red) is based on the ETYS transfer capability using FES 2022 data, shown below.

The current boundary capability is limited to 11.6GW due to a thermal constraint on the Grain - Kingsnorth & Grain - Tilbury circuits

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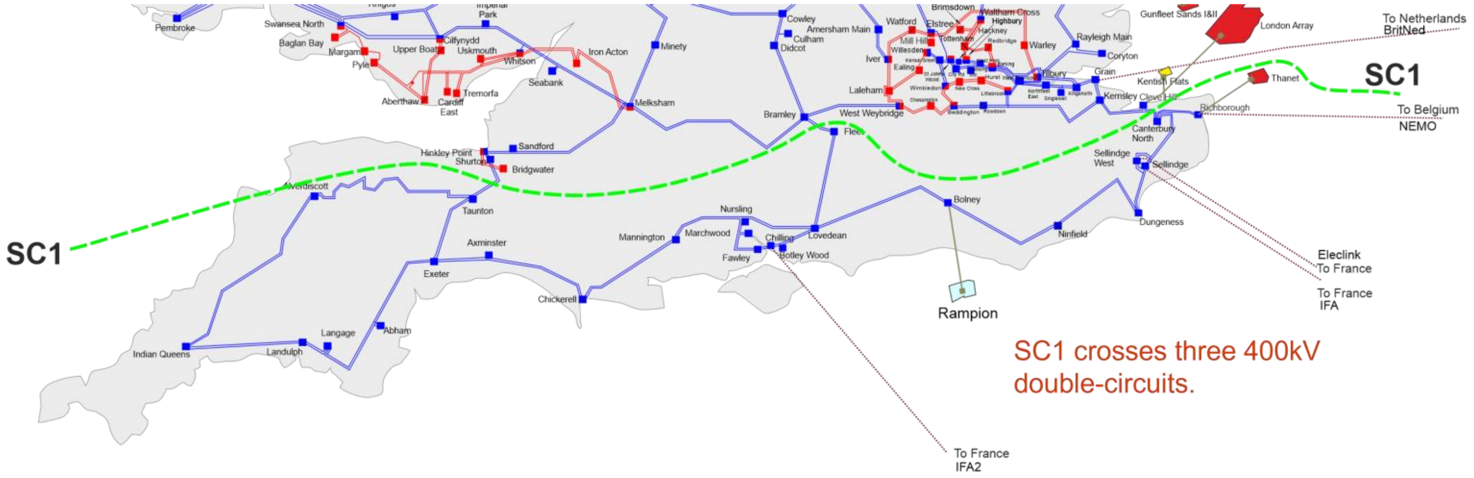
Boundary SC1 – South Coast

Boundary SC1 runs parallel with the south coast between the Severn and Thames estuaries.



At times of peak winter GB demand, the power flow is typically north to south across the boundary, with more demand enclosed in the south of the boundary than supporting generation.

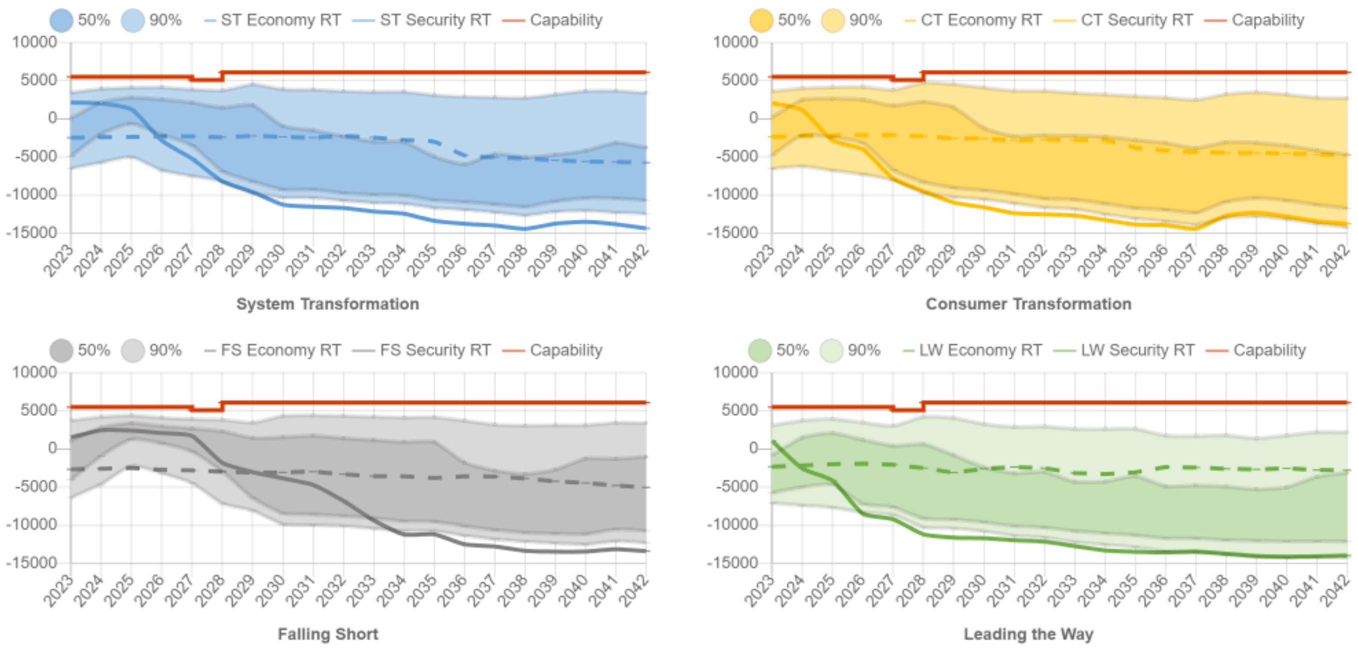
Interconnector activity can significantly influence the boundary power flow. The current interconnectors to France, the Netherlands and Belgium connect at Sellindge, Grain and Richborough respectively.

The interconnectors to Europe have a significant impact on the power transfers across SC1. A 2GW interconnector such as IFA can make 4GW of difference on the boundary from full export to full import mode or vice versa.

The biggest potential driver for SC1 will be the connection of new continental interconnectors. With their ability to transfer power in both directions, boundary SC1 could be overloaded much more than normal with conventional generation and demand.

Across all four scenarios in the FES, the SQSS security required transfer follows a generally flat pattern, whereas the economy required transfer moves from exporting to importing from 2024 – 2029 depending on scenario. The volatility of interconnector activity can be seen in the required transfers as the requirements swing from power flow south and north.

The SQSS calculation of required transfers does not place high loading on the interconnectors so the transfers are not seen to peak at very high values.



The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 3.85GW due to a voltage compliance constraint at the Dungeness 400kV substation

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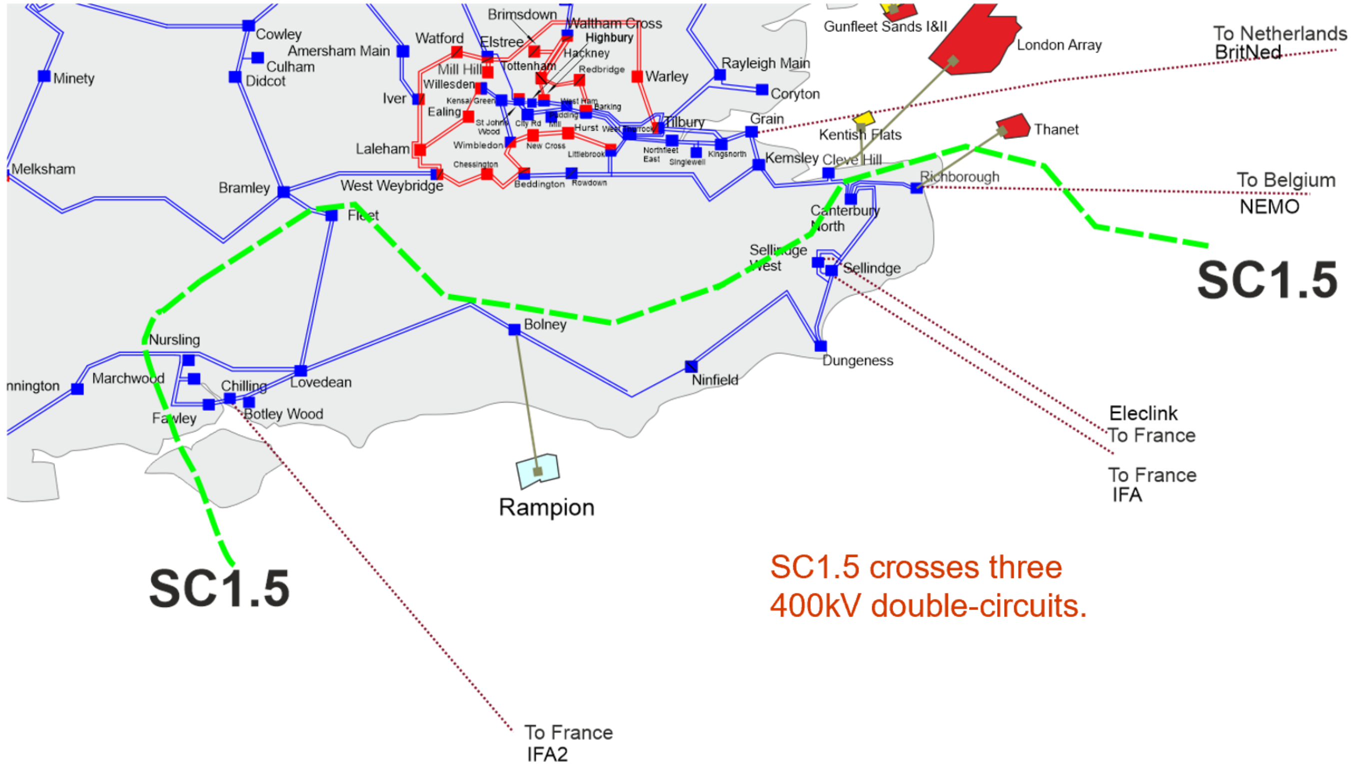
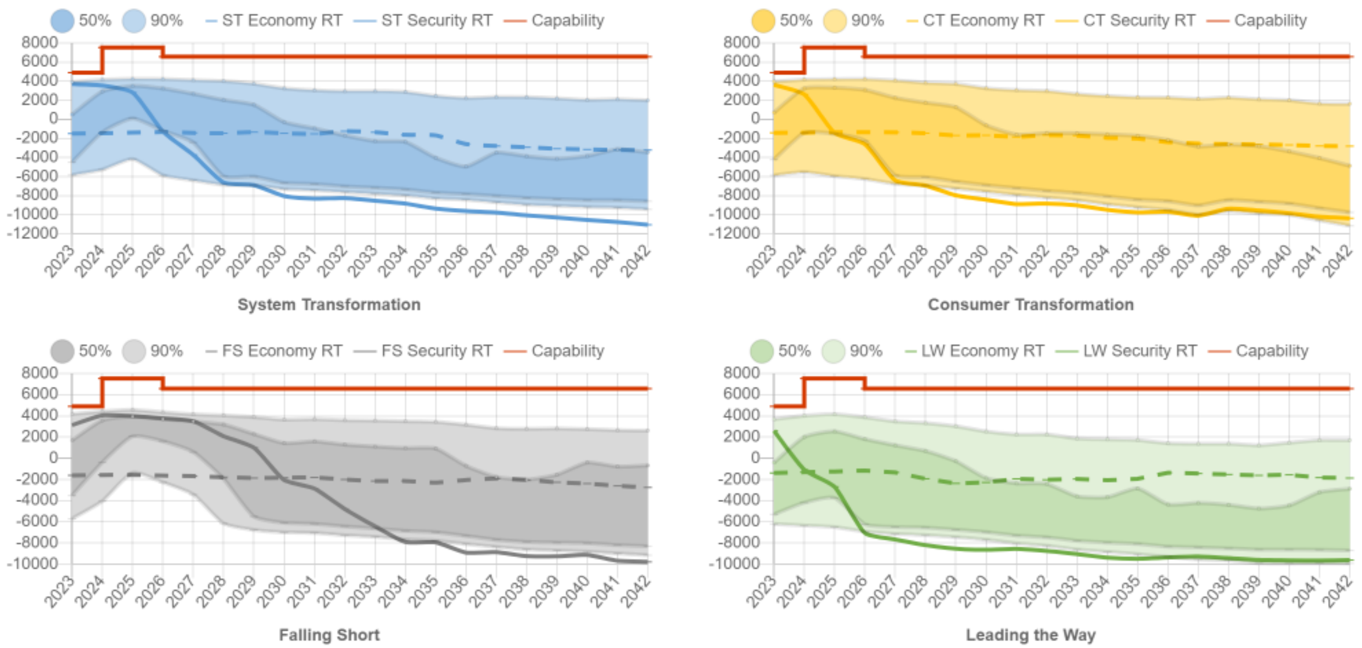
Boundary SC1.5 – South Coast

Boundary SC1.5 is a new boundary created between SC1 and SC2 to capture issues to the west of Nursling. The boundary crosses over the double circuits between Nursling – Mannington, Bramley – Fleet and Cleve Hill – Canterbury.





At times of peak winter GB demand, the power flow is typically north to south across the boundary, with more demand enclosed in the south of the boundary than supporting generation.

Interconnector activity can significantly influence the boundary power flow. There is a new interconnector connecting at Chilling this boundary captures.

The interconnectors with Europe have a large impact on the power transfers across SC1.5 as a 2.0GW interconnector can make 4.0GW of difference on the boundary if it moves from import to export.

The volatility of interconnector activity can be seen in the wide spread of expected boundary flows depicted by the central darker band. Transfers (shown above) do not place high loading on the interconnectors, so the transfers are not seen to peak at very high values.

The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 5.56GW due to a thermal constraint on the the Bramley - Fleet 400kV circuit

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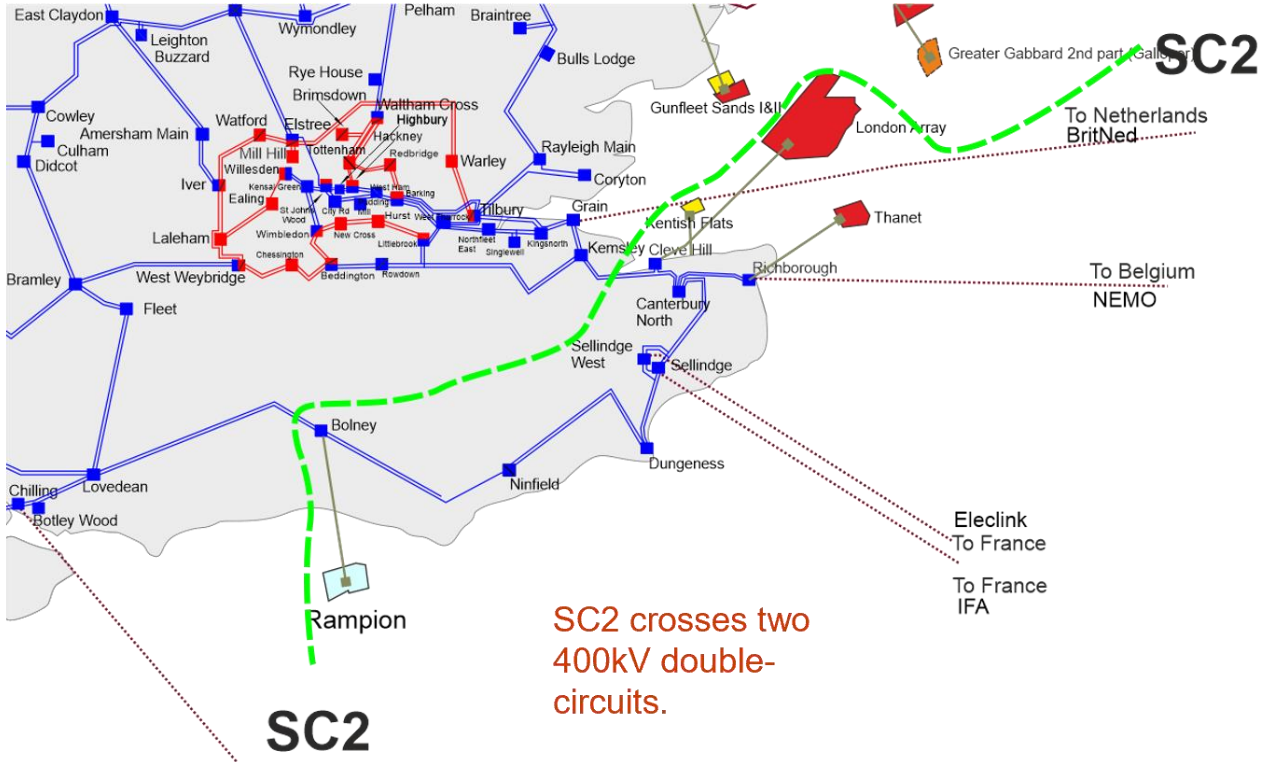
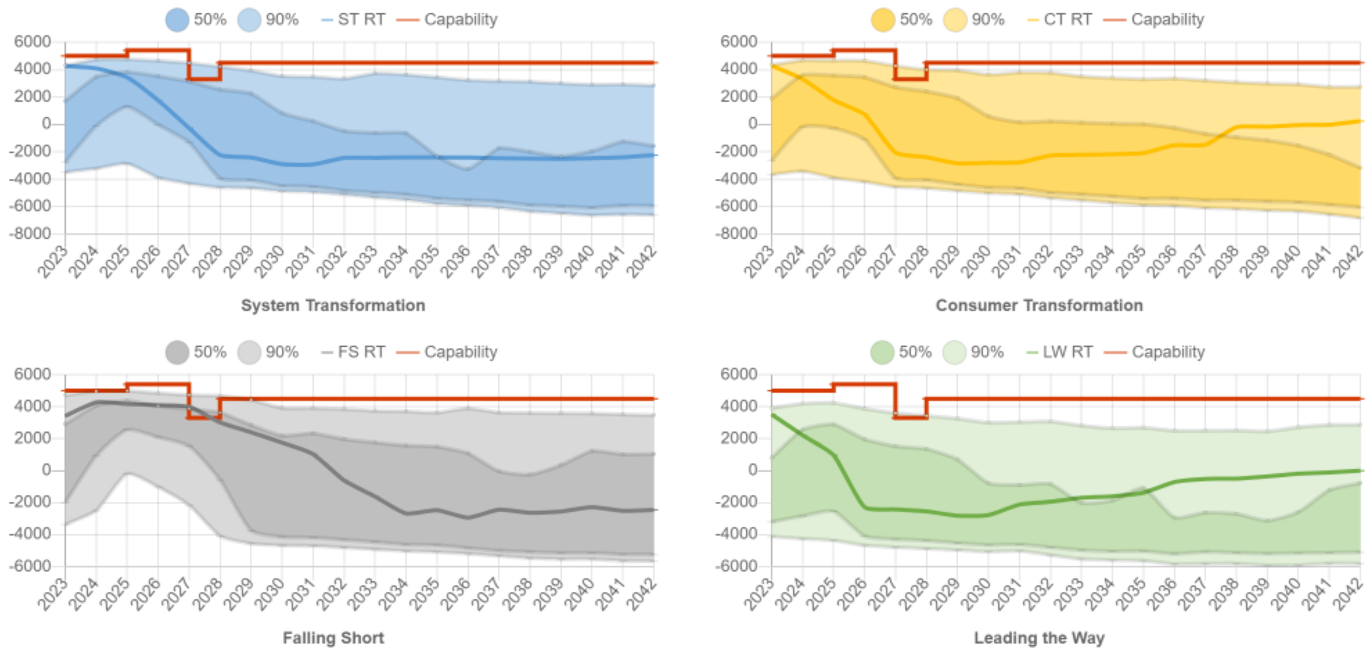
Boundary SC2 – South Coast

SC2 is a subset of the SC1 boundary created to capture transmission issues specifically in the south part of the network between Kemsley and Lovedean.





The relatively long 400kV route between Kemsley and Lovedean feeds significant demand and connects both large generators and interconnection to Europe. A fault at either end of the route can cause it to become a long radial feeder which puts all loading on the remaining two circuits which can be restrictive due to circuit ratings and cause voltage issues.

Additional generation and interconnectors are contracted for connection below SC2 which can place additional burden on the region. The closure of Dungeness has contributed to voltage stability constraints in the region.

The interconnectors with Europe have a large impact on the power transfers across SC2 as a 2.0GW interconnector can make 4.0GW of difference on the boundary if it moves from import to export.The volatility of interconnector activity can be seen in the wide spread of expected boundary flows depicted by the central darker band similar to SC1.5. Transfers do not place high loading on the interconnectors, so the transfers are not seen to peak at very high values here either.

The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 3.75GW due to voltage compliance constraints

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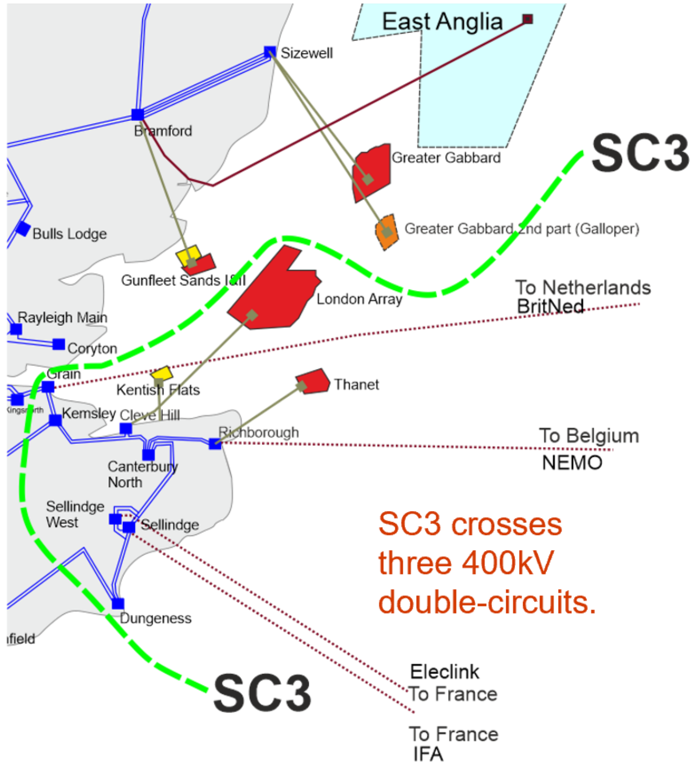
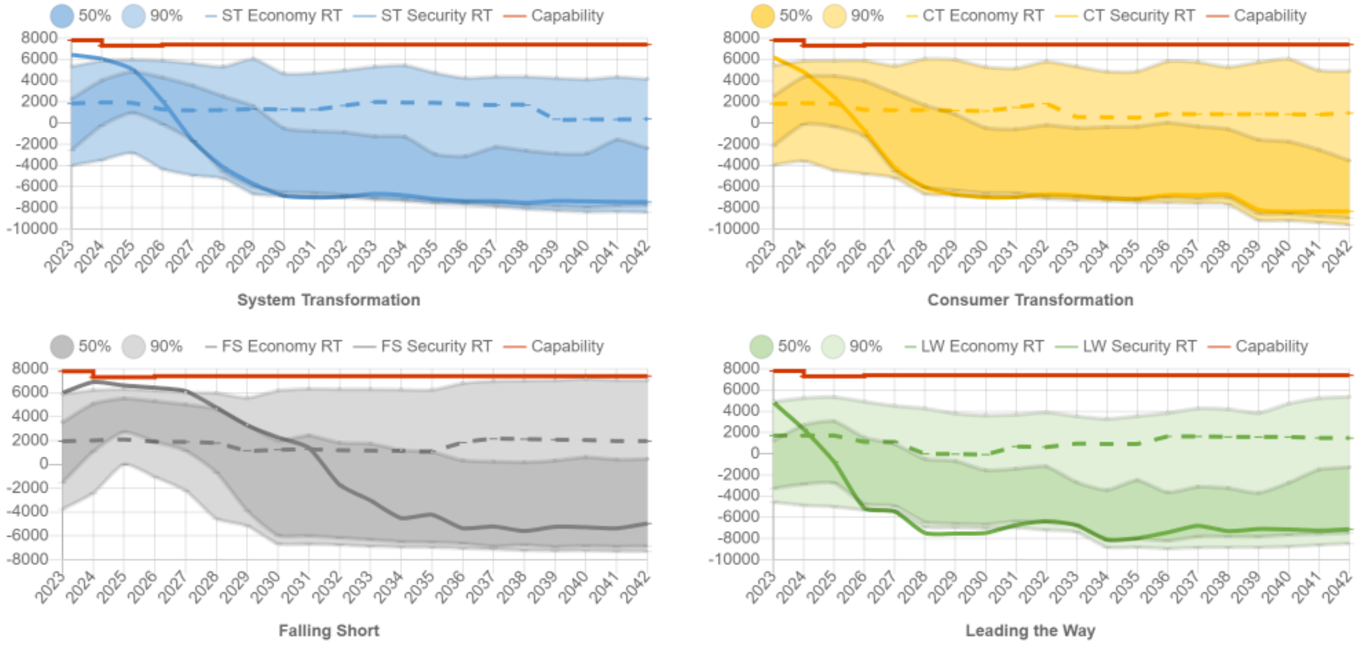
Boundary SC3 – South Coast

Boundary SC3 is created to capture transmission issues specifically in the south-east part of the network.





The current and future interconnectors to Europe have a significant impact on the power transfers across SC3. The current interconnectors to France, the Netherlands and Belgium connect at Sellindge, Grain and Richborough respectively.

Across all four scenarios in the FES, the SQSS security required transfer follows similar patterns and is mainly lower compared to the economy required transfer. In general, the economy required transfer faces a decline over time, albeit it does not reflect the interconnectors uncertainties. The uncertainty of interconnector activity can be seen in the wide spread of the boundary flows depicted by the central darker band.

The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 6.7GW due to a thermal constraint on the Grain – Tilbury 400kV circuit

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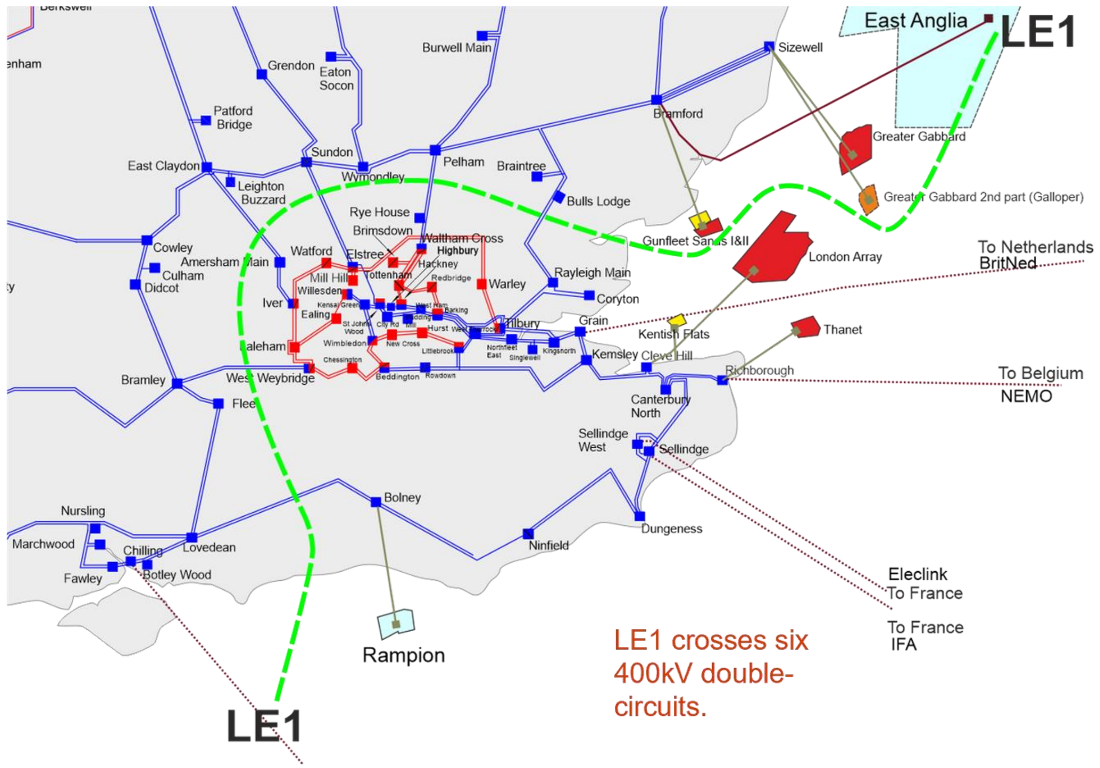
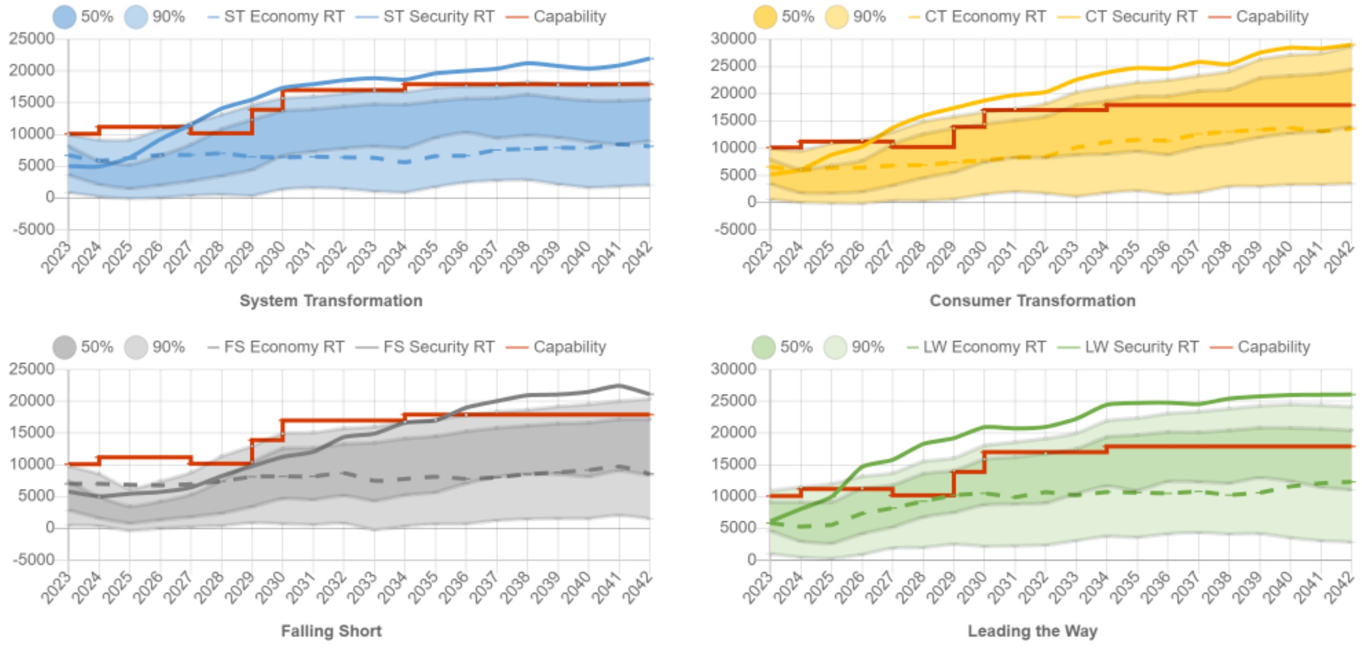
Boundary LE1 – South East

Boundary LE1 encompasses the south-east of the UK, incorporating London and the areas to the south east of it.





LE1 is characterised by two distinct areas. Within London, there is high local demand and little generation. The remainder of the area contains both high demand and high levels of generation. In particular, there are a number of gas power generators in the Thames estuary area and an interconnector to the Netherlands, while connected to the south-east coast are a number of wind farms, interconnectors to France and Belgium, as well as nuclear and gas power stations.

LE1 almost exclusively imports power from the north and west into the south-east, and the purpose of the boundary is to monitor flows in this direction. With the existing and proposed interconnectors importing power from the continent, power flows enter London from all directions, to the extent that flows across LE1 reduce and limited constraints are seen.

However, with an increased number of interconnectors, and (in some scenarios) increased likelihood of them exporting power in future years, LE1 can become a higher demand area, with any locally generated power feeding straight into the interconnectors. As such, the circuits entering LE1 from the north can become overloaded as power is drawn into and through London toward the south and east.

Across all four scenarios in the FES, the SQSS economy required transfer grows beyond existing boundary capability from 2023 and the expected power flows are less than the required transfer and the uncertainty of interconnector activity can be seen in the wide range of the boundary flows.

The current boundary capability is limited to 9.6GW due to a thermal constraint on the Elstree – Sundon 400kV circuit

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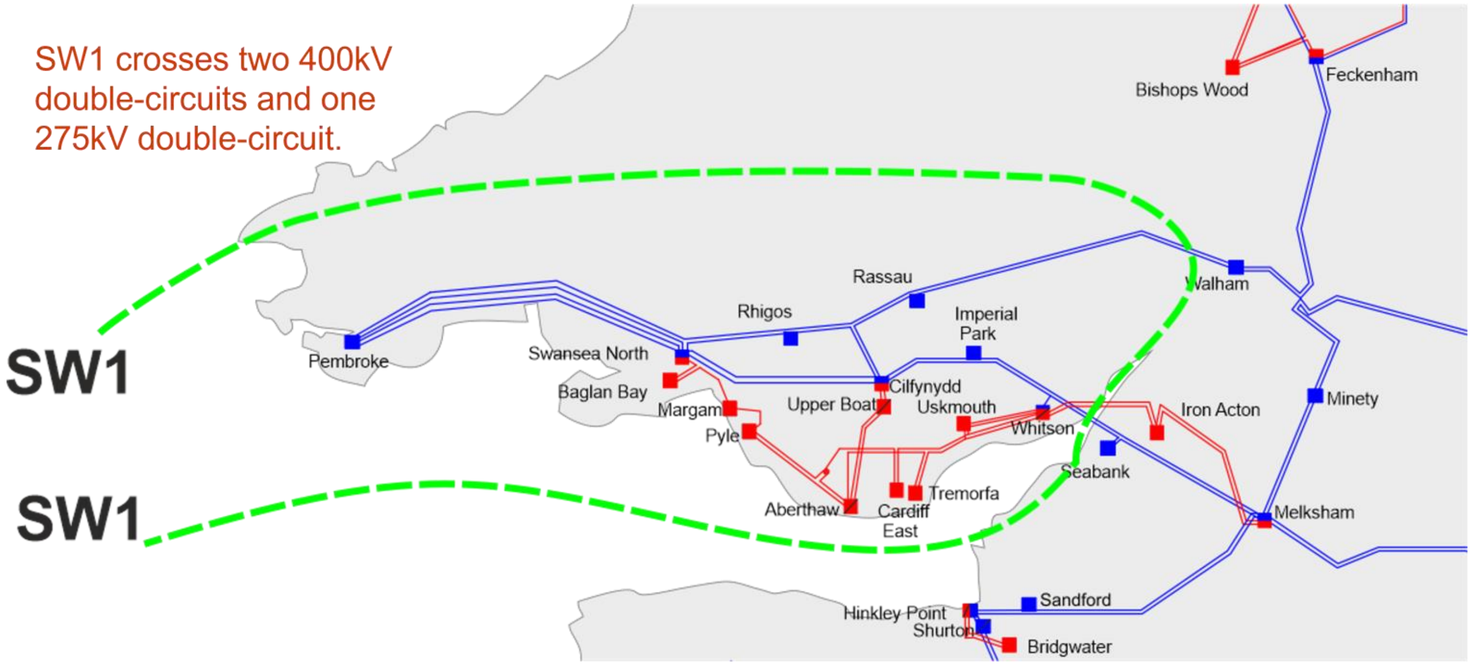
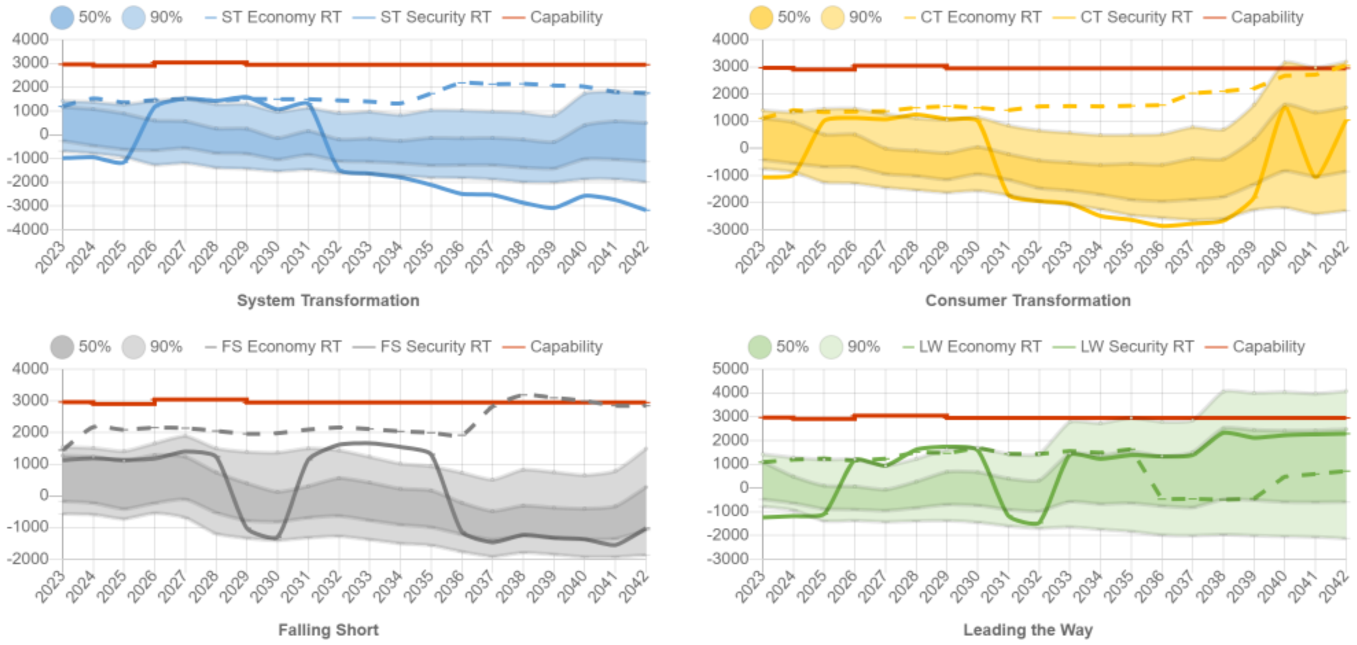
Boundary SW1 – South Wales

Boundary SW1 encloses South Wales and is considered a wider boundary.





Contained within the boundary is a mixture of generation types including gas combined cycle, coal, wind and solar. Some of the older power stations are expected to close but new generation capacity is expected to connect, including new generators powered by wind, gas, solar and tidal.

South Wales includes demand consumptions from the major cities, including Swansea and Cardiff, and the surrounding industry.

The boundary requirements are well within the boundary's present capability, and we expect this to remain the case for the foreseeable future, as seen in the boundary chart.

The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2022. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The current boundary capability is limited to 2.9GW due to a thermal constraint on the Imperial Park - Melksham circuits

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Improving ETYS to integrate a wider range of system needs

Improving ETYS to integrate a wider range of system needs

The ETYS is the ESO's view of how the future demand of the transmission system will be met. Currently, this focuses mainly on bulk power transfer requirements, particularly during winter-peak conditions.

As operation of the National Electricity Transmission System (NETS) becomes increasingly complex, we need to expand our view of system needs across the year. This will require the use of innovative analysis techniques and the development of new tools. We are looking to bring together our work on year-round thermal analysis, our development of new tools for voltage & stability, and learning from the success of our NOA pathfinders to inform how we can communicate a wider set of system needs in ETYS.

As part of the ongoing Network Planning Review, we are exploring how we can further enhance our communication of system needs in ETYS, not only to include thermal year-round needs but also voltage and stability needs, at a high-level, in line with our ongoing tools development. We summarise in this chapter the progress to-date and how you can get involved to share your feedback.

We would like to hear your views on how we can improve the ETYS, we have set up a short survey to gather feedback.

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Year-round thermal analysis

We have continued to develop our year-round thermal tool, POUYA (POwer Uncertainty Year-round Analyser).

POUYA allows us to capture the power transfer limitations on the GB NETS not only during the winter but also across the other seasons in a year, driven by the seasonal characteristics of low carbon energy resources and circuit ratings.

This year, we are presenting a few examples of how we can communicate year-round thermal system needs. We would like to hear your thoughts on what additional information you would find helpful. Our new and improved version of the POUYA tool is still undergoing development and validation, therefore the examples presented here are based on our previous POUYA analysis using generation, demand, and network backgrounds from year 1 ETYS 2021.

The examples we showcase provide insights on:

- Seasonal variations of thermal overloading,
- A wider view of limiting assets and their potential impacts on constraints,
- Multiple contingencies and their likelihood to cause network constraints,
- Year-round boundary transfers (overloaded/not overloaded).

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Year-round thermal analysis

Where are we now?

In our March 2022 report on the POUYA tool we shared an update on the tool's development and some initial results demonstrating POUYA's ability to identify boundary limitations under different seasons.

As we take further steps in the development of year-round thermal analysis, we are now exploring a range of ideas on how we can communicate year-round thermal needs to support the development of our 'business as usual' process. We see the communication of year-round needs as serving the following purposes:

- Providing insight to our stakeholders into limitations or network needs across other seasons.
- Identifying additional scenarios that should be considered for detailed analysis.
- Identifying opportunities for targeted network or commercial solutions.

Ongoing development

Certain capabilities of the POUYA tool are still under development in preparation for future ETYS publications. These additional capabilities include:

- Enabling our year-round system needs assessments to consider scheduled outages of transmission assets, more closely aligning our network planning studies with operational considerations. The results presented here have been conducted on an intact transmission network.
- Indicative constraint costs for individual overload occurrences and contingency scenarios.
- Developing data insight to identify underlying drivers for network limitations and identify scenario trends.

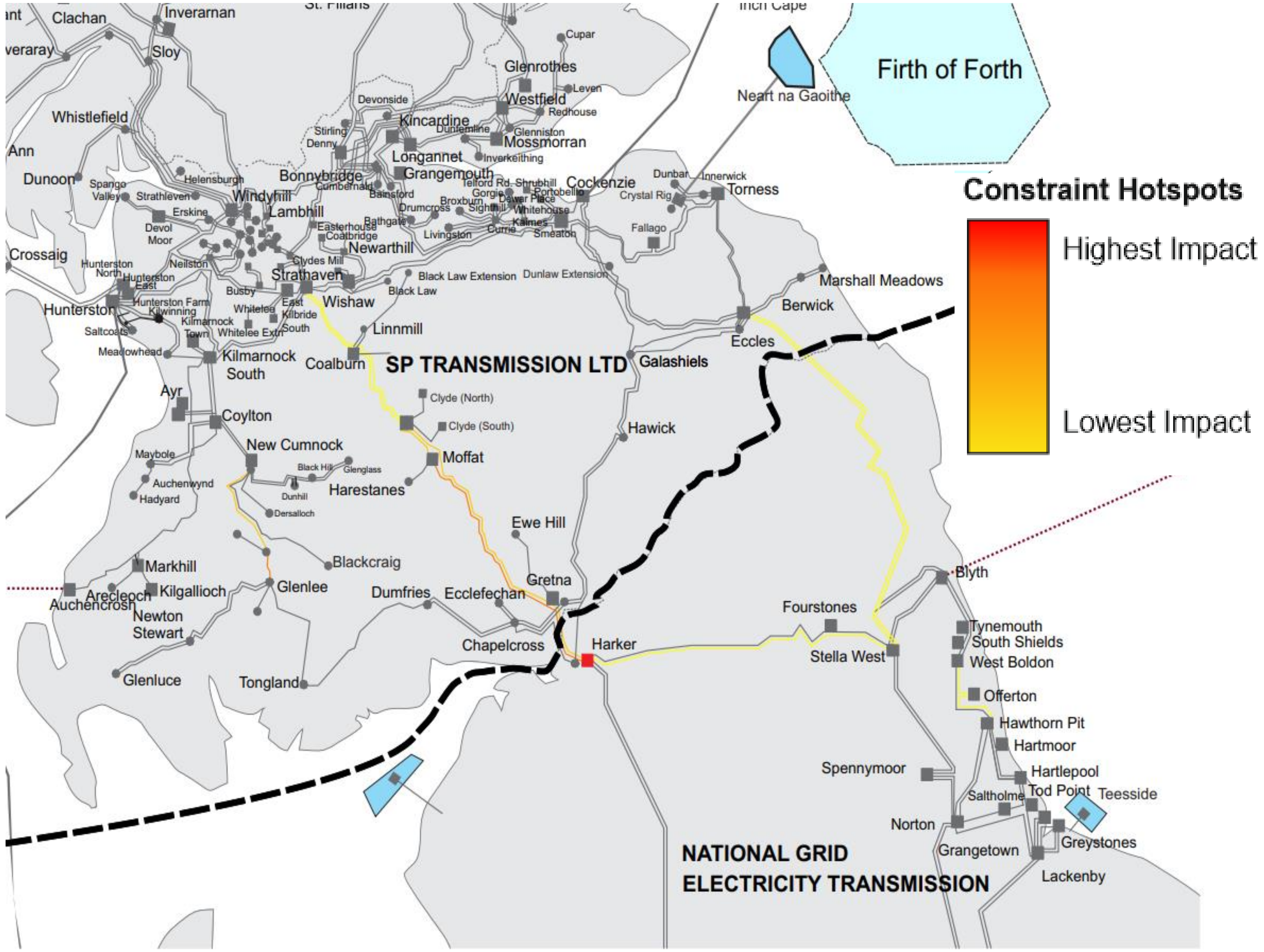
We will continue to develop this process over the next year and transition these practices into our 'business as usual' processes. We will be exploring how to integrate the year-round system needs assessment into our existing options assessment process, to further improve our network investment decision making process.

Year-round thermal analysis

System Needs on a geographic map

The map to the right shows a geographical representation of the transmission assets which experienced overloading across all seasons for the B6 contingencies. We indicate the constraint hotspots using a heatmap key with the impact of the constraint representing a measure of the likelihood and severity of the overloading on that asset.

In this example, Harker SGTs were identified as the constraint with the 'highest impact' across the four seasons. This limiting asset was the same as identified in our deterministic winter peak ETYS 2021 studies. A geographic map can provide readers with a visual representation of constraints bottlenecks that could help with the development of targeted network solutions.



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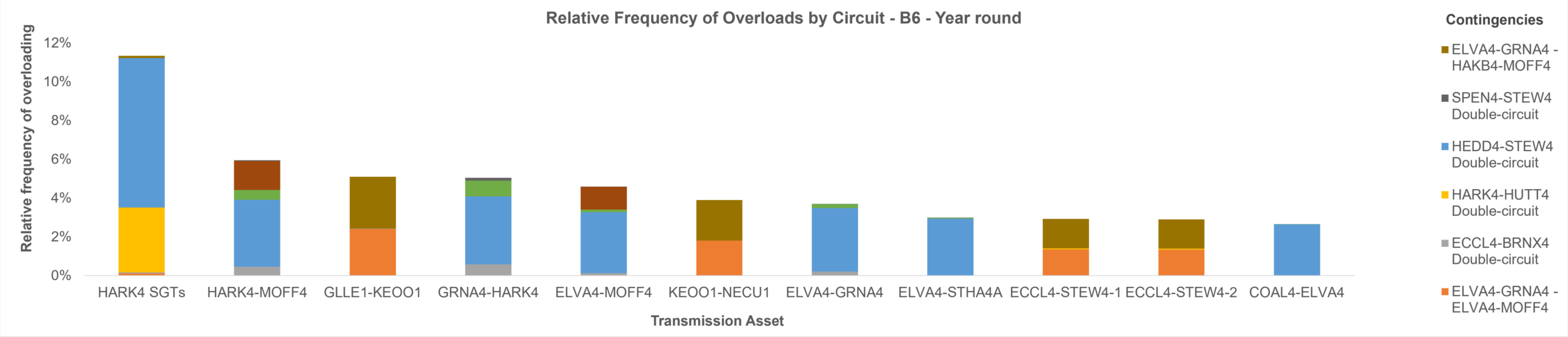
Year-round thermal analysis

Relative frequency of asset overloading

The chart below shows the relative frequency of overloads experienced by individual transmission assets (the percentage of overloads occurring on that asset as a percentage of the total overload occurrences over the whole year or individual season). Using this we can identify and communicate not only the most severe limiting asset but also identify other assets which are limiting boundary capability, or assets which could become limiting after the current limitation is resolved, across the range of snapshots.

The second most frequently overloaded assets other than the Harker SGTs identified was the Harker – Moffat 400kV single-circuit, this is the limiting asset identified for the B6 boundary in the ETYS 2022 studies (following the implementation of the HAEU reinforcement which changed the banking arrangement on two SGTs at Harker, alleviating some of the constraint on the SGTs at Harker 400kV substation).



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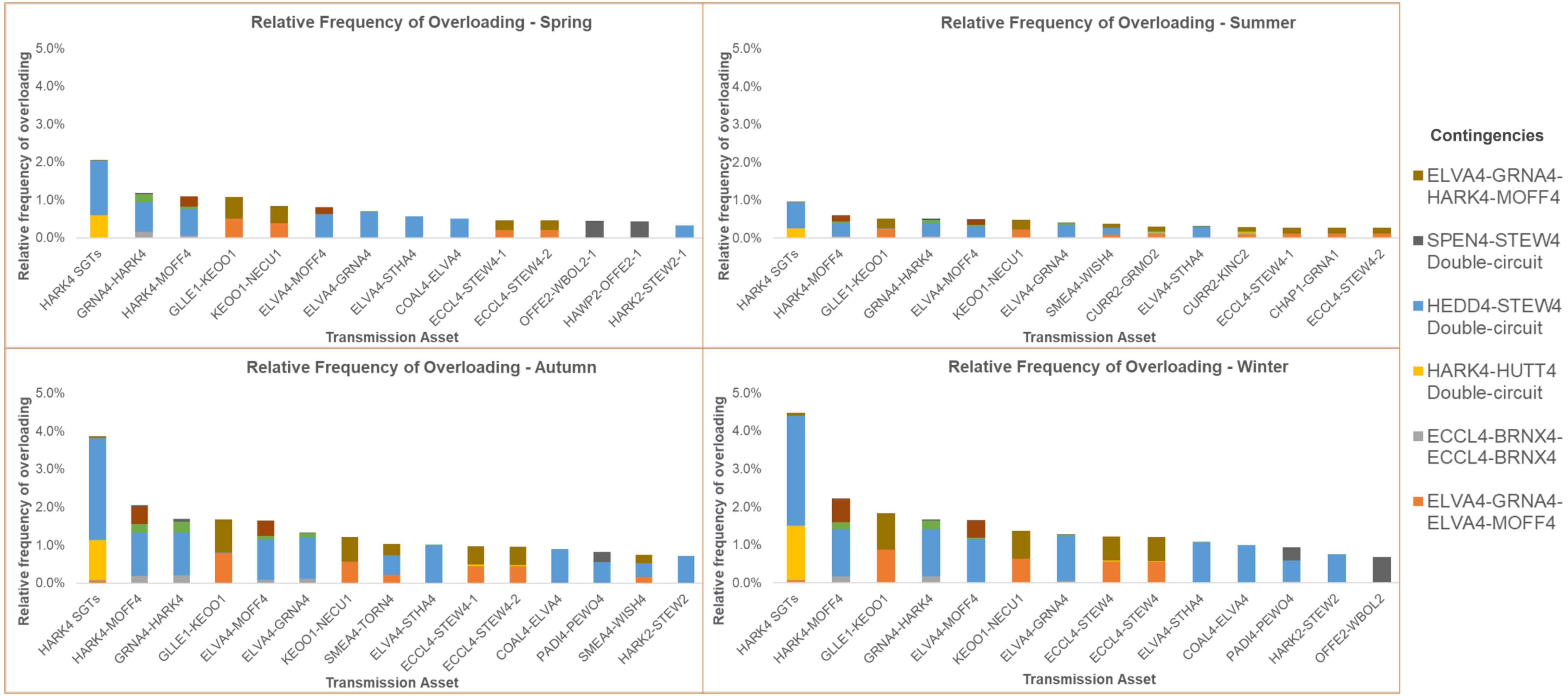
Year-round thermal analysis

Relative frequency of asset overloading - Seasonal



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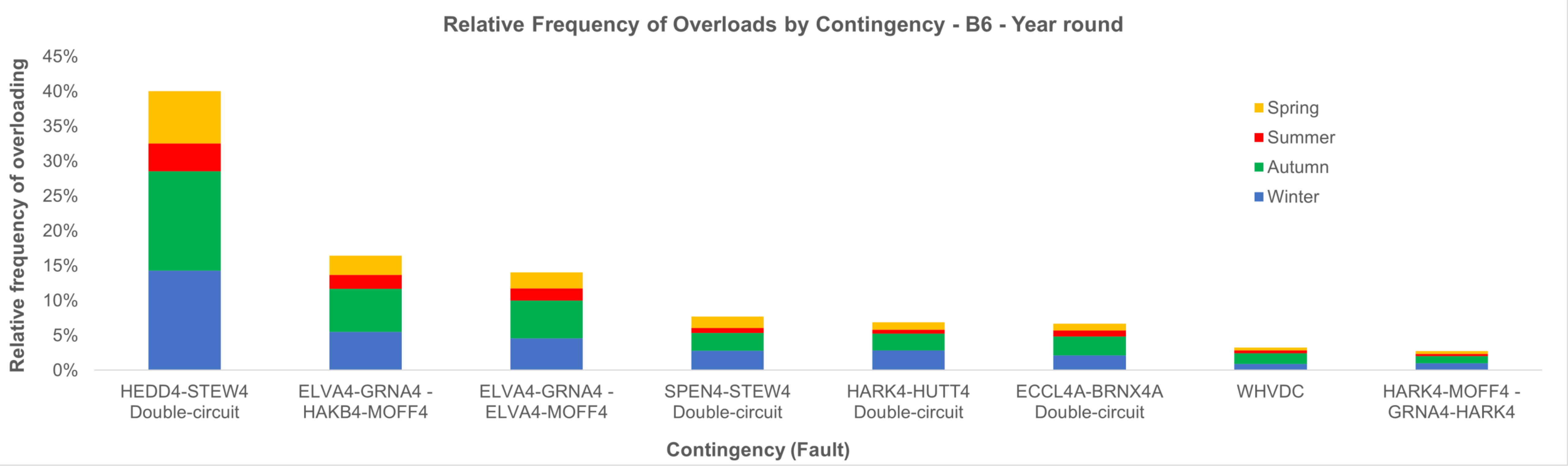
Year-round thermal analysis

Relative frequency of overload by contingency

This representation helps identify some of the critical contingencies for a given boundary together with an indication of how overloading frequency differs across the seasons. As the generation background, demand profile, and asset thermal ratings change across the year, the frequency and severity of the overloads occurrences across the network will differ across the seasons. From our POUYA studies, in the summer and Spring periods, lower network flows generally result in less frequent overload occurrences. autumn and winter experience much greater volumes of thermal overloading at a similar frequency to one another.

Boundary flows across B6 are on average just 3.5% lower in autumn than winter, whereas asset thermal ratings can be the same or up to 20% lower in autumn than in winter. This means that although the volume of flows in autumn may be lower than in winter, it is possible that a similar or higher frequency of overloading may be observed in autumn than winter and will largely depend on the seasonal thermal rating of individual assets.



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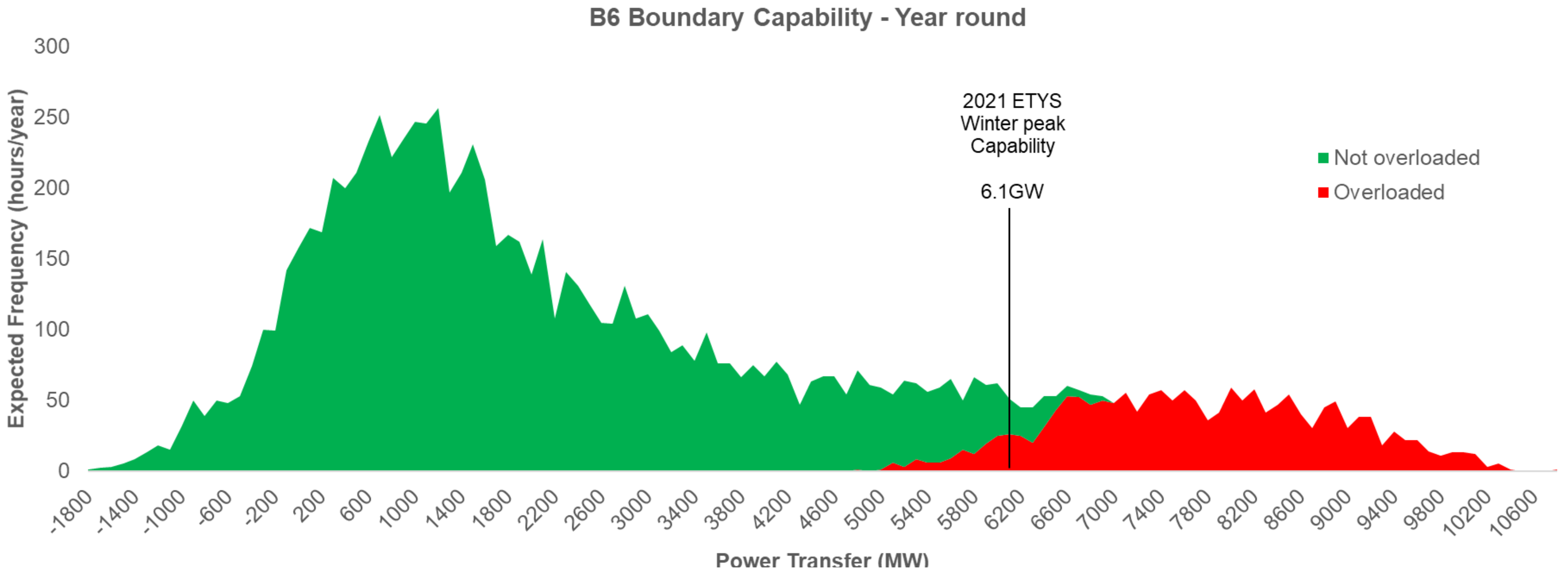
Year-round thermal analysis

Boundary transfers (overloaded/not overloaded)

For each snapshot studied by POUYA the boundary transfer is determined. By considering whether any assets are overloaded under that snapshot we can define this boundary transfer as ‘overloaded’ or ‘not overloaded’.

As shown in the charts below and on the following page, the overloaded and not overloaded outcomes may overlap, and acceptable boundary transfers may occur at flows higher than the single snapshot winter-peak boundary capability. For example, for the indicated 6.1GW winter-peak capability of B6, our test POUYA data identified 137 snapshots where this capability would be insufficient to meet boundary requirements. This means that for 137 hours (1.5%) of the year, additional boundary capability would be required. However, because this additional capability requirement is not persistent throughout the year, short-term operational activities (e.g., via the balancing mechanism) could satisfy this requirement in a more economical manner.



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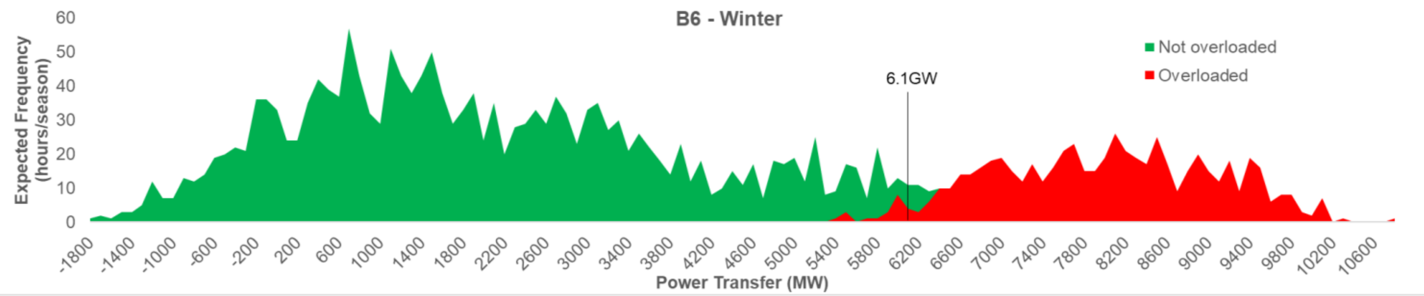
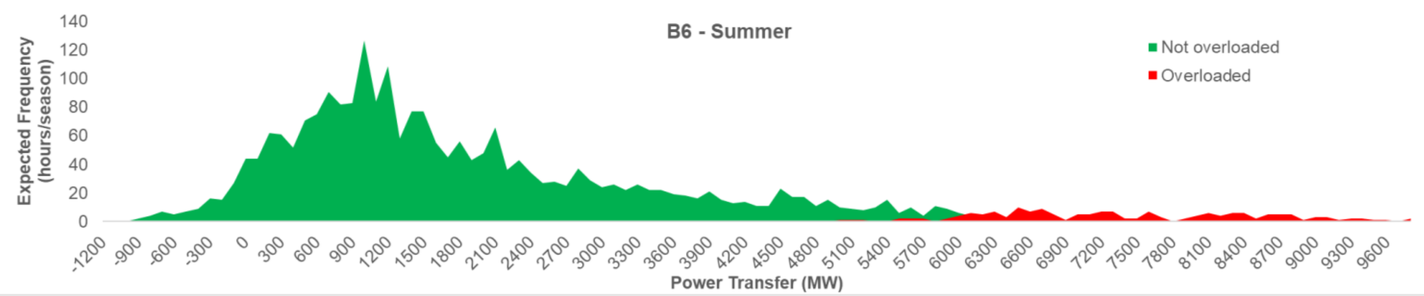
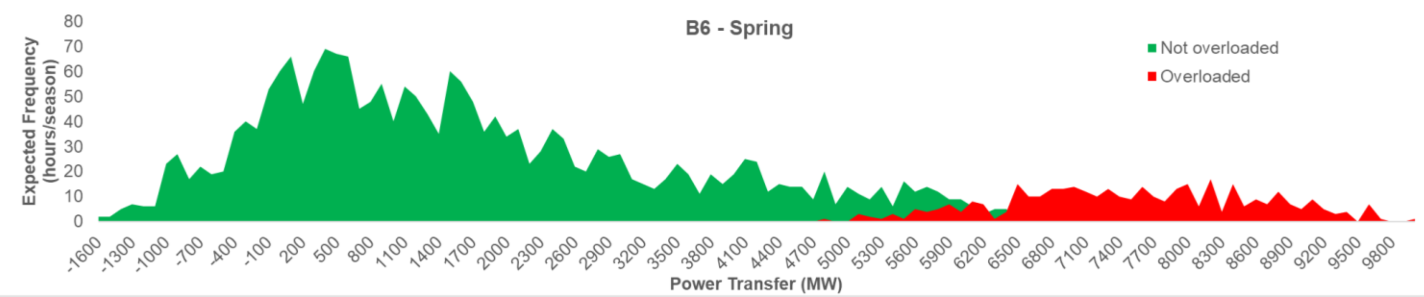
Year-round thermal analysis

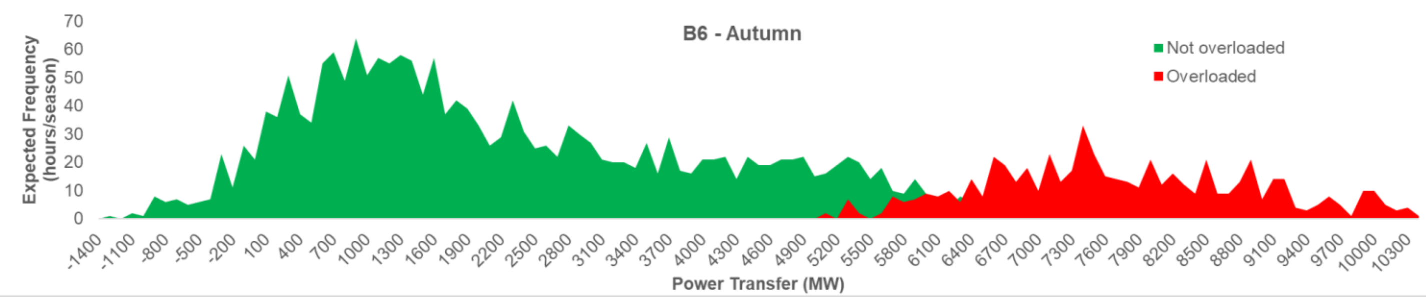
Boundary Transfers (overloaded/not overloaded)

As indicated in the ‘Ongoing developments’ section above, we are still developing functionality to allow POUYA to calculate constraint costs associated with relieving specific overloads. As we expand our analysis to capture not only frequency and severity of overloads but also consider likely economic (constraint) impact, we hope to be able to further explore some risk-based approaches.









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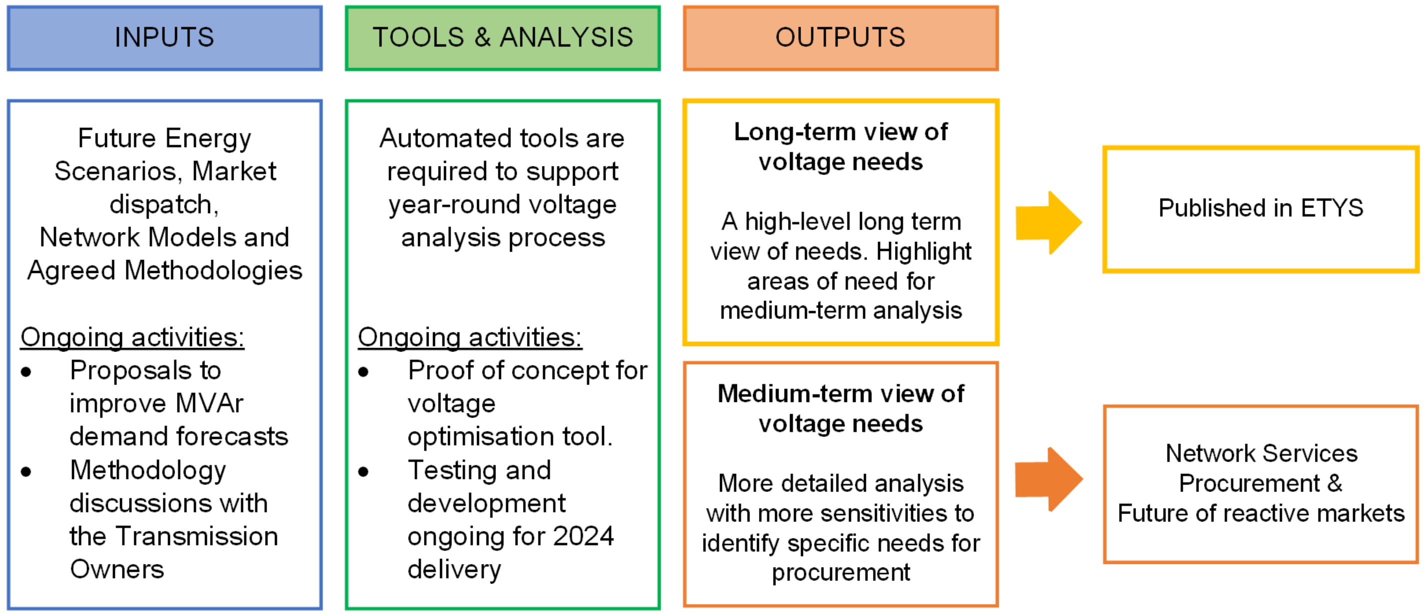
Voltage needs in ETYS

Our ambition is to communicate a long-term view of year-round voltage needs in ETYS with more specific procurement needs communicated through our reactive markets, which are still under development.

To develop an enduring repeatable process, we have mapped out the key components of our future end-to-end voltage process (shown in the figure below) and identified areas that require further development to allow us to achieve an enduring state.



Inputs: The voltage analysis process will take generation and demand profiles from the FES scenarios which will be fed into our market dispatch tool to produce a credible year-round economic dispatch that is applied to our network models. We are in the process of reviewing the methodology with the Transmission Owners and we are progressing actions to improve our MVAr demand forecasts.

Tools and Analysis: Our current approach is manual and time consuming and will not be suited for analysis of multiple year-round snapshots. Voltage analysis tools have been tested as part of a proof of concept to help automate the analysis process for multiple year-round analysis. These tools should help identify both high or low voltage issues concurrently and communicate them on a geographic map. A full project is being taken forward to deliver a voltage optimiser tool by the end of 2024.

Outputs: We would like to provide more clarity on how we will communicate system needs in the future. Once our tools are delivered, we envision that the ETYS will provide a high-level long-term view of needs highlighting trends in system needs and areas requiring more detailed analysis that will be undertaken through our medium-term process. The medium-term will involve more detailed analysis to identify specific needs for which we need to run procurement events ensuring sufficient lead-time to address the need. These needs will be communicated through the future reactive markets, once established.

Our new process will ensure that we capture all voltage system needs and procure services to reduce possible voltage constraint issues, driving down constraint costs and ensuring that we can operate the system in a secure and reliable manner.

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Stability needs in ETYS

Our ambition is to communicate a long-term view of year-round stability needs in future ETYS publications with more specific procurement needs communicated through our stability market, which is still under development

Further work is still ongoing to develop tools and techniques to allow year-round long-term stability analysis (via automation). While we develop our analytical capabilities, we will continue to communicate stability needs via our dedicated stability pathfinder page where we currently communicate stability needs when they are identified. Once our tools and processes mature, we will integrate a long-term view of stability needs within ETYS.

Where are we now?

The identification of stability constraints is more complex, and work is still ongoing to further test and develop tools to allow us to undertake year-round stability assessments.

In Spring 2022, we concluded our Network Innovation Allowance (NIA) project with energy consultants TNEI to build a machine learning (ML) tool for labelling stable and unstable system conditions. This innovation project demonstrated the capability for such a tool to be built but highlighted some key difficulties in implementing it with our current models, data and systems. The key challenges included:

- Challenges establishing feasible solutions for the ETYS network model for year-round conditions
- Challenges with data quality relating to dynamic characteristics of generators

The NIA project successfully demonstrated a proof of concept, but the above challenges prevented the project from completing its aims of training a tool to run on the full GB system. Further development and testing is ongoing, including enhancing our modelling data to allow us to test and identify key functionality and enhancement required to run year-round scenarios on our network models. We will continue to provide you with updates as we develop this work.

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System needs at the Transmission-Distribution Interface

Over the past year, we have undertaken a review on whether system needs at the Transmission/Distribution (T/D) interface could be communicated within ETYS.

We have worked with the Transmission Owners (TO) and Distribution Network Owners (DNO) as part of the Electricity Networks Association (ENA) Open Networks WS1B Product 5 on the Network Development Plan to review whether system needs at the T/D interface should be published and if so, where they could best be communicated.

Following publication of the DNO Network Development Plans (NDP), stakeholders have requested for more information to be published from a transmission interface perspective to help complement the Network Headroom reports. Stakeholders feel that because the NDP only indicates distribution constraints it could be potentially misleading regarding capacity constraints and an additional view on transmission would give a fuller picture.

TOs have shared some of the work they have done previously to indicate Grid Supply Point (GSP) capacities based on contracted connections, and the importance of not just indicating capacity at the GSP but also constraints on the wider network. Previous experience of trialling a range of approaches around communicating needs at the transmission interface has meant that TOs have opted not to publish any GSP ‘capacity’ type data based on feedback received from their stakeholders on its accuracy. Also, from a connections-perspective, the challenge with communicating ‘limits’ or ‘capacity’ is that the data becomes obsolete as soon as published because the connections process is live and always changing.

The TOs agreed to assess the feasibility of providing a snapshot of demand / generation of Earliest in-service date (EISDs) for all GSPs on an annual basis to DNOs for their NDPs (specifically to add to the Network Scenario Headroom Report tables). An output in March 2023 could potentially be used by DNOs to supplement their May 2023 Network Scenario Headroom Report tables.

ESO supports the proposed approach to communicate a view of T/D interface EISDs at the point of publication of DNO Network Scenario Headroom Reports. As this is a single snapshot view, it provides direct value when aligned to the DNO publication timelines as the ETYS publication is later in the year and would not provide the full context compared to publication alongside the DNO data sets. For more information on this, please see the Form of Statement of Network Development Plans - 2022 Update published by ENA Open networks in December 2022.

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Further Information

nationalgridESO

Appendices overview

Appendix A - System Schematics and Geographic Drawings

Download system schematics and geographic drawings of the current NETS, showing the locations of existing power stations and reactive compensation plants.

Appendix B - System Technical Data

See the basic network parameters such as connectivity and impedances that allow modelling of the transmission network.

Appendix C - Power Flow Diagrams

Download winter peak power flow diagrams that demonstrate the impact of future changes on the transmission network.

Appendix D – Fault Levels Narrative

Indications of fault levels calculated at two system conditions; at peak demand level and also at minimum demand levels for the current and future transmission network.

Appendix D Fault Levels Minimum

You can view the fault level data at minimum demand.

Appendix D Fault Levels Peak

You can view the fault level data at peak demand.

Appendix E – FES charts and workbook

Learn more about energy storage and interconnectors, summer minimum demand and embedded generation in relation to the NETS.

Appendix F – Contracted Generation

Find out more about the generators on the network.

Appendix G – Nodal Demand

You can view the demand by grid-supply point at winter peak.

Appendix H – Further Information on inputs and methodologies

See how the FES generation, demand and interconnector data is applied to the network simulation models.

Appendix I – Transmission Losses

Learn more about the drivers that may impact the total volume of future transmission losses on the NETS.

ETYS Archive

View all of the past EYTS reports dating back to 2012.

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Meet the Team

Supporting Parties

Producing the ETYS requires support and information from a range of stakeholders and internal teams. Parties who provide support and information that makes our work possible include:

- The GB electricity Transmission Owners
- The SO Energy Insights team who provides us with FES
- Our customers

Don’t forget you can email us with your views on ETYS at: transmission.etys@nationalgrideso.com.

You can also stay up to date with our latest developments from Strategic Network Development by signing up to our monthly newsletter.

Head of Networks
Julian Leslie

Strategic Network Development Manager
Paul Wakeley

System Capability Manager
Faith Natukunda

Strategic Network Development

In addition to publishing the ETYS, we are responsible, together with the transmission licence holders, for developing a holistic strategy for the NETS. This includes performing the following key activities:

- The management and implementation of the Network Options Assessment (NOA) process in order to assess the need to progress wider transmission system reinforcements.

- Producing recommendations on preferred options for NETS investment under the ITPR arrangements and publishing results annually in the NOA report.

Network requirements and the Electricity Ten Year Statement

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Cost-benefit analysis for the NOA & tCSNP

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Network Operability and Data Modelling

In our Network Operability department, we are responsible for studying a variety of power system issues including generator and HVDC compliance. We develop and produce the System Operability Framework publications.

From our Data and Modelling department we produce power system models and datasets for network analysis. We also manage the technical aspects of the GB and European electricity frameworks, codes and standards that are applicable to network development.

Network data used in ETYS

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The System Operability Framework (SOF)

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Glossary – 1 / 5

Acronym	Phrase	Explanation
	Ancillary services	Services procured by a system operator to balance demand and supply and to ensure the security and quality of electricity supply across the transmission system. These services include reserve, frequency control and voltage control. In GB these are known as balancing services and each service has different parameters that a provider must meet.
ACS	Average cold spell	Average cold spell is defined as a particular combination of weather elements which gives rise to a level of winter peak demand which has a 50% chance of being exceeded as a result of weather variation alone. There are different definitions of ACS peak demand for different purposes.
	Boundary allowance	An allowance in MW to be added in whole or in part to transfers arising out of the NETS SQSS economy planned transfer condition to take some account of year-round variations in levels of generation and demand. This allowance is calculated by an empirical method described in Appendix F of the Security And Quality of Supply Standards (SQSS).
	Boundary transfer capacity	The maximum pre-fault power that the transmission system can carry from the region on one side of a boundary to the region on the other side of the boundary while ensuring acceptable transmission system operating conditions will exist following one of a range of different faults.
CBA	Cost-benefit analysis	A method of assessing the benefits of a given project in comparison to the costs. This tool can help to provide a comparative base for all projects to be considered.
CCS	Carbon capture and storage	Carbon capture and storage is a process by which the CO2 produced in the combustion of fossil fuels is captured, transported to a storage location and isolated from the atmosphere. Carbon capture and storage can be applied to large emission sources like power plants used for electricity generation and industrial processes. The CO2 is then compressed and transported for long-term storage in geological formations or for use in industrial processes.
	Climate change targets	Targets for share of energy use sourced from renewable sources. The 2020 UK targets are defined in the Directive 2009/28/EC of the European Parliament and of the Council of the European Union, see here
CCGT	Combined cycle gas turbine	Gas turbine that uses the combustion of natural gas or diesel to drive a gas turbine generator to generate electricity. The residual heat from this process is used to produce steam in a heat recovery boiler which, in turn, drives a steam turbine generator to generate more electricity.
CHP	Combined heat and power	A system whereby both heat and electricity are generated simultaneously as part of one process. Covers a range of technologies that achieve this.
CSNP	Centralised Strategic Network Plan	The ESO's new electricity transmission network planning output which addresses all load related planning.
CT	Consumer Transformation	This scenario achieves the 2050 decarbonisation target in a decentralised energy landscape.
	Contracted generation	A term used to reference any generator who has entered into a contract to connect with the National Electricity Transmission System (NETS) on a given date while having a transmission entry capacity (TEC) figure as a requirement of said contract.
	Deterministic	A deterministic system is a system in which no randomness is involved in the development of future states of the system.
	Double-circuit overhead line	In the case of the onshore transmission system, this is a transmission line which consists of two circuits sharing the same towers for at least one span in SSEN Transmission's system or NGET's transmission system or for at least two miles in SP Transmission's system. In the case of an offshore transmission system, this is a transmission line which consists of two circuits sharing the same towers for at least one span.
DC	Direct current	An electric current flowing in one direction only.
DSR	Demand side response	A deliberate change to an industrial and commercial user's natural pattern of metered electricity or gas consumption, brought about by a signal from another party.
DNO	Distribution Network Operator	Distribution Network Operators own and operate electricity distribution networks.
	Embedded generation	Power generating stations/units that don't have a contractual agreement with the Electricity System Operator (ESO). They reduce electricity demand on the National Electricity Transmission System.

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Glossary – 2 / 5

Acronym	Phrase	Explanation
ENTSO-E	European Network of Transmission System Operators	Electricity ENTSO-E is an association of European electricity TSOs. ENTSO-E was established and given legal mandates by the EU's Third Legislative Package for the Internal Energy Market in 2009, which aims at further liberalising electricity markets in the EU.
ESO	Electricity System Operator	An entity entrusted with transporting electric energy on a regional or national level, using fixed infrastructure. Unlike a TO, the ESO may not necessarily own the assets concerned. For example, National Grid ESO operates the electricity transmission system in Scotland, which is owned by Scottish Hydro Electricity Transmission and Scottish Power Transmission.
EU	European Union	A political and economic union of 28 member states that are located primarily in Europe.
FACTS	Flexible alternating current transmission system	FACTS devices are static power-electronic devices that utilise series and/or shunt compensation. They are installed in AC transmission networks to increase power transfer capability, stability, and controllability of the networks.
FES	Future energy scenarios	The FES is a range of credible futures which has been developed in conjunction with the energy industry. They are a set of scenarios covering the period from now to 2050, and are used to frame discussions and perform stress tests. They form the starting point for all transmission network and investment planning, and are used to identify future operability challenges and potential solutions.
GEP	Grid entry point	A point at which a generating unit directly connects to the National Electricity Transmission System. The default point of connection is taken to be the busbar clamp in the case of an air insulated substation, gas zone separator in the case of a gas insulated substation, or equivalent point as may be determined by the relevant transmission licensees for new types of substation. When offshore, the GEP is defined as the low voltage busbar on the platform substation.
GSP	Grid supply point	A point of supply from the GB transmission system to a distribution network or transmission-connected load. Typically only large industrial loads are directly connected to the transmission system.
GTYS	Gas Ten Year Statement	The GTYS illustrates the potential future development of the (gas) National Transmission System (NTS) over a ten year period and is published on an annual basis.
GW	Gigawatt	1,000,000,000 Watts, a measure of power.
GWh	Gigawatt hour	1,000,000,000 Watt hours, a unit of energy.
GB	Great Britain	A geographical, social and economic grouping of countries that contains England, Scotland and Wales.
HND	Holistic Network Design	The Holistic Network Design (HND) is a first of its kind, integrated approach for connecting 23GW of offshore wind to Great Britain. By considering future offshore generation out to 2030, infrastructure can be planned to bring power to the grid cohesively, ensuring maximum benefit for consumers, local communities and the environment.
HNDFUE	Holistic Network Design Follow up Excercise	Following the publication of the HND and the NOA Refresh, the ESO is undertaking an HND follow-up exercise known as "HNDFUE", to consider additional offshore wind connections from the Celtic Sea and ScotWind offshore leasing rounds. This is expected to be published in March 2023.
HVAC	High voltage alternating current	Electric power transmission in which the voltage varies in a sinusoidal fashion, resulting in a current flow that periodically reverses direction. HVAC is presently the most common form of electricity transmission and distribution, since it allows the voltage level to be raised or lowered using a transformer.
HVDC	High voltage direct current	The transmission of power using continuous voltage and current as opposed to alternating current. HVDC is commonly used for point to point long-distance and/or subsea connections. HVDC offers various advantages over HVAC transmission, but requires the use of costly power electronic converters at each end to change the voltage level and convert it to/from AC.
	Interconnector	Electricity interconnectors are transmission assets that connect the GB market to Europe and allow suppliers to trade electricity between markets.
LCPD	Large Combustion Plant Directive	The Large Combustion Plant Directive is a European Union directive which introduced measures to control the emissions of sulphur dioxide, oxides of nitrogen and dust from large combustion plant.
LW	Leading the Way	A scenario from the Future Energy Scenarios (FES) where net zero is achieved at the fast pace with a high level of societal change and a rapid speed of decarbonation

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Glossary – 3 / 5

Acronym	Phrase	Explanation
	Load factor	The average power output divided by the peak power output over a period of time.
	Marine technologies	Tidal streams, tidal lagoons and energy from wave technologies see here
MW	Megawatt	1,000,000 Watts, a measure of power.
MWh	Megawatt hour	1,000,000 Watt hours, a measure of power usage or consumption in 1 hour.
	Merit order	An ordered list of generators, sorted by the marginal cost of generation.
MITS	Main Interconnected Transmission System	This comprises all the 400kV and 275kV elements of the onshore transmission system and, in Scotland, the 132kV elements of the onshore transmission system operated in parallel with the supergrid, and any elements of an offshore transmission system operated in parallel with the supergrid, but excludes generation circuits, transformer connections to lower voltage systems, external interconnections between the onshore transmission system and external systems, and any offshore transmission systems radially connected to the onshore transmission system via single interface points.
NETS	National Electricity Transmission System	The National Electricity Transmission System comprises the onshore and offshore transmission systems of England, Wales and Scotland. It transmits high-voltage electricity from where it is produced to where it is needed throughout the country. The system is made up of high voltage electricity wires that extend across Britain and nearby offshore waters. It is owned and maintained by regional transmission companies, while the system as a whole is operated by a single Electricity System Operator (ESO).
NETS SQSS	National Electricity Transmission System Security and Quality of Supply Standards	A set of standards used in the planning and operation of the National Electricity Transmission System of Great Britain. For the avoidance of doubt, the National Electricity Transmission System is made up of both the onshore transmission system and the offshore transmission systems.
NGET	National Grid Electricity Transmission plc	National Grid Electricity Transmission plc (No. 2366977) whose registered office is 1-3 Strand, London, WC2N 5EH.
	Network access	Maintenance and system access is typically undertaken during the spring, summer and autumn seasons when the system is less heavily loaded and access is favourable. With circuits and equipment unavailable, the integrity of the system is reduced. The planning of system access is carefully controlled to ensure system security is maintained.
NOA	Network Options Assessment	The NOA is the process for assessing options for reinforcing the National Electricity Transmission System (NETS) to meet the requirements that the Electricity System Operator (ESO) finds from its analysis of the Future Energy Scenarios (FES).
OFGEM	Office of Gas and Electricity Markets	The UK's independent National Regulatory Authority, a non-ministerial government department. Their principal objective is to protect the interests of existing and future electricity and gas consumers.
	Offshore	This term means wholly or partly in offshore waters.
	Offshore transmission circuit	Part of an offshore transmission system between two or more circuit breakers which includes, for example, transformers, reactors, cables, overhead lines and DC converters but excludes busbars and onshore transmission circuits.
	Onshore	This term refers to assets that are wholly on land.
	Onshore transmission circuit	Part of the onshore transmission system between two or more circuit breakers which includes, for example, transformers, reactors, cables and overhead lines but excludes busbars, generation circuits and offshore transmission circuits.
OCGT	Open cycle gas turbine	Gas turbines in which air is first compressed in the compressor element before fuel is injected and burned in the combustor.
	Peak demand	The maximum power demand in any one fiscal year: Peak demand typically occurs at around 5:30pm on a week-day between December and February. Different definitions of peak demand are used for different purposes.

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Glossary – 4 / 5

Acronym	Phrase	Explanation
PA	Per annum	per year.
PV	Photovoltaic	A method of converting solar energy into direct current electricity using semi-conducting materials.
	Planned transfer	A term to describe a point at which demand is set to the National Peak when analysing boundary capability.
	Power supply background (aka generation background)	The sources of generation across Great Britain to meet the power demand.
	Probabilistic	Model or approach where there are multiple possible outcomes, each having varying degrees of certainty or uncertainty of occurrence. This is based on the idea that you cannot be certain about results or future events but you can judge whether or not they are likely, and act on the basis of this judgment.
QB	Quadrature booster	A quadrature booster is a type of transformer also known as a phase shifting transformer and it is used to control the amount of real power flow between two parallel lines.
	Ranking order	A list of generators sorted in order of likelihood of operation at time of winter peak and used by the NETS SQSS.
	Reactive power	Reactive power is a concept used by engineers to describe the background energy movement in an alternating current (AC) system arising from the production of electric and magnetic fields. These fields store energy which changes through each AC cycle. Devices which store energy by virtue of a magnetic field produced by a flow of current are said to absorb reactive power; those which store energy by virtue of electric fields are said to generate reactive power.
	Real power	This term (sometimes referred to as “Active Power”) provides the useful energy to a load. In an AC system, real power is accompanied by reactive power for any power factor other than 1.
	Seasonal circuit ratings	The current carrying capability of circuits. Typically, this reduces during the warmer seasons as the circuits’ capability to dissipate heat is reduced. The rating of a typical 400kV overhead line may be 20% less in the summer than in winter.
	SSEN Transmission	Scottish Hydro-Electric Transmission (No.SC213461) whose registered office is situated at Inveralmond HS, 200 Dunkeld Road, Perth, Perthshire PH1 3AQ.
SP	Steady Progression	This scenario makes progress towards decarbonisation through a centralised pathway, but does not achieve the 2050 target.
	SP Transmission	Scottish Power Transmission Limited (No. SC189126) whose registered office is situated at Ochil House, 10 Technology Avenue, Blantyre G72 0HT.
	Summer minimum	The minimum power demand of the transmission network in any one fiscal year. Minimum demand typically occurs at around 06:00am on a Sunday between May and September.
	Supergrid	That part of the National Electricity Transmission System operated at a nominal voltage of 275kV and above.
SGT	Supergrid transformer	A term used to describe transformers on the NETS that operate in the 275–400kV range.
	Switchgear	The term used to describe components of a substation that can be used to carry out switching activities. This can include, but is not limited to, isolators/disconnectors and circuit breakers.
	System inertia	The property of the system that resists changes. This is provided largely by the rotating synchronous generator inertia that is a function of the rotor mass, diameter and speed of rotation. Low system inertia increases the risk of rapid system changes.
	System operability	The ability to maintain system stability and all of the asset ratings and operational parameters within pre-defined limits safely, economically and sustainably.
SOF	System Operability Framework	The SOF identifies the challenges and opportunities which exist in the operation of future electricity networks and identifies measures to ensure the future operability
	System stability	With reduced power demand and a tendency for higher system voltages during the summer months, fewer generators will operate and those that do run could be at reduced power factor output. This condition has a tendency to reduce the dynamic stability of the NETS. Therefore network stability analysis is usually performed for summer minimum demand conditions as this represents the limiting period.

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Acronym	Phrase	Explanation
ST	System Transformation	Scenario from the Future Energy Scenarios (FES) where the target of reaching net zero is achieved by a moderate level of societal change and a low-moderate level of decarbonisation
	Thermal Constraint	The maximum power transfer achievable without exceeding the heat dissipation limitations of the circuits.
	Transmission circuit	This is either an onshore transmission circuit or an offshore transmission circuit.
tCSNP	Transitional Centralised Strategic Network Plan	The Transitional Centralised Strategic Network Plan was put in place to ensure that the ESO can identify key investments for the onshore network to facilitate offshore wind generation targets by 2030 .
TEC	Transmission entry capacity	The maximum amount of real power deliverable by a power station at its grid entry point (which can be either onshore or offshore). This will be the maximum power deliverable by all of the generating units within the power station, minus any auxiliary loads.
	Transmission losses	Power losses that are caused by the electrical resistance of the transmission system.
TO	Transmission Owners	A collective term used to describe the three transmission asset owners within Great Britain, namely National Grid Electricity Transmission, Scottish Hydro–Electric Transmission Limited and SP Transmission Limited.
TSO	Transmission System Operators	An entity entrusted with transporting energy in the form of natural gas or electricity on a regional or national level, using fixed infrastructure.
	Voltage Constraint	The transmission operation limitation to maintain transmission assets within statutory limits. The limits are to keep assets within safe and secure voltage ranges.

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