Electricity Ten Year Statement

#ETYS2023

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Foreword

Paul Wakeley
Head of Strategic Network Development
Electricity System Operator (ESO)

Welcome to our Electricity Ten Year Statement (ETYS). The ETYS is the Electricity System Operator's (ESO) view of future transmission requirements, and the capability of Great Britain's National Electricity Transmission System (NETS) based on our latest Future Energy Scenarios (FES). The ETYS 2023 enables us to understand what investment and development is required to maintain a safe and reliable operational network, while enabling us to achieve our zero-carbon ambition.

Our analysis this year continues to highlight that over the next 10-20 years, we see increased requirements across some key network boundaries. The Holistic Network Design (HND) and its Follow Up Exercise (HNDFUE) are being developed to connect offshore wind to meet government targets. The offshore networks they recommend also deliver great value, providing additional routes for power to flow across the transmission system relieving some of our most constrained network boundaries, however, as we strive towards Net Zero, the requirements of the system will continue to grow.

Reaching Net Zero and achieving security of supply will mean securing the NETS against a wider range of scenarios across the entire year. Practically this means expanding our view of thermal system needs beyond a 'single worst-case' winter-peak scenario. This means we are working with more data than ever before as we assess and communicate our system requirements.

We are also integrating our annual voltage screening results into ETYS this year, to capture some of the challenges we face across both low-load and high flow conditions on the transmission network. This is in line with our ambition to expand ETYS to communicate a wider range of system needs. Our voltage screening analysis is undertaken on a regional basis, allowing us to highlight areas that could face challenges with voltage in the future. From this, we then undertake more detailed analysis on identified regions and explore how best to procure solutions to meet these needs.

Over the coming 12-18 months the ESO will transition into the Future System Operator – taking a broader, whole system view on how Great Britain can deliver on its Net Zero ambitions while maintaining a reliable and affordable energy supply. As part of this transition, our network planning process is evolving. During this transition we will develop our second Transitional Centralised Strategic Network Plan (TCSNP2) consisting of the ETYS, the Network Options Assessment (NOA) and Holistic Network Design Follow-up Exercise (HNDFUE) as we move forward to our enduring Centralised Strategic Network Plan (CSNP) process.

As part of this transition, we have made two key changes to ETYS this year, firstly we are publishing the core ETYS 2023 boundary charts and commentary earlier in order to allow meaningful time for industry engagement. Secondly, we will publish the technical appendices of the ETYS to align with the Beyond 2030 report. This will allow us to ensure that our maps and data reflect the latest investment decisions made.

We have received a direction from Ofgem to allow us to make these changes and will continue to work together with Ofgem and you our stakeholders as we transition to the CSNP.

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Key Messages

Key Message 1

Over the next decade the GB Electricity Transmission System faces growing system needs

Our analysis this year continues to show growing system needs driven primarily by low carbon and renewable generation. This will drive requirements for new network capability as we continue to move towards the 2035 government target of 100% zero carbon electricity system and beyond. Much of this network capability will be delivered through new infrastructure, both onshore and offshore, and hence we fully support the recommendations in the Transmission Commissioners report which will enable a more timely and streamlined delivery of this new infrastructure.

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Key Message 2

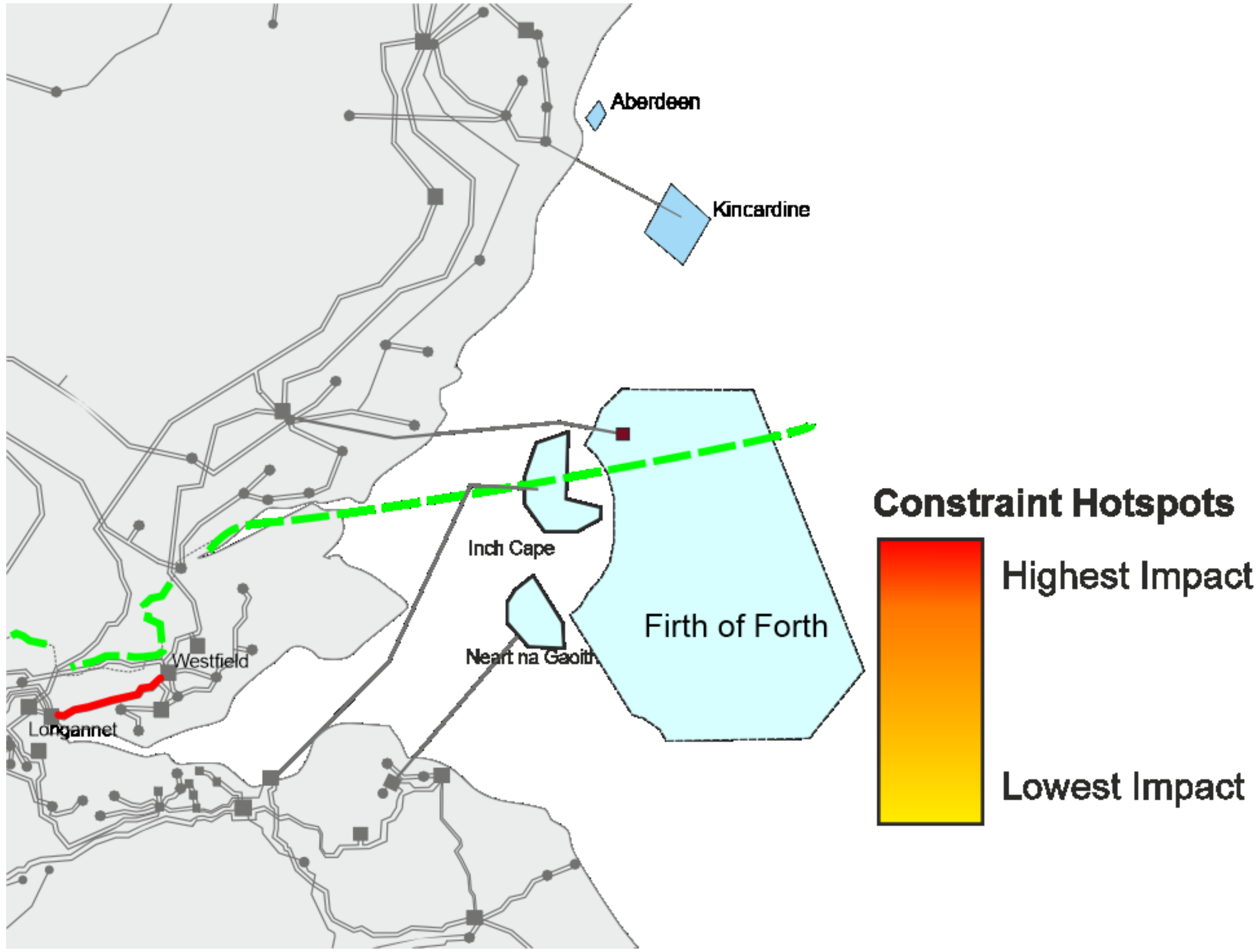
Our year-round analysis this year highlights that winter peak still drives majority of the bulk power transfer needs. As generation, demand and the network evolves, our expanded tool capabilities mean that we are now well placed to identify any additional needs arising in other seasons of the year.

We are working with more data than ever before to analyse system needs across the different seasons in a year.

This year we have continued to develop our end-to-end process to analyse year-round thermal needs across the transmission network. The results shown in Our year-round system needs chapter, are part of a new enduring processes to assist us in identifying and managing thermal system needs across an entire year, rather than just at winter peak.

Our year-round analysis identifies components on the network which become overloaded, causing limitations to power flow. As part of our analysis so far, we are able to identify overloaded assets across Winter, Spring, Summer, and Autumn with Winter currently experiencing the most severe overloads.

The tool capabilities we have developed to-date mean that as the future generation, demand and network evolve, we now have the capabilities to identify any limitations that might arise in other seasons, a major improvement from single winter peak snapshot analysis. We expect this expanded view of needs across seasons to further allow us identify and communicate additional system needs for our interested stakeholders to identify new solutions that are perhaps not captured through traditional winter peak analysis.



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Key Message 3

We will need to address emerging high and low voltage issues on the GB Electricity Transmission System over the next decade.

Voltage is a local issue driven by the changes in local generation, demand, and the evolving network. High voltage issues primarily arise in low load conditions while low voltage issues arise in high flow conditions.

This year, we have integrated the results of our annual voltage screening process into ETYS. We have identified regions that could have emerging voltage needs over the next decade and we will continue to explore options to address these needs.

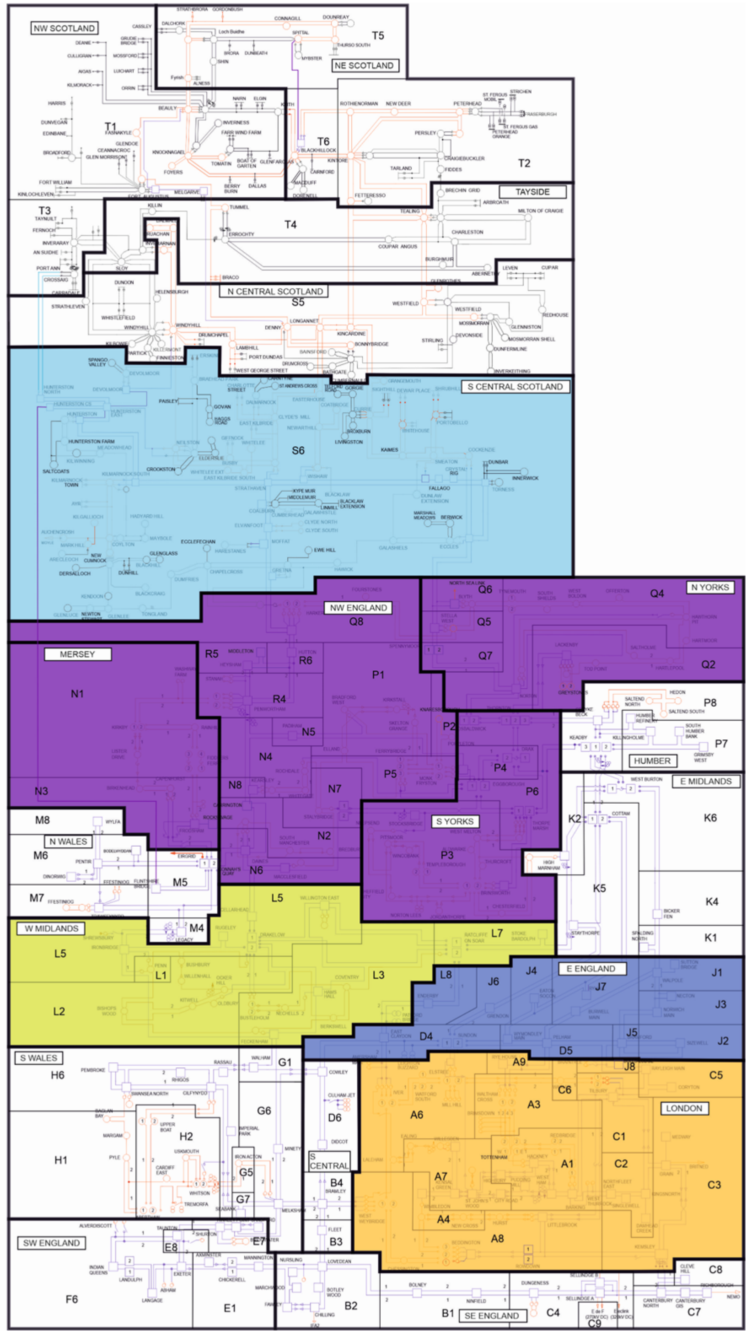
Scotland - The decline of synchronous generation in the region is reducing the local generation available to manage the local voltage during low loading scenarios. Future generation growth in this region is primarily from renewable generation located at the peripherals of the network and we require different solutions to ensure we are managing high voltages into central Scotland.

North of England - This region experiences high voltage due to generation closures and a combination of network changes that pose challenges to manage the voltage. During periods of high flows from Cumbria and Scotland, the Mersey region could experience low voltages.

North Wales and Midlands - This region experiences high voltage when the long transmission lines are lightly loaded with limited local voltage support.

East of England – Future renewable generation in this region mainly connects at the edges of this region, and any future closure of local generation plant could result in the need for voltage support to manage high voltage. Also, during periods of high north to south flows, this region experiences low voltages especially when generators are on outage or have restricted reactive capability.

South England - High voltage in London arises from the high gain from cable circuits, particularly overnight when demand is low, combined with reliance on local generation plant. The South East Coast of England also faces low voltage issues due to high imports and high exports on interconnectors.



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Key Message 4

Click on the boundary names to view the boundary flows

Timely and coordinated network reinforcements will significantly help reduce network constraints

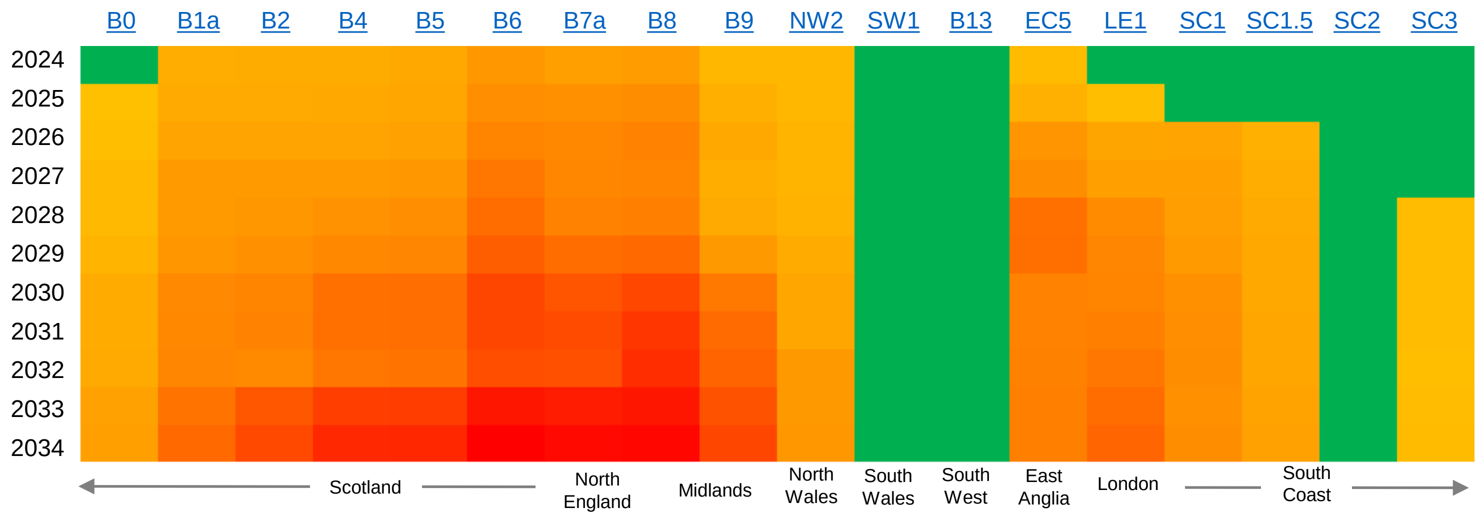
The ETYS describes the network capability by looking at the maximum secured power transfer between two regions or the power transfer across a boundary. To operate the network safely, we must make sure that the power flow across the boundary does not exceed the capability of the system between the two 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 Beyond 2030 report on the Leading the way FES 2023 scenario, showing how these options can significantly reduce constraints by increasing the power transfers across boundaries.

The ESO are proactively developing non-build solutions to network constraints and the Constraints Management Intertrip Service (CMIS) is being developed for the EC5 boundary following success of the B6 service.

As the ESO transition into the Future System Operator and our network design evolves, we will take a whole-systems approach to developing the network.

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



Excess flows beyond boundary capability **with the Beyond 2030 report's recommended options applied***

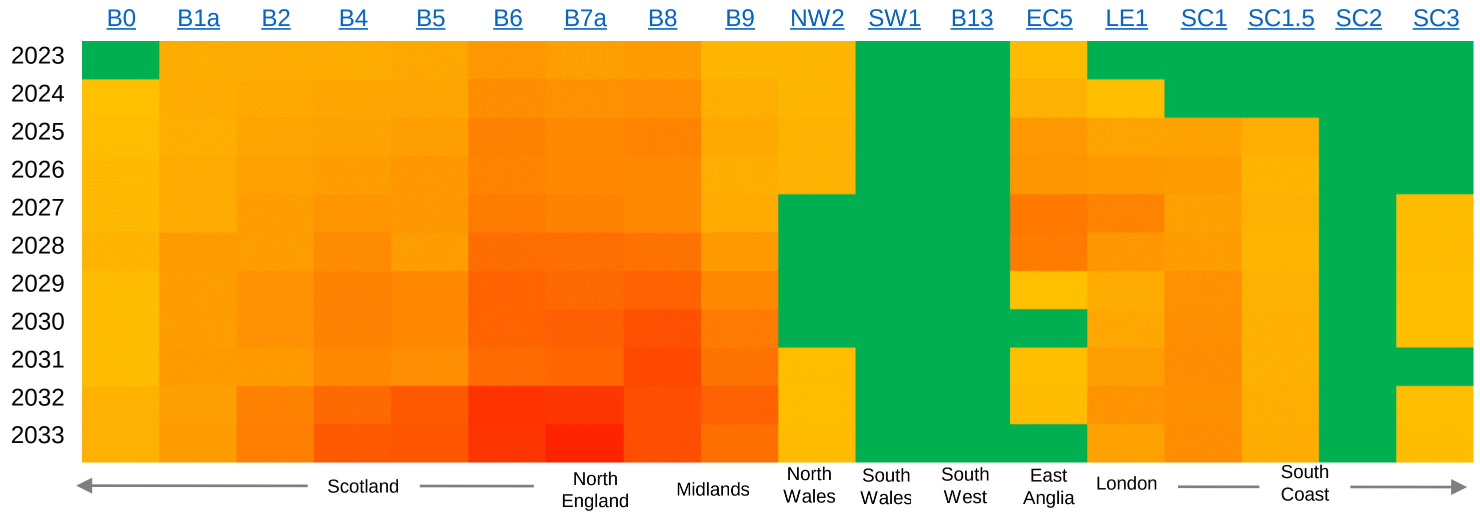


*Chart uses the 2021/22 Refresh NOA recommendations against *Leading the Way* scenario in FES 2023 flows

Our ETYS analysis

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 understand where investment and development is needed to help us achieve our zero-carbon ambition. Our ETYS 2023 key messages explain the key system need insights from our analysis of the latest Future Energy Scenarios.

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 through reinforcing the network to continue delivering electricity reliably. Once we have assessed the network requirements, we invite stakeholders to propose solutions to these requirements.

These proposals were traditionally 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 stopped.

We're currently transitioning from the NOA, to a new Centralised Strategic Network Plan (CSNP.) The CSNP should ensure holistic development of the NETS.

What's new in ETYS 2023?

The way we communicate our electricity transmission network requirements is changing as we expand our view of system needs across a year. Building on examples from ETYS 2022, we will include a summary of year-round system needs for selected boundaries across the National Electricity transmission System (NETS.)

We have also incorporated our annual voltage screening report into this year's publication, with the intention of showing our stakeholders a clearer picture of all transmission requirements over the next 10 years – in one place.

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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 in the surrounding offshore waters.

The NETS is otherwise known as the Electricity Transmission network which spans across Great Britain. The network comprises a mixture of overhead cables, underground cabling and subsea cables – the size of these assets varies from of 400kV, 275kV and 132kV assets. These are all linked together via substations across the country that then connect separately owned generators, interconnectors, large demands, and distribution systems.

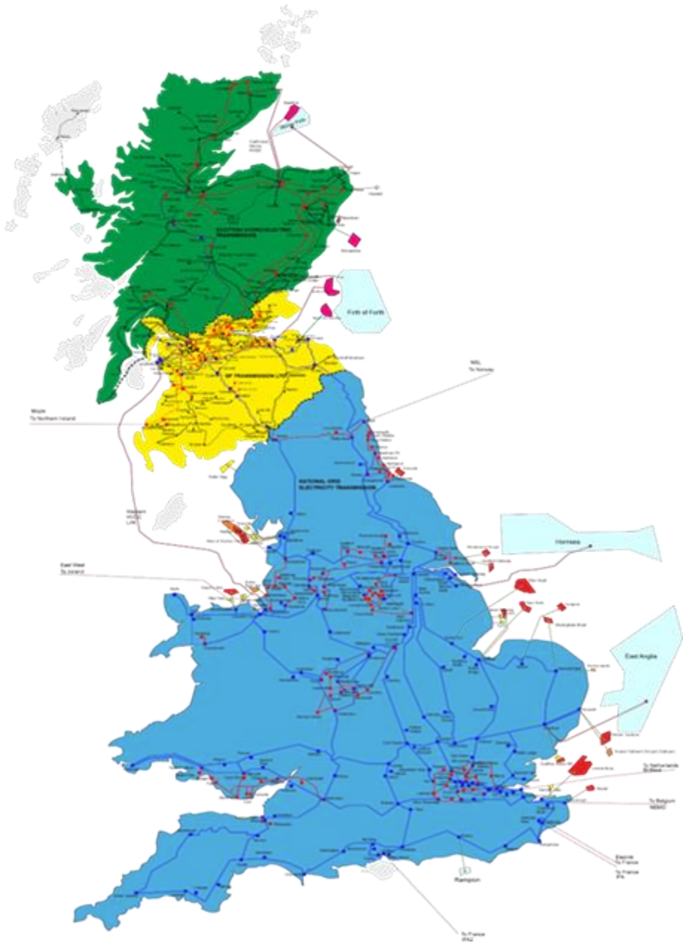
Electricity Distribution comprises of network below 275kV in England and Wales and 132kV in Scotland which transports electricity from Transmission "highways" to consumer.

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.

Great Britain has three onshore Transmission Owners that separately own the network. These are:

- 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.

There are also 24 licenced offshore transmission owners (OFTOs) appointed through Ofgem's competitive tendering process. They own the assets that connect operational offshore wind farms to the transmission or distribution network.



Together with the Transmission Owners we regularly assess and model network behaviour under different conditions to test it's resilience. We assess where the network may be under strain for various reasons and this analysis accumulates into the ETYS.

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

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Our thermal analysis - 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.

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.

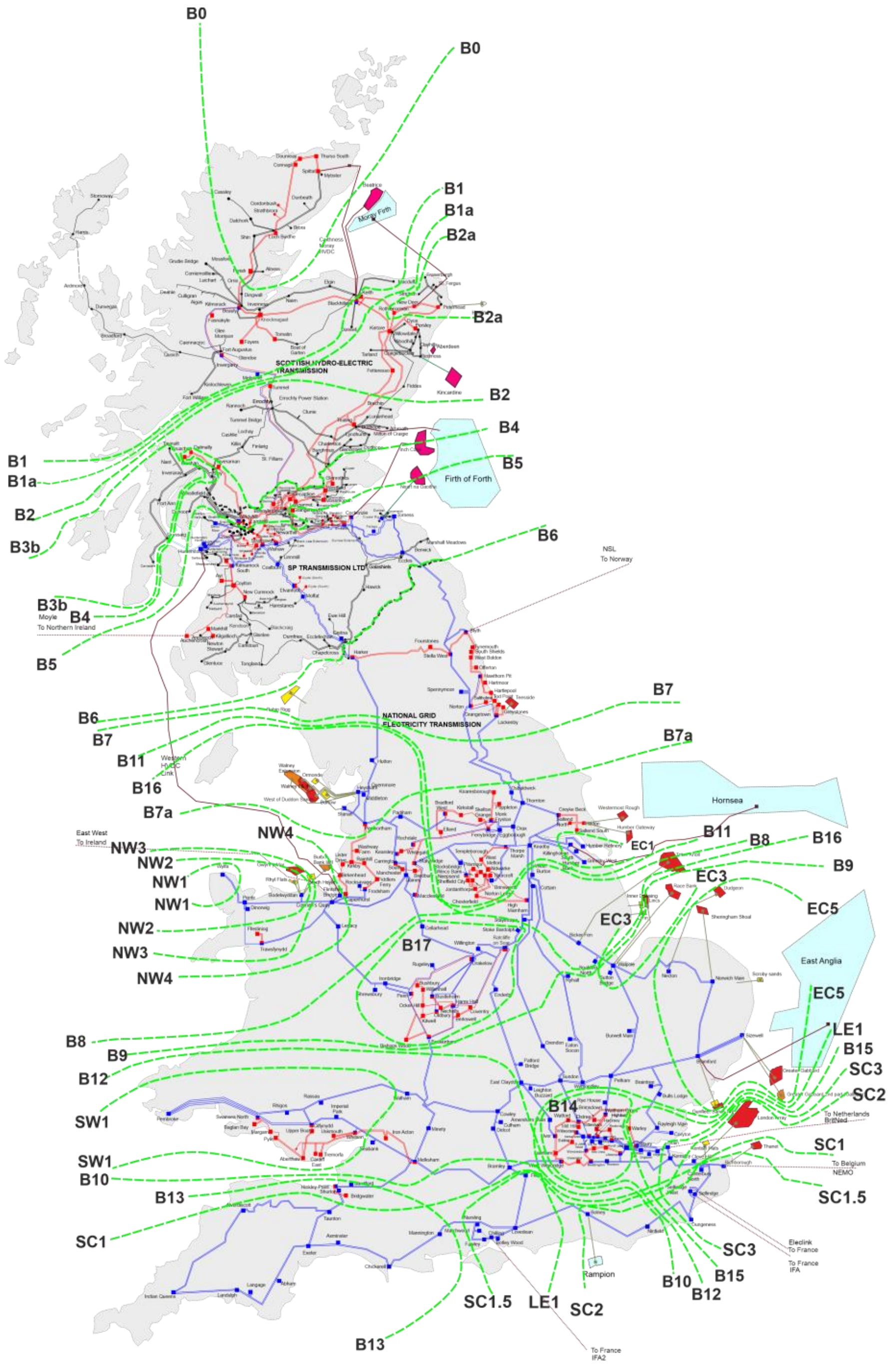
The boundaries used by ETYS can be split into two different types:

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 System Security and Quality of Supply Standard (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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Our thermal analysis – How we assess the network

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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Our thermal analysis - determining boundary capability

The "Boundary Capability" is the maximum MW flow that can be transferred across a boundary while maintaining compliance with the NETS SQSS.

ETYS capability is only presented for year one as a check against SQSS planning compliance. 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.

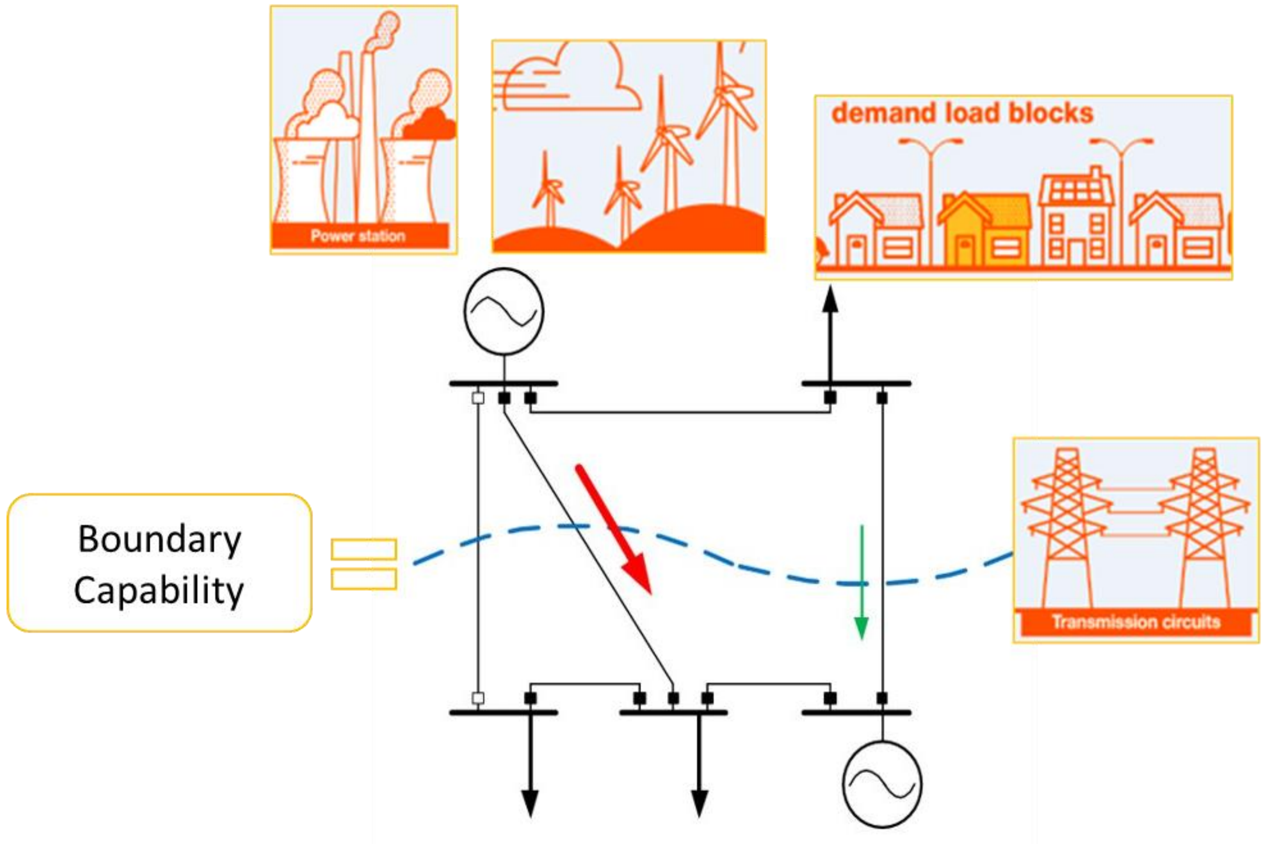
We do not know precisely how much new capacity there will be, when it will connect, or when existing generation will shut down. Our FES provides four credible scenario pathways to 2050 and we use these to identify expected future boundary flows as required by the NETS SQSS.

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 Requirements section.



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Our voltage analysis - voltage screening process

How do the ESO manage voltage?

To keep voltage stable, we can increase it by injecting reactive power and decrease it through absorption of reactive power. Power stations provide reactive power services when they are generating electrical power. The electricity system itself can also be used to provide reactive power; this could come from reactive equipment or from the electrical properties of cables and overhead lines. In the past, the ESO mainly used to take action to manage low voltage but now there are fewer industrial processes and spinning turbines, we mainly manage voltage when it is higher than normal.

Our voltage screening analysis is new for the ETYS this year as we integrate the work from our traditional separate report into our main publication. Voltage needs on the NETS will be communicated on our regional drivers section, within Electricity Transmission Network Requirements.

Our voltage screening methodology

Our screening process is published in chapter 5 of our NOA methodology as part of the high voltage management process. The screening process is the first step in the overall process and it identifies and prioritises the region(s) which should be further explored with detailed power system studies. Following detailed analysis the priority of some regions identified could change. System needs confirmed through detailed analysis could lead to competitive Network Service procurement. The screening process is set out in the charts on the right.

Voltage is a localised property of the transmission system determined by configuration of the local network and the nature of generation and demand in a region. Reactive power - unlike real power - has a localised effect, so voltage control measures are most effective when applied closer to the problem. These issues can therefore be grouped into regions - with an assessment of each conducted separately.

Voltage Screening Process

Dependency and Network change identification: When a plant is utilised frequently to provide voltage support, its scheduled closure may increase difficulty keeping the network voltages within SQSS limits. Our screening process identifies any of these dependencies, alongside the potential impact of future network changes or the variation of generation and demand forecasted in the FES.

Historic data analysis: In our role as the ESO, we collect vast quantities of commercial and operational data from Supervisory control and data acquisition (SCADA) and other metering systems across the country. Areas of high historic spend, combined with frequent large voltage excursions will be highlighted as part of the screening process. The root cause of any voltage issues are analysed more in-depth through post-fault analysis.

Likelihood and lead time: As part of the screening process, the conditions under which high-voltage issues arise are analysed and their likelihood assessed. This helps determine whether identified voltage issues are likely to persist into the future or are driven by one-off events.

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Our voltage needs on the NETS

Why do we see voltage needs on the NETS?

We’re committed to communicating network needs to the industry so that essential action can be taken to secure the NETS. Over the last decade, the regulation of voltage by controlling reactive power has become particularly demanding due to issues such as:

The new shape of our energy landscape – compared with the historic abundance of synchronous power plants providing the flexibility of dispatching both active and reactive power output on the system. Reactive power delivery is now increasingly relying on assets such as capacitors, shunt reactors, Static Var Compensators (SVCs), as well as renewable generation. Depending on an asset’s physical location on the network, they can be far away from where voltage issues are and may be less effective.

Decreasing minimum demand (typically during summer) - due to consumer behaviour, an increase in embedded generation, improved efficiency in electrical goods year on year and a decrease in industrial demand. This causes lightly loaded lines, resulting in a high gain on the system, leading to higher voltages. This is particularly challenging in regions with cable circuits or long overhead lines. It is also worth noting that the power output from renewables does not follow demand - it follows the weather - low demand in the evening coinciding with high wind, could result in a reduction of synchronised plant running on the system leading to limited voltage support.

Fault events - leading to challenges ensuring the network voltage remains within its limits. Conversely to minimum demand, the annual peak electricity demand has been increasing. During a fault on the network, the number of circuits that transfer power from one area to another can reduce. This increases the power flow on remaining circuits which could lead to voltage depression. Therefore, voltage support is required following faults to ensure voltage stays within compliance limits. During a period of minimal generation, faults on the system can lead to issues with high voltage step change and potentially risk breaching high voltage limits.

Local phenomena - The closure of power stations can cause a reduction in voltage support on the system. The screening process explores if locations have a reliance on local assets as well.

It is important to monitor these issues as part of our routine planning and operation activities, as well as to identify further issues that could emerge in the future.

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Our voltage needs on the NETS – Contd.

When do we see voltage needs on the NETS?

The power flow behaviour on our system causes a significant difference to voltage characteristics. Issues seen during summer are entirely different to those seen in winter as explained below.

Summer minimum periods: Peak solar output causes localised high voltage on sunny days in areas with substantial solar generation connecting to the grid. This, coupled with reduced synchronous generation in our baseload causes challenges and requires reactive compensation. If essential reactive equipment is out of service due to faults or should a fault coincide with a planned outage, it can become increasingly challenging to operate the system efficiently and economically. Managing voltage overnight is even more onerous, especially in areas with a lot of underground cable networks. The gain produced from the cables exacerbate high voltage issues, requiring us to take circuits out of service for voltage control. Given that maintenance season tends to be in the summer, additional circuits could be out of service for planned outage works making it complex to switch out circuits for voltage control as this might affect demand security.

Winter peak periods: Voltage management can be challenging during periods of high flows. During this peak, high power flows can be seen when for example offshore/far away generation must meet demand which is predominantly located in the centre of the country. This stresses the transmission system to its capacity limits. Typically, if a fault were to occur, it would reduce the number of routes for power to flow, leading to low voltage on the network during high flows. For such secured events we must ensure that there is an adequate level of static and dynamic reactive power to keep the voltage within the limits detailed in the SQSS.

High interconnector power flows: Since interconnector flows are dictated by the energy price differential between GB and the European continent, the flows on the interconnector can switch from importing into Great Britain to exporting. This can stress network assets and could result in a change from high to low voltage and vice versa. Voltage Source Converter (VSC) interconnectors on the system do have a reactive power range which can help in such situations.

Reactive power output from generation: Penetration of renewables is increasing at both distribution and transmission network level, which has led to a decline in national demand seen at the transmission level. Generators play a key role in regulating voltage by dispatching reactive power at the request of the Electricity National Control Centre (ENCC).

Outages which weaken the network: When circuits are on outage, switching further circuits out on voltage control becomes difficult and compromises on other priorities such as demand security. As a result, we must carefully assess outages on voltage control equipment which also tend to be requested in the summer.

Faults on voltage control equipment: These faults can be temporary, long term or even permanent requiring replacement. This limits the maintenance that can be carried out on remaining assets, making it more unreliable and susceptible for faults.

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Further analysis

Stability needs in the 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 when they are identified via our dedicated stability pathfinder page. Once our tools and processes mature, we will integrate a long-term view of stability needs within ETYS.

Pathfinders update

To support the ESO's ambition to operate the NETS at zero-carbon from 2025, the ESO has launched stability pathfinders to deliver necessary changes to the network. As part of the third phase – the ESO has secured new contracts worth £1.3bn to provide network stability services without the use of carbon over these periods. These contracts represent a cost benefit of £14.9bn between 2025 and 2035. More information in the "phase 3 news" section can be found here.

Y-1 Stability market

In 2021, we launched the Stability Market Design innovation project to explore the optimal design for enduring stability markets, with a focus on value for consumers. As a result of this work, in the April 2023 Markets Roadmap we set out the proposal to procure stability services across several timescales:

- Long-term Y-4
- Mid-term Y-1
- Short-term D-1

The first step to launch the Stability Market is to initiate the mid-term (Y-1) market, with the intention to undertake the first mid-term (Y-1) tender round later this year (2023). Our latest modelling indicates that in many circumstances across the next few years, the requirement to maintain system stability can be met through a combination of self-dispatched generation, demand, and Stability Pathfinders. For the remaining periods, we have identified an opportunity to optimise how stability is secured through the mid-term (Y-1) market and deliver consumer savings versus the alternative actions currently available to us.

Innovation projects

New NIA stability project, STARTZ – Stability Requirements Calculation Towards Net Zero

Current stability calculation methods use a number of assumptions and approximations and there may be room to make the process more accurate. This project reviews the ESO's stability requirement calculations and explores the potential for new methodologies, machine learning and automation to enhance accuracy and efficiency to inform procurement market activities and future network planning. Suggested improvements to the methodology will be tested and validated against detailed system modelling.

This project will support the energy transition by ensuring the grid remains stable while more renewable generation is integrated into the network. It will provide value for money for consumers, as there is less variance in our estimates so the balancing services required will be more accurately predicted and procured. The potential to use automation and machine learning to calculate stability needs will make the process more efficient and reduce the risk of human error which could affect the results. Further details available here.

Tool development - NOA enhancement stability project

The NOA Enhancements project is looking to improve current NOA process and assess more systems needs and in more granularity. We have reviewed our current processes for stability assessments across ESO and have launched an IT project to develop a product to enable us to do more analysis in less time. We are working to develop automation tools for assessing future stability requirements more frequently and consistently. This includes 3 main modules (1) system inertia calculation for the future years based on the published FES scenarios, (2) a module to measure short-circuit ratio in grid system as one of common metrics of system strength which could help highlight weaker regions of the network and a useful indicator for managing system strength in both planning and operational time scale, and (3) rotor angle stability screening module to quickly identify unstable snapshots in future years.

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Electricity Transmission Network Requirements

ESO

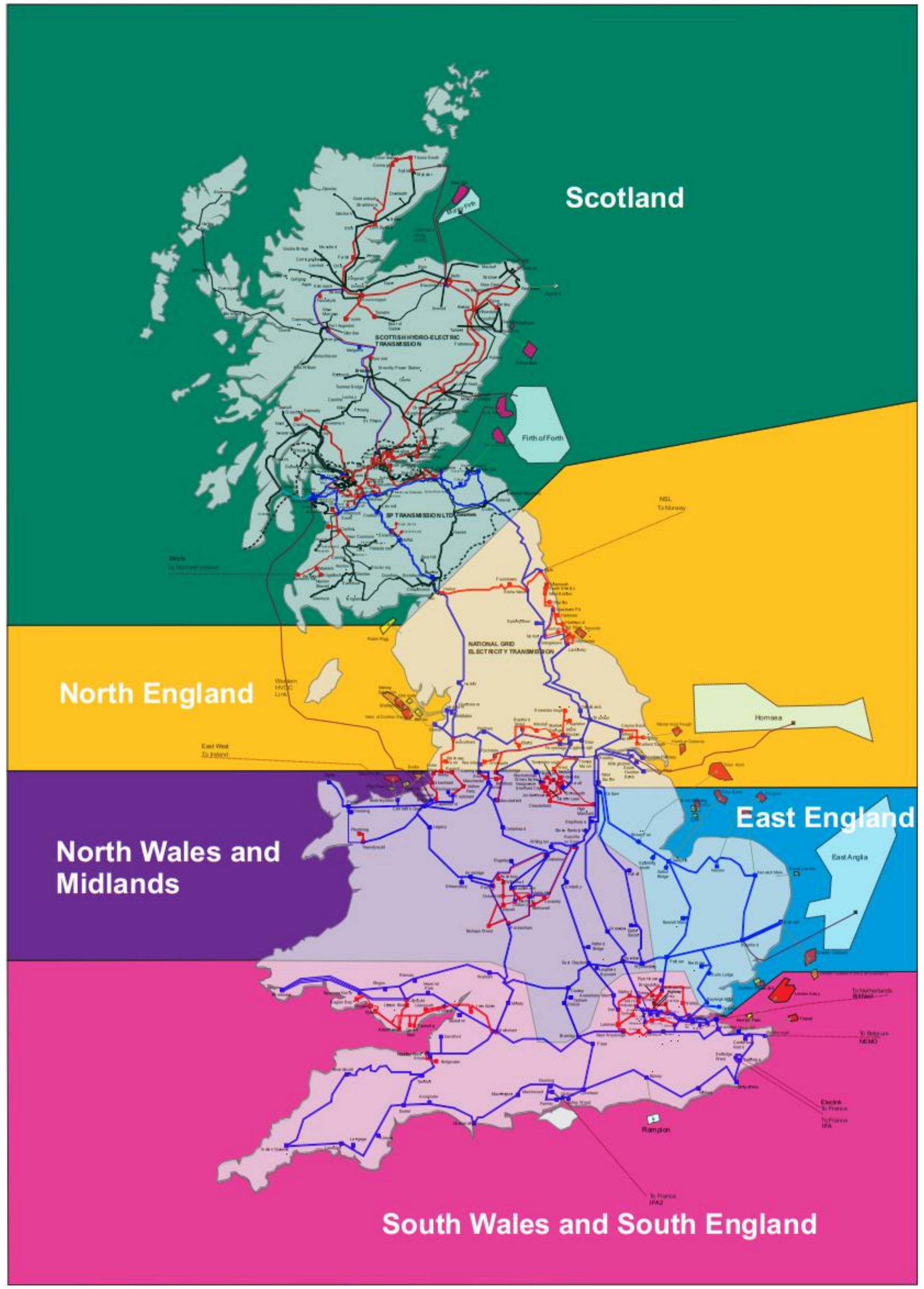
Introduction

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 thermal and voltage characteristics of the NETS – On a regional basis.
- Discuss the thermal characteristics of each of the NETS boundaries.
- Provide analysis to show how and when, in the years to come, the NETS could 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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Communicating our thermal needs

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.

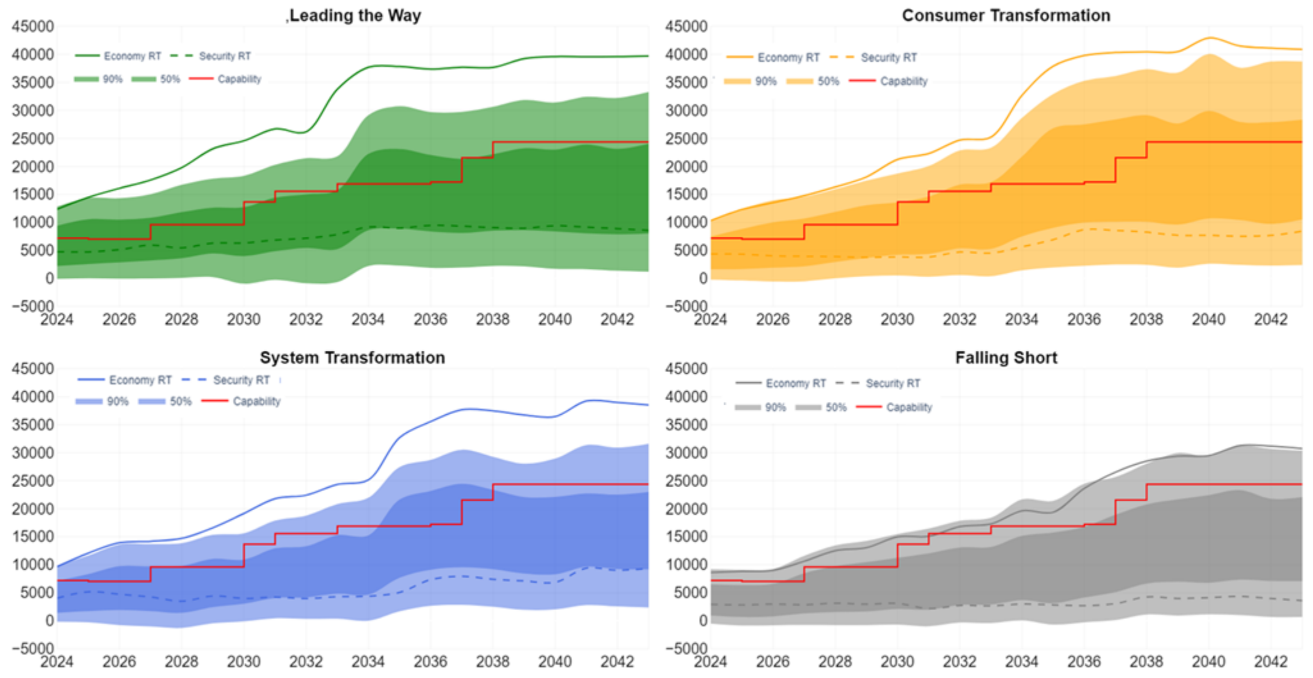
Each scenario has different generation and demand so produces different boundary power flow expectations. From applying the methodology in the NETS SQSS for wider boundary planning requirements (as discussed in the previous chapter), we determine for each scenario:

- The economy criteria - solid coloured line
- Security criteria - dashed coloured line
- Current and future NOA capability (where available) - solid red line

The capability line (red line) is based on the recommendations from the Beyond 2030 report. 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 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 2023 FES and ETYS processes. Where the NOA transfer capability is not available, there is a red line that provides the transfer capability from ETYS 2022.

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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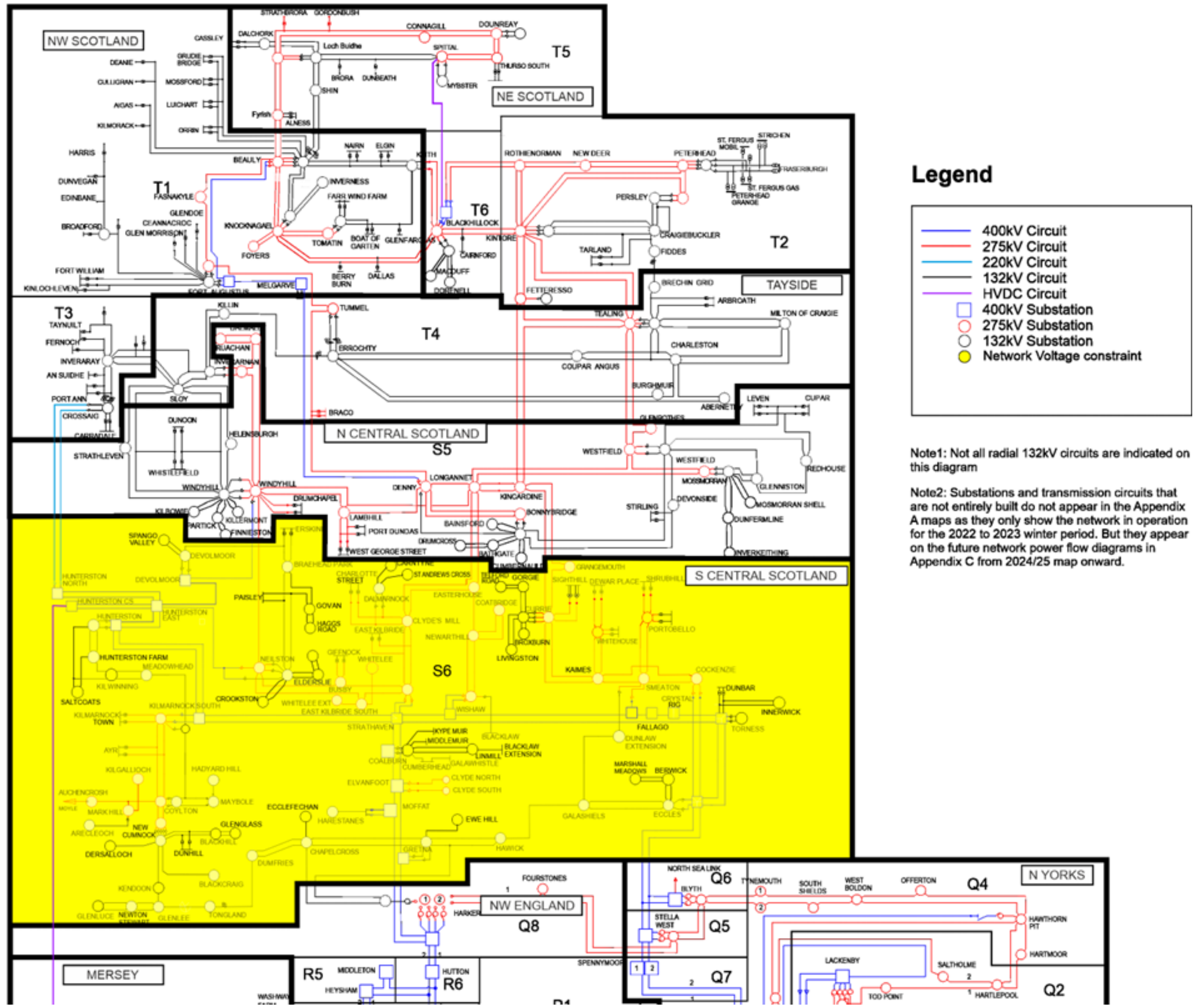
Communicating our Voltage needs

Voltage screening is new for ETYS 2023 and will be presented from a regional perspective (Regional voltage drivers.)

Highlighted yellow areas on our NETS regional diagrams will show areas identified through our voltage screening process on the NETS that could face voltage needs over the next 10 years. These areas have been identified through our annual voltage screening process outlined in the "Our ETYS analysis" section and is included in our NOA Methodology. These charts will be accompanied by a general commentary surrounding voltage behaviour in the regional area.



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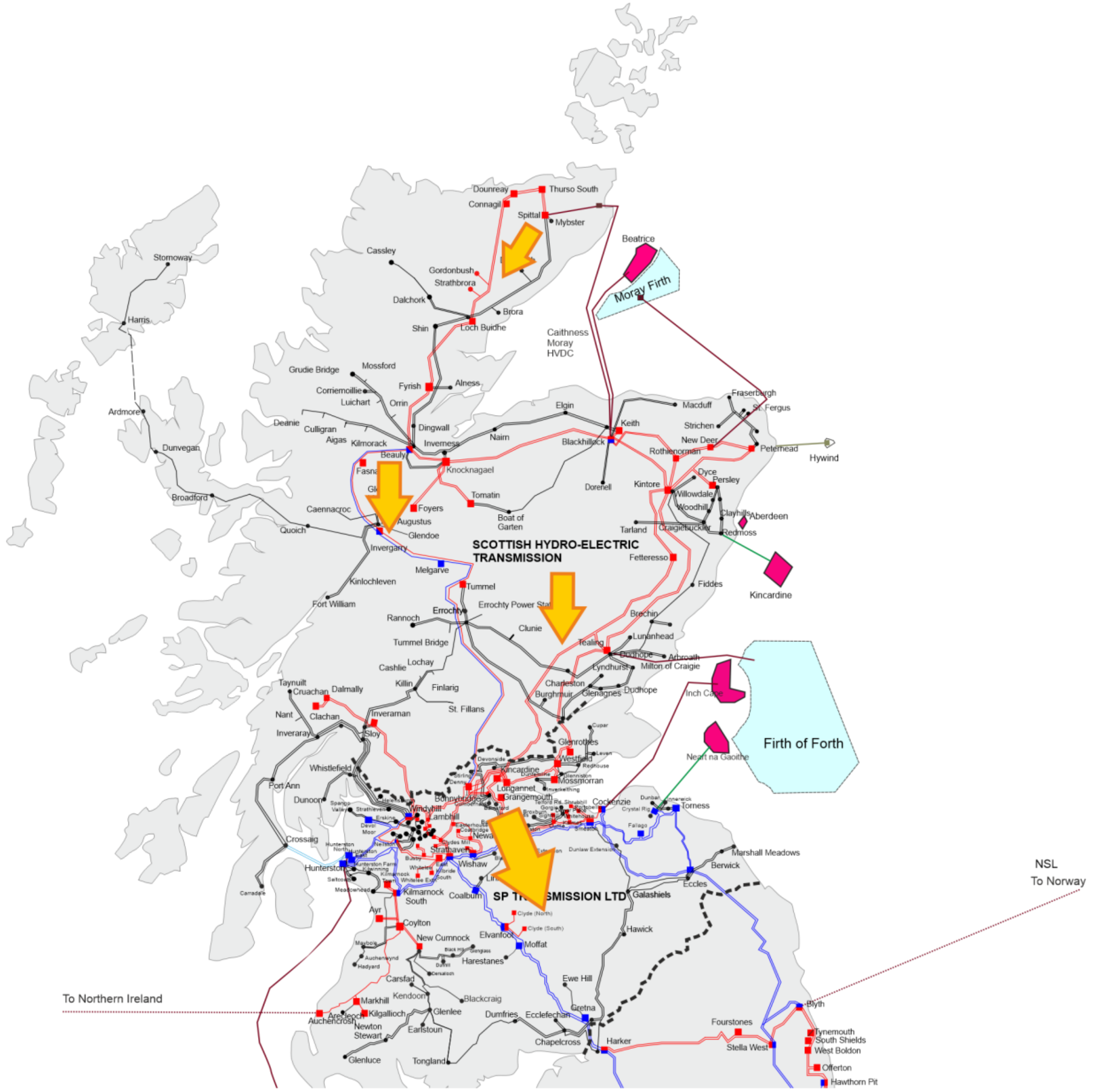
Scotland

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 2033, 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 2023 / Scotland 23

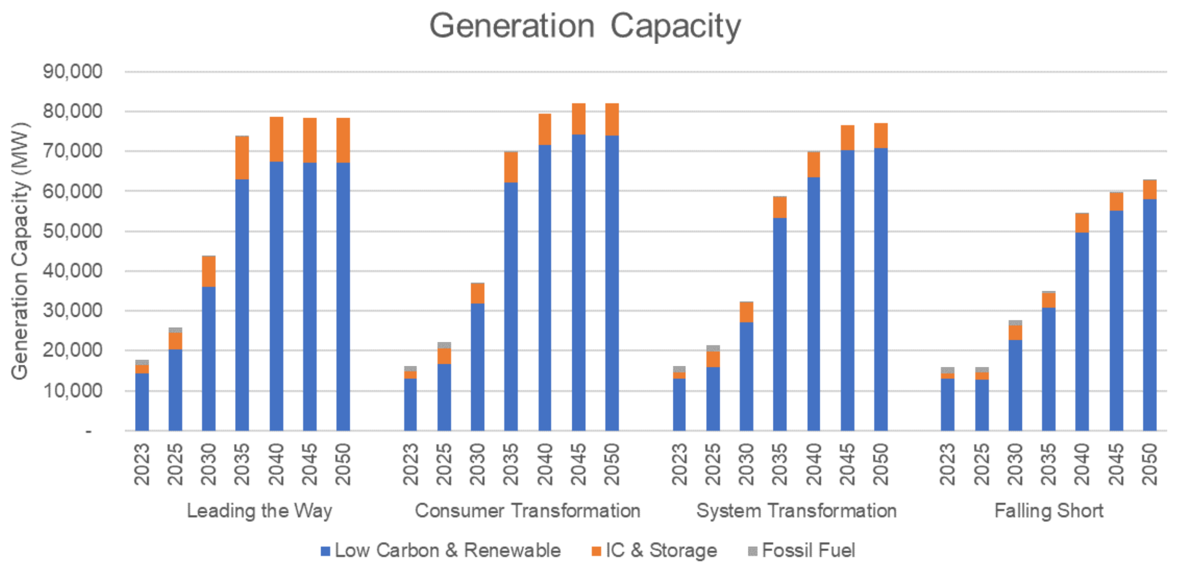
Regional thermal drivers - Scotland

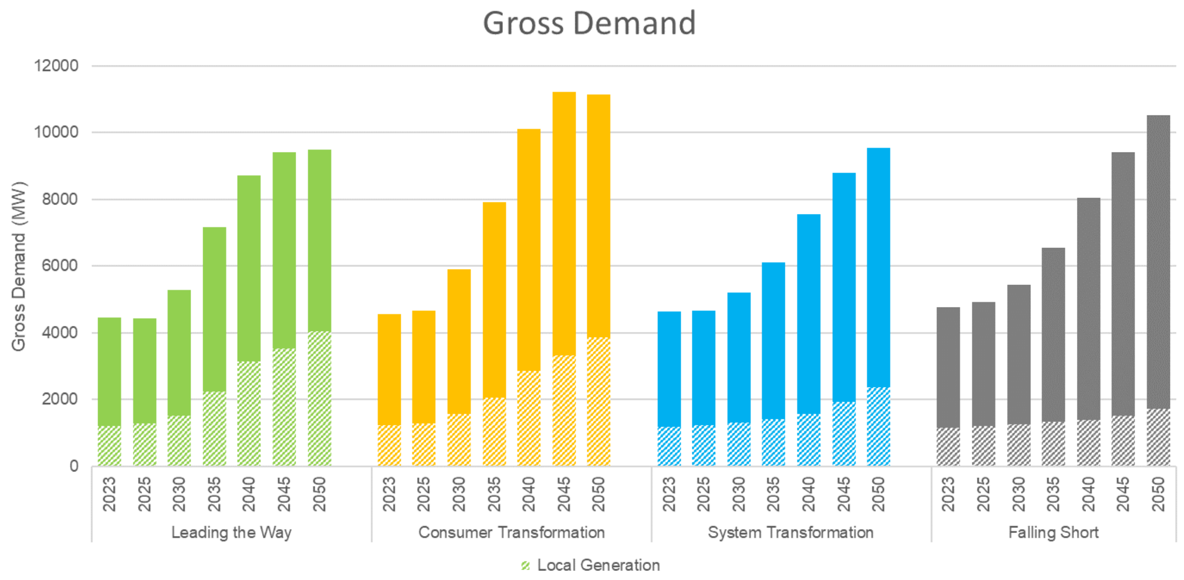
Scotland continues to experience a significant increase in renewable generation capacity due to its abundant availability of natural resources, often in areas where the transmission network is limited.

Over the next 10 years, this swift growth in renewable generation capacity, mainly from offshore wind, will substantially contribute to greater power transfer requirements across the Scottish boundaries. This will increase the network reinforcement needs across some boundaries.

Scotland's current winter peak gross demand is 4GW rising to approximately 6GW by 2030. Its generation capacity is 17.8 GW rising to approximately 43 GW in the Leading the Way scenario by 2030. Across all the ESO's Future Energy Scenario modelling, generation capacity of fossil fuel in Scotland reaches almost zero between 2030 - 2035. Generation capacity in Scotland heavily exceeds demand and thus Scotland will be expected to export power into England most of the time, except during periods of prolonged low wind, where the reverse may occur.

As Scotland's renewable generation over the next 10 years increases, so too does the power transfer requirements across the Scottish boundaries increase as a result (the Scottish NETS boundaries are B0, B1a, B2, B3b, B4 and B5 and B6). This will increase the network reinforcement needs across some boundaries.





ETYS 2023 / Scotland 24

Regional thermal drivers - Scotland

With the anticipated generation development in the north of Scotland, including on the Western Isles, Orkney and the Shetland Islands, there may be local limitations on power transfer from these remote locations to the main transmission routes (B0, B1a). Network reinforcements are planned which will alleviate some of these limitations, facilitating the transfer of renewable generation to the mainland.

Alongside needed network reinforcements to address the constraints across the B6 boundary (Anglo - Scottish border), the ESO has developed and procured a commercial non-build solution, the B6 Constraint Management Intertrip Service (CMIS), to help alleviate constraints. 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. After going live in April 2022, this service has provided savings to the consumer of £80m in constraint costs during its first ten months of operation.

ETYS 2023 / Scotland 25

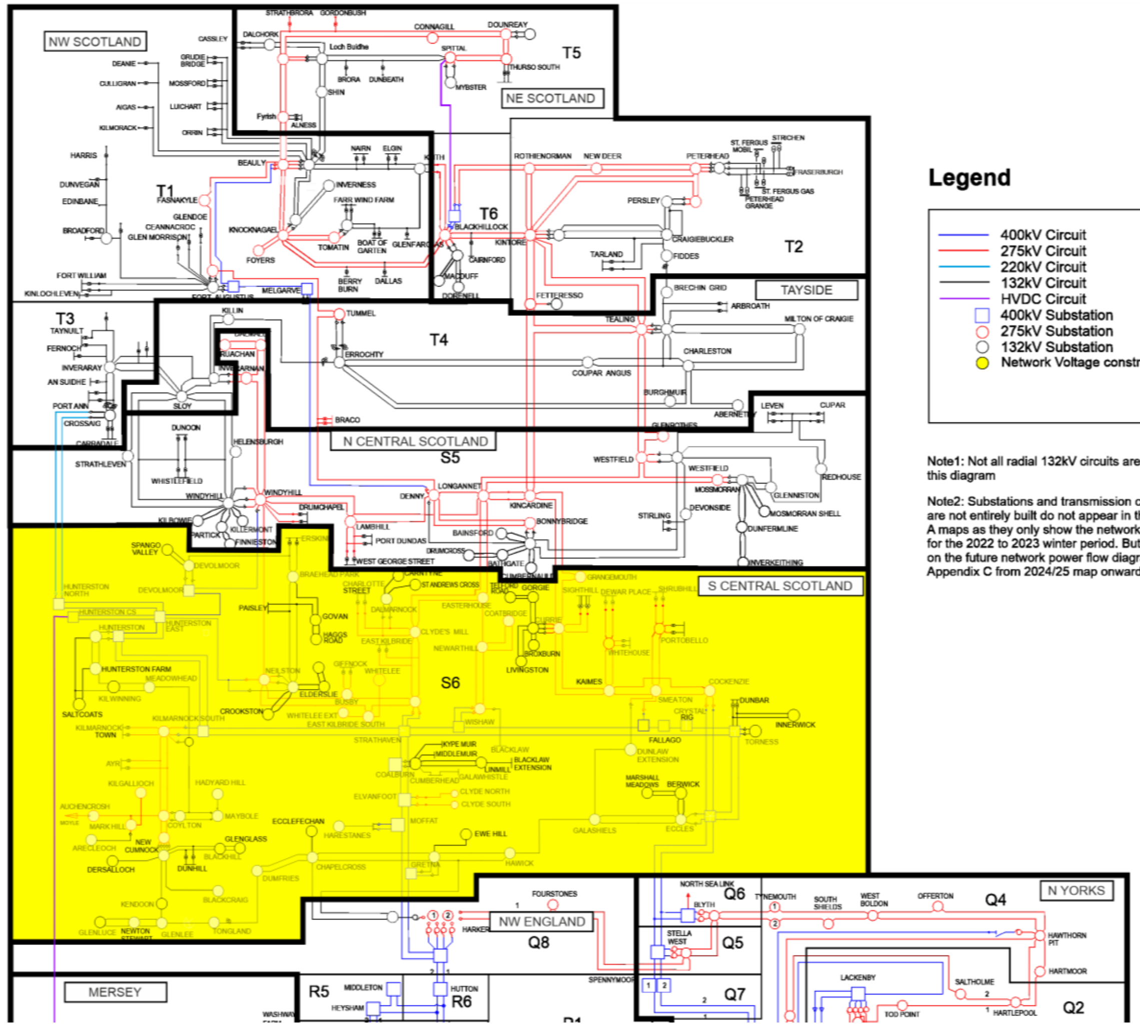
Regional voltage drivers - Scotland

Scotland has seen a decline in synchronous generation that currently limits the local generation available to support the local voltage

Over the next decade, there is a significant growth in renewable generation expected in Scotland however, this is located at the peripherals of the network and would not be effective at managing voltages into central Scotland.

The decline in synchronous generation, primarily from fossil fuel generation, in Scotland could result in low short circuit level and inertia system operability challenges. To overcome this, the NOA Stability Pathfinder Phase 2 has successfully procured cost effective services which will meet our short-circuit level and inertia needs in the Scottish region, these solutions can also support voltage in the area and contracts were awarded mid-2022. We expect two synchronous compensators and two grid forming battery storage devices from 2024 and two additional grid forming battery storage devices, one from 2025 and one from 2026 in Central Scotland region as part of Stability Pathfinder Phase 2 project.

The map to the right shows South Central Scotland identified through our voltage screening process.



Legend

- 400kV Circuit
- 275kV Circuit
- 220kV Circuit
- 132kV Circuit
- HVDC Circuit
- 400kV Substation
- 275kV Substation
- 132kV Substation
- Network Voltage constraint

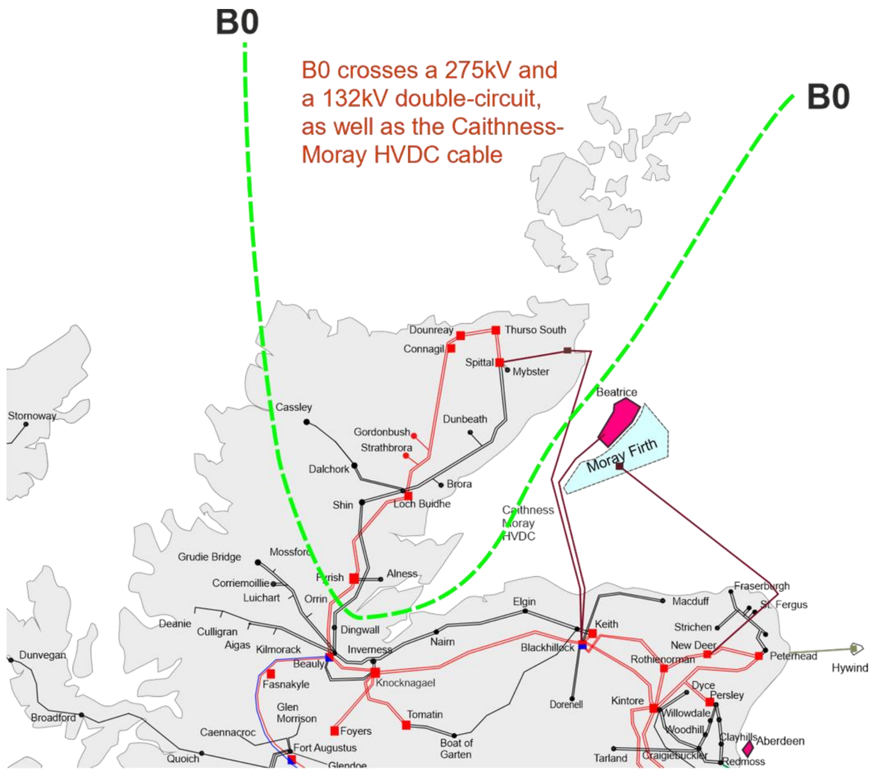
Note1: Not all radial 132kV circuits are indicated on this diagram

Note2: Substations and transmission circuits that are not entirely built do not appear in the Appendix A maps as they only show the network in operation for the 2022 to 2023 winter period. But they appear on the future network power flow diagrams in Appendix C from 2024/25 map onward.

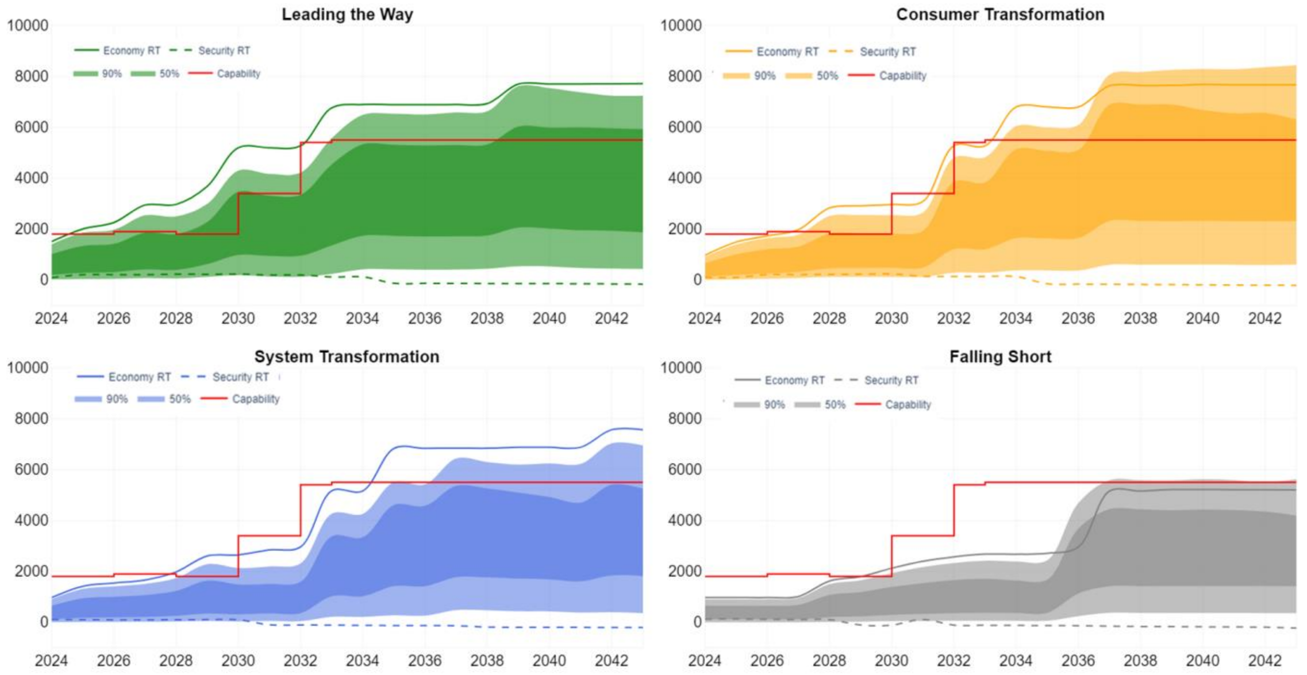
ETYS 2023 / Scotland 26

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.



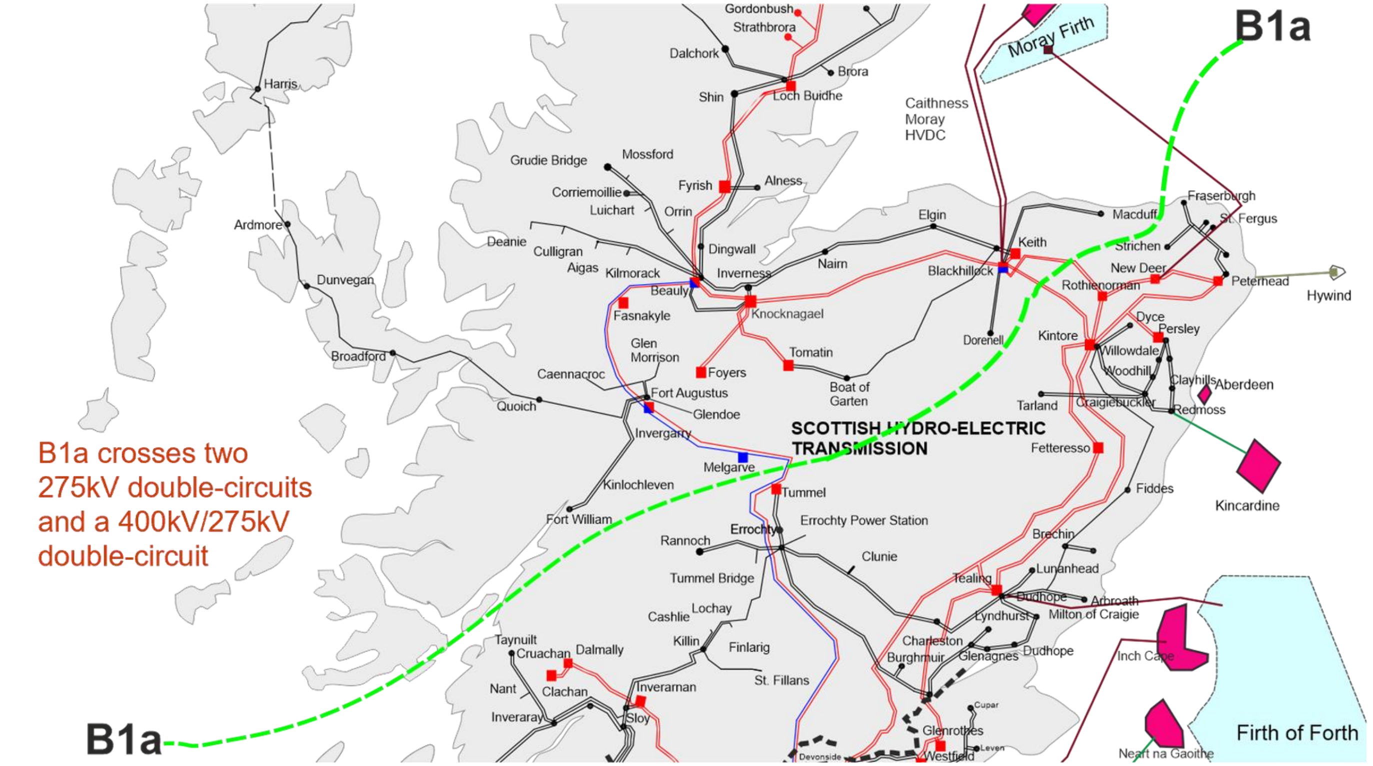
The capability line (in red) is based on the recommendations from the NOA Refresh 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

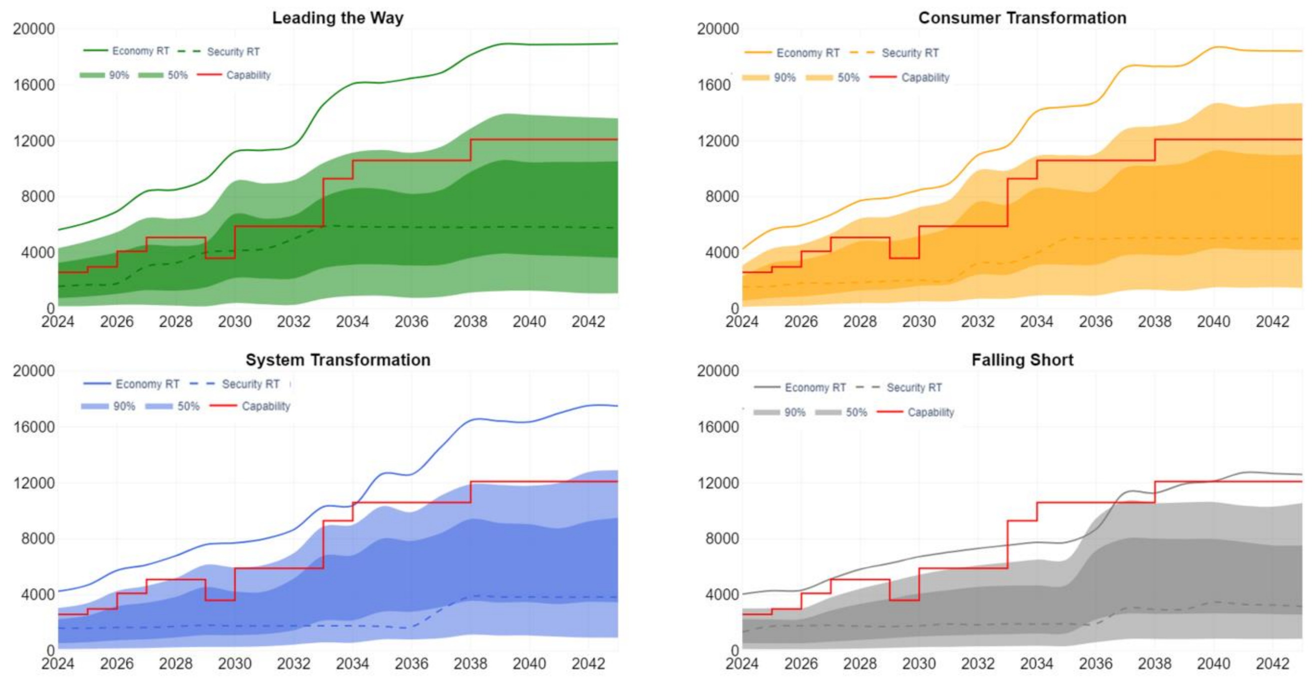
The boundary capability is limited to 1.15GW due to a thermal constraint on the Beauly - Shin 132kV circuit

ETYS 2023 / Scotland 27

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.





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.

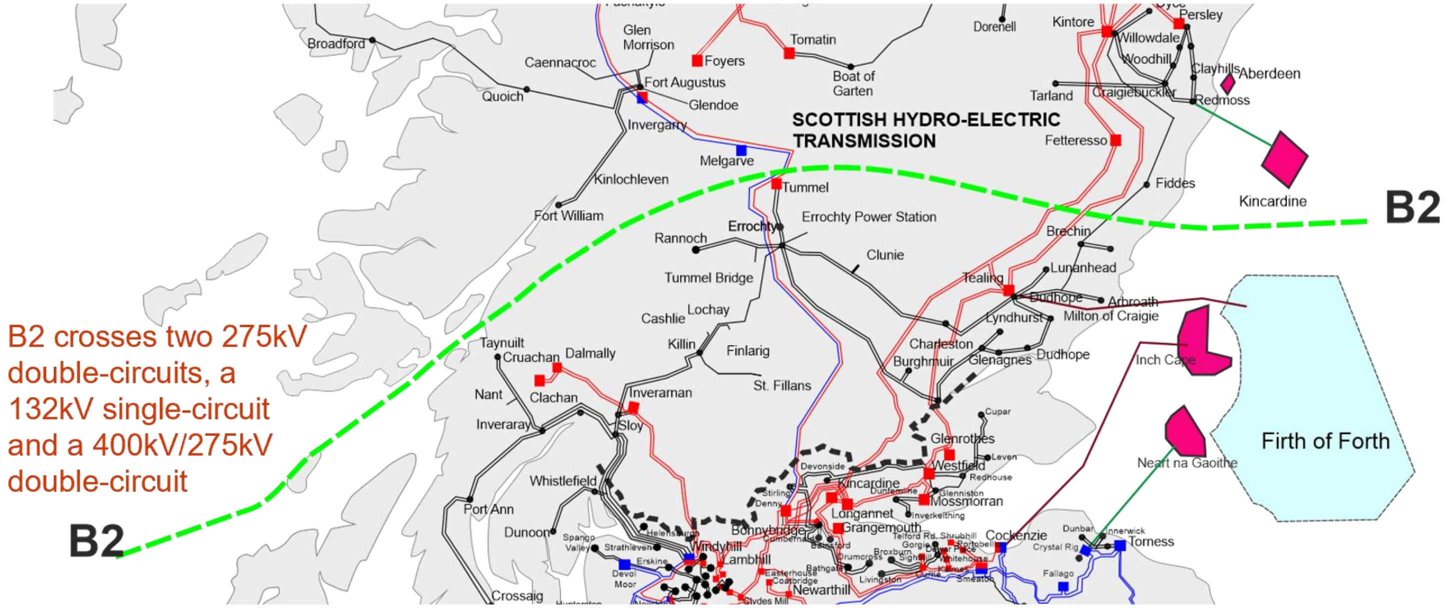
In all the future energy scenarios, there is an increase in the power transfer through B1a due to the large volume of renewable generation connecting to the north of this boundary. Contracted generation behind boundary B1a includes the renewable generation on the Western Isles, Orkney and the Shetland Isles with a considerable volume of large and small onshore wind developments. Future connection of new pumped storage assets in the North-West of the country is planned.

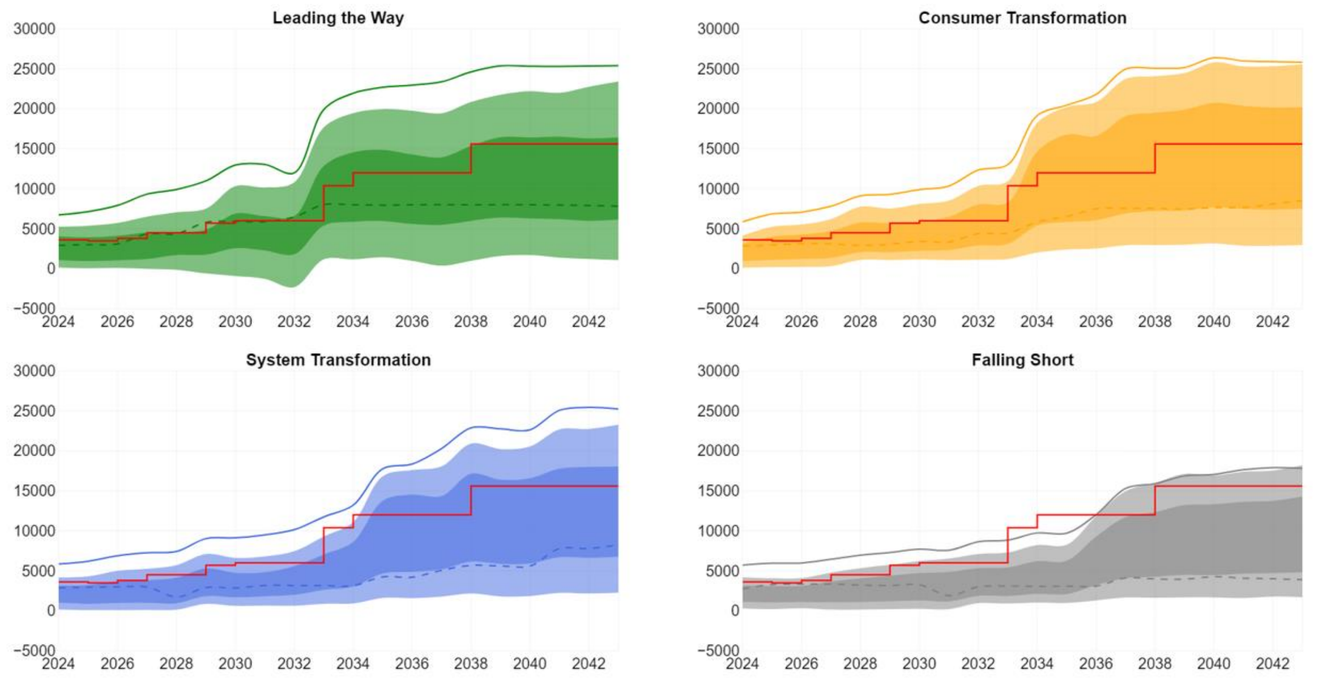
The capability line (in red) is based on the recommendations from the Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

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 generation behind boundary B2 includes both onshore and offshore wind, with the potential for additional pumped storage. Thermal generation lies between boundaries B1a and B2, as do several offshore windfarms and proposed future HVDC interconnection to Norway.

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.

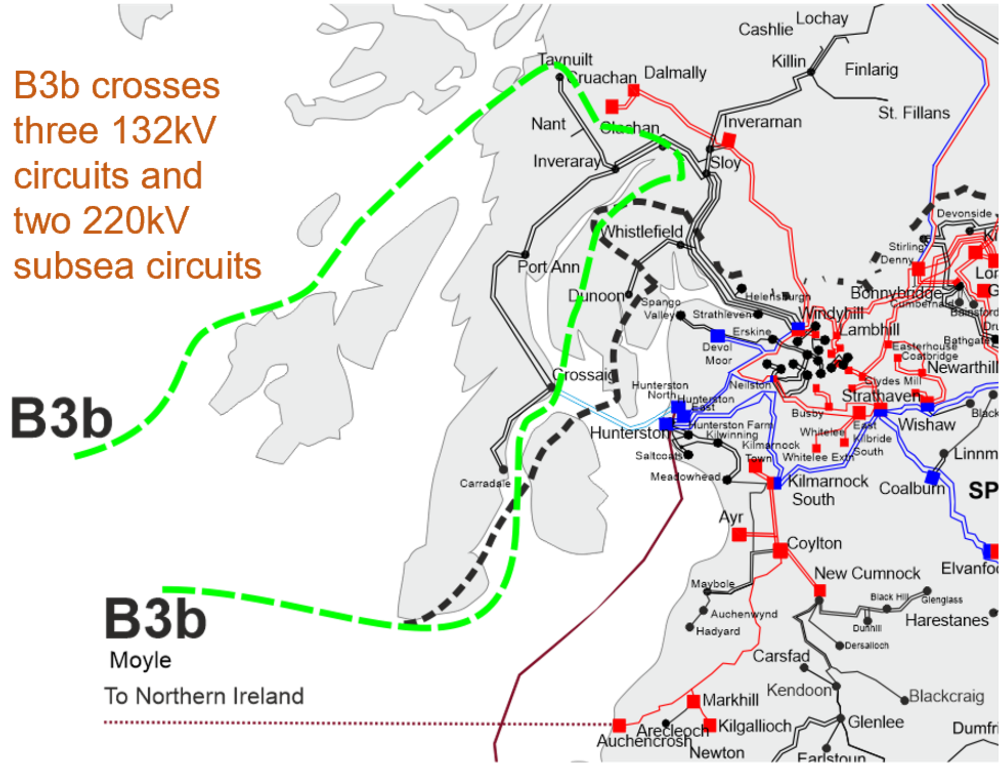
The capability line (in red) is based on the recommendations from the Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

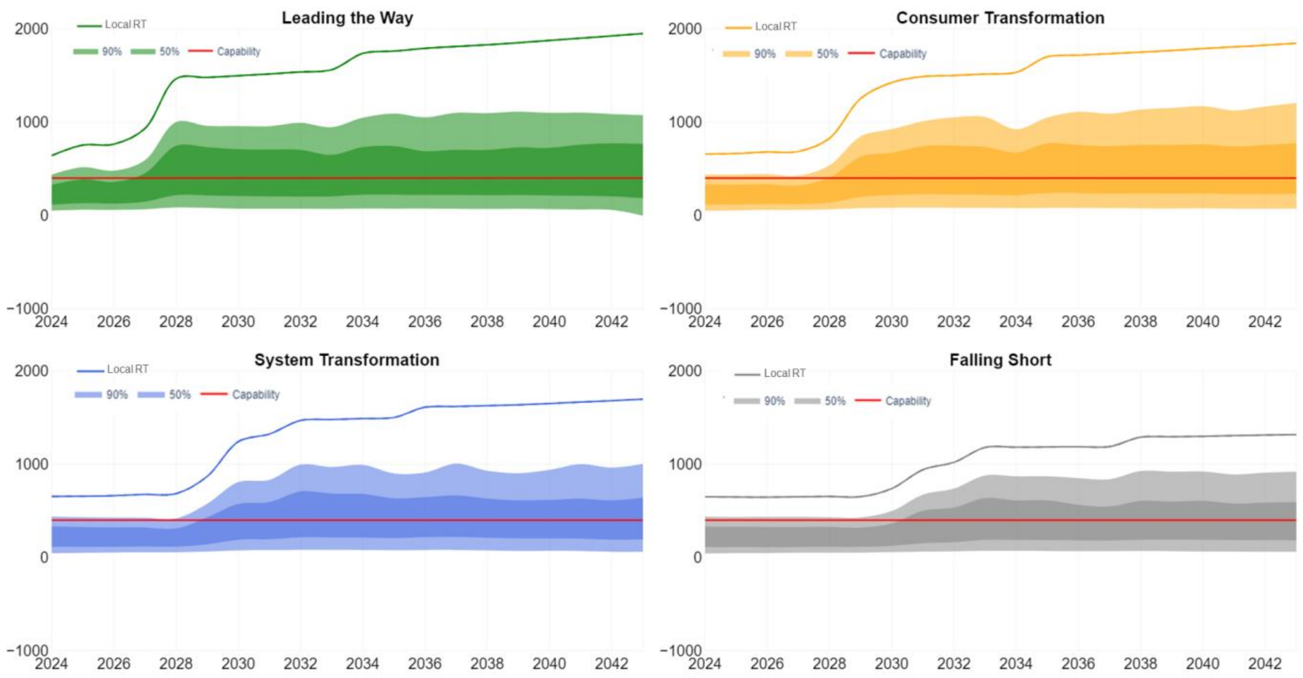
The boundary capability is limited to 2.6GW due to a thermal constraint on the Fetteresso - Kincardine 275kV circuit

ETYS 2023 / Scotland 29

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 capability line (in red) is based on the ETYS base (year 1) transfer capability, using the 2022 FES and ETYS data as inputs. The 50%, 90% and Economy RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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.

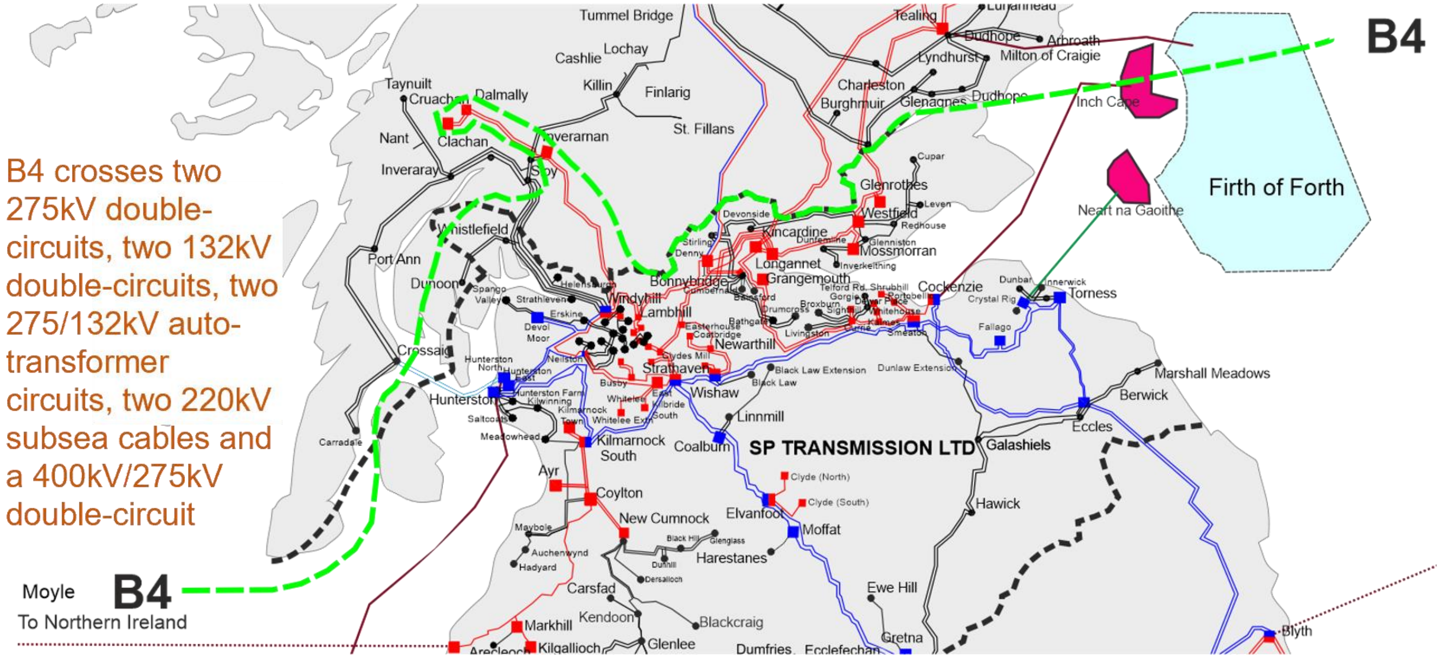
B3b is not currently subject to NOA reinforcement options as current contracted enabling works for customer connections will increase the ability to export power from this region, effectively splitting the network in the South West and altering the boundary.

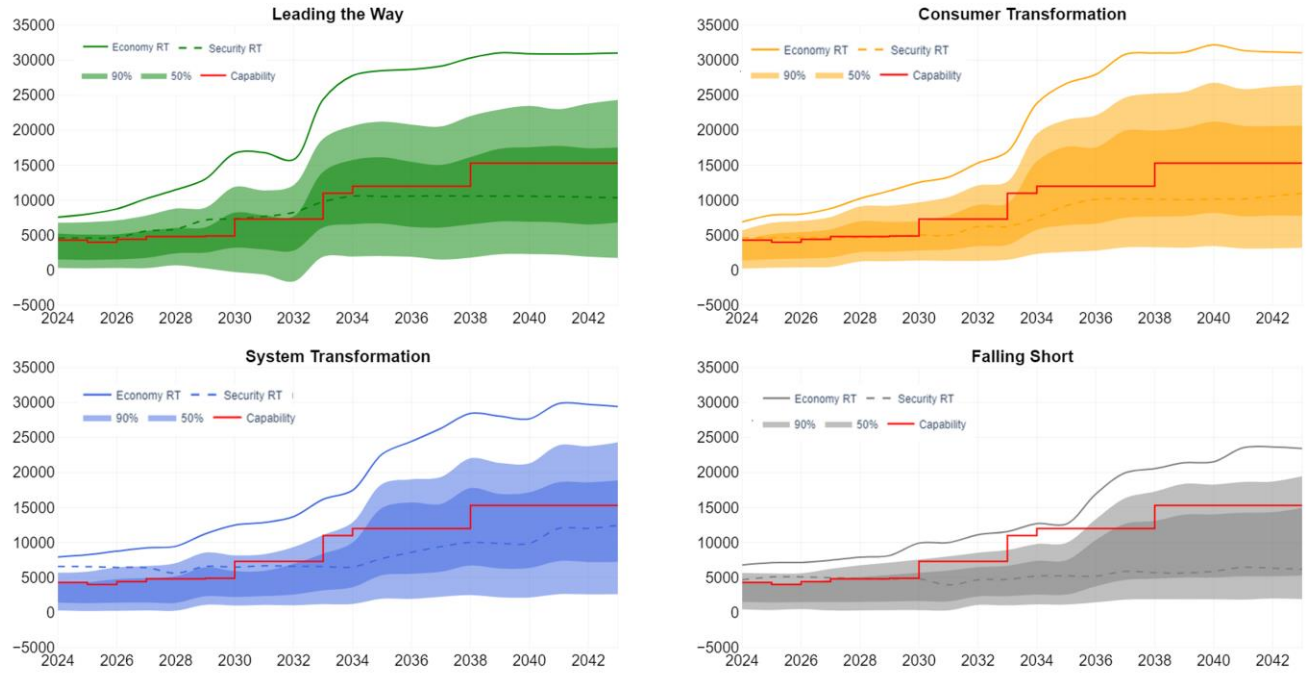
The boundary capability is limited to 0.44GW due to a thermal constraint on the Inveraray - Sloy 132kV circuit

ETYS 2023 / Scotland 30

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.

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.

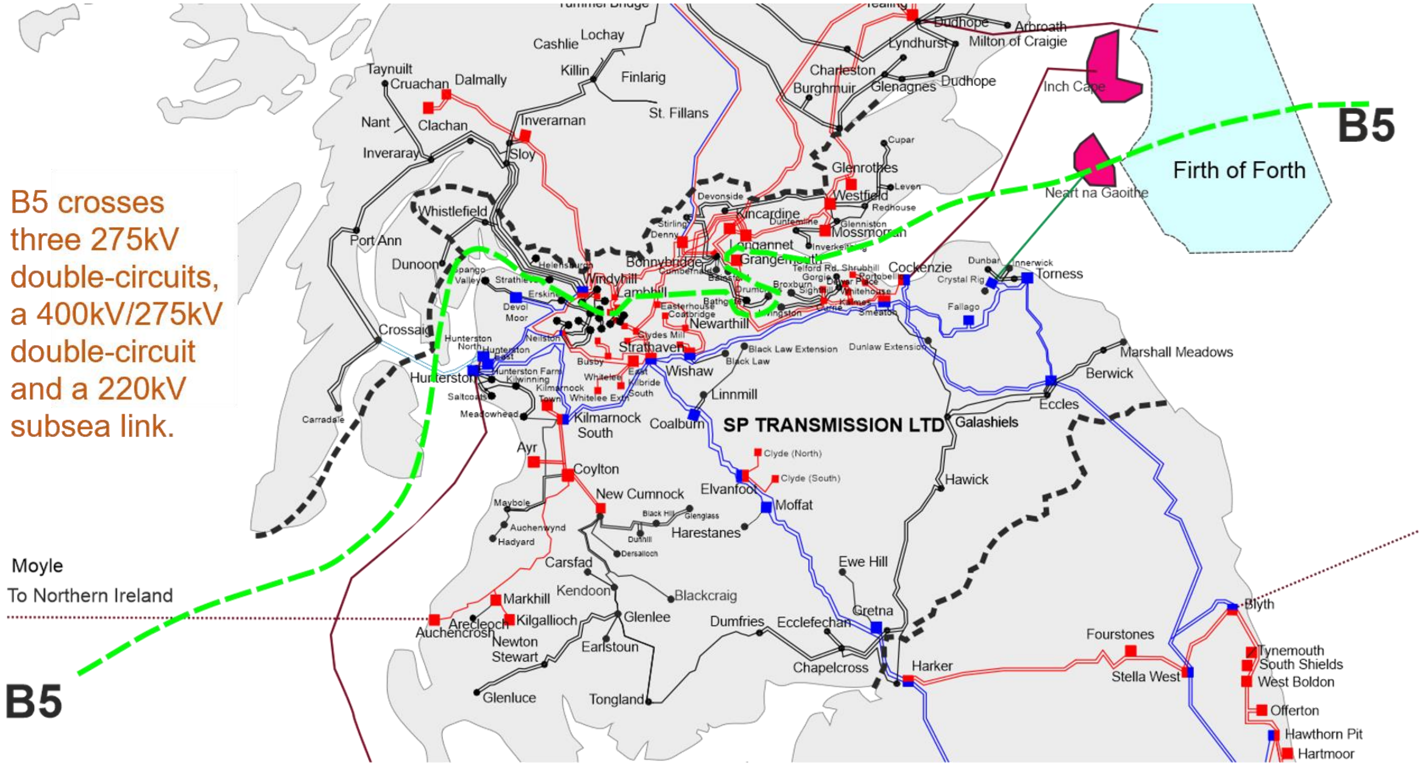
The capability line (in red) is based on the recommendations from the Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

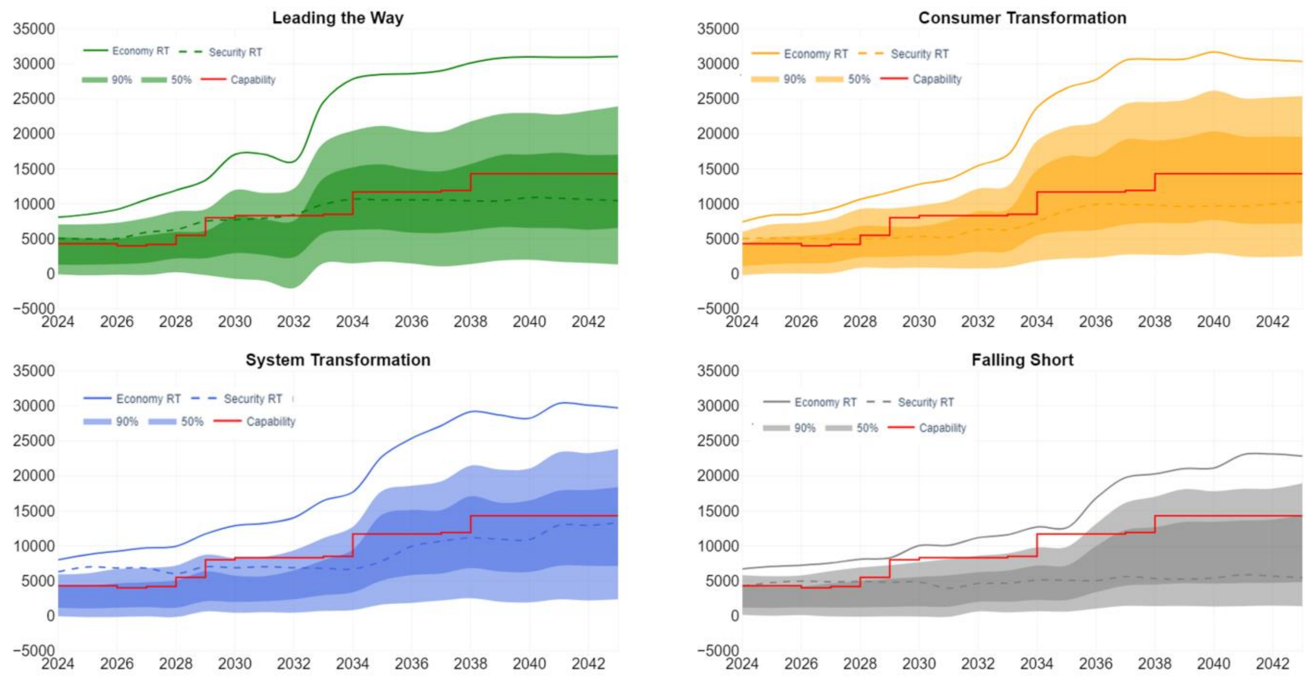
The boundary capability is limited to 3.4GW due to a thermal constraint on the Westfield - Longannet 275kV circuit

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.

B5 crosses three 275kV double-circuits, a 400kV/275kV double-circuit and a 220kV subsea link.





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.

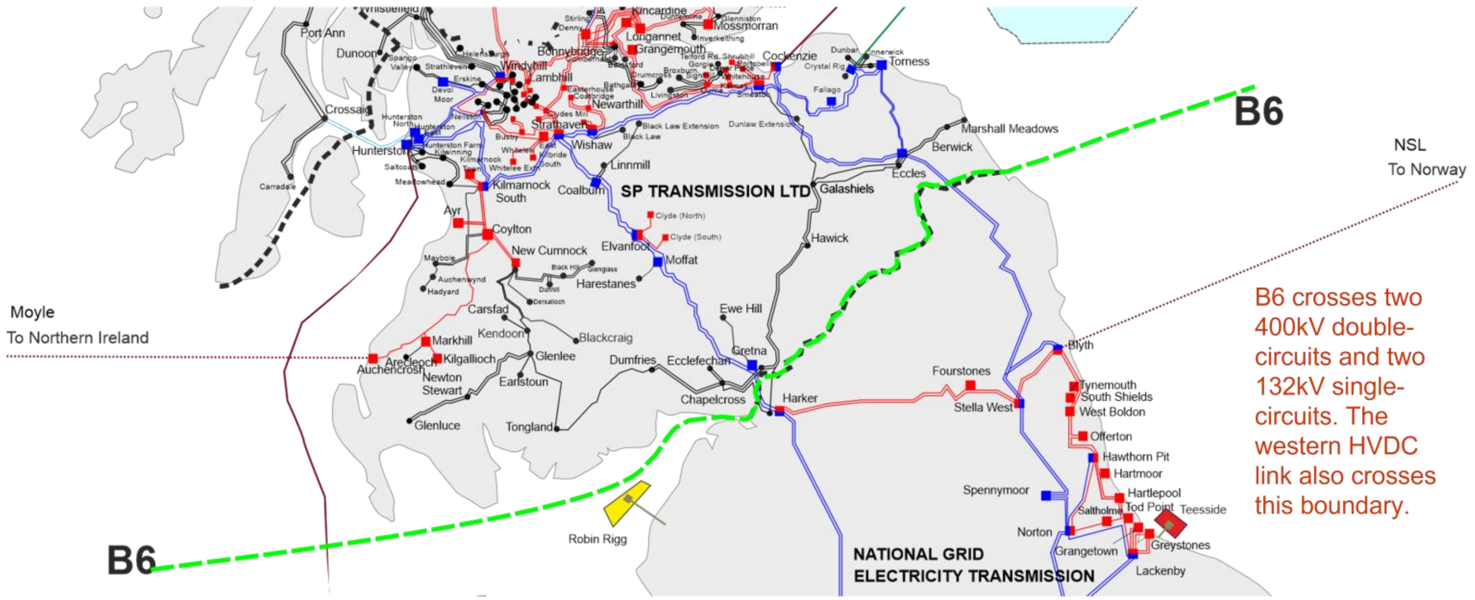
The capability line (in red) is based on the recommendations from the Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

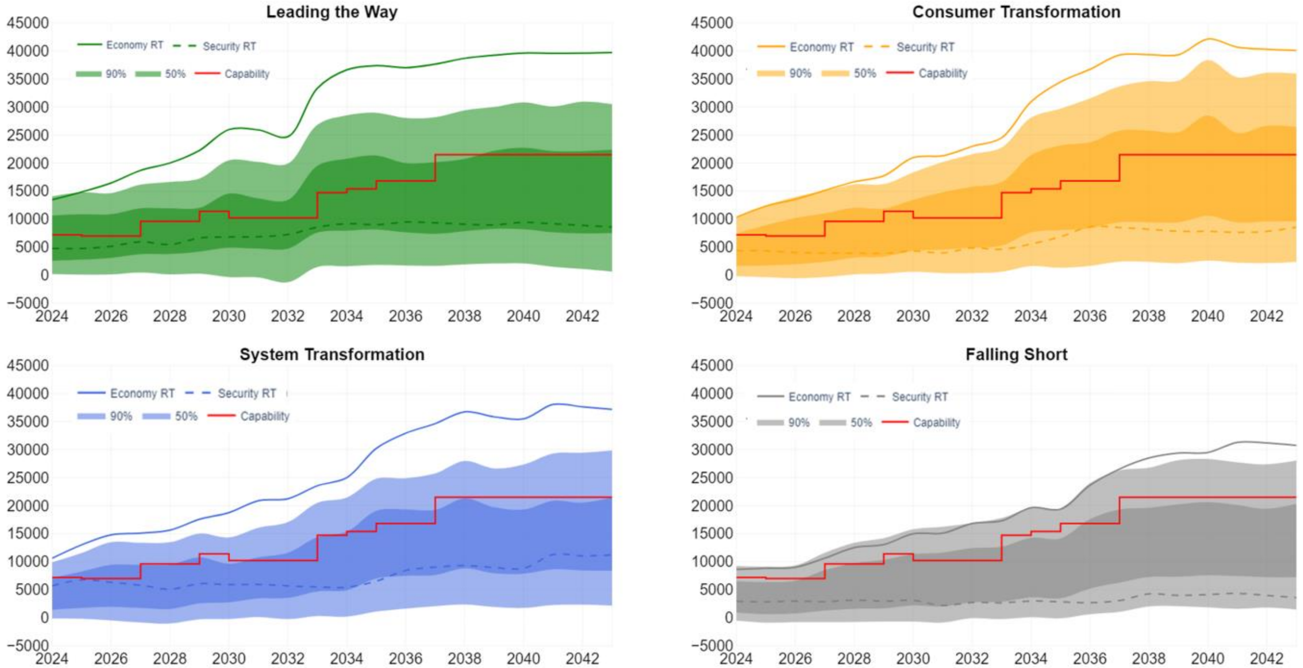
ETYS 2023 / Scotland 32

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 variable nature of wind generation. During periods of low generation output in Scotland, it is credible to have power flowing from south to north feeding Scottish demand.

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 synchronous plant capability 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 Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

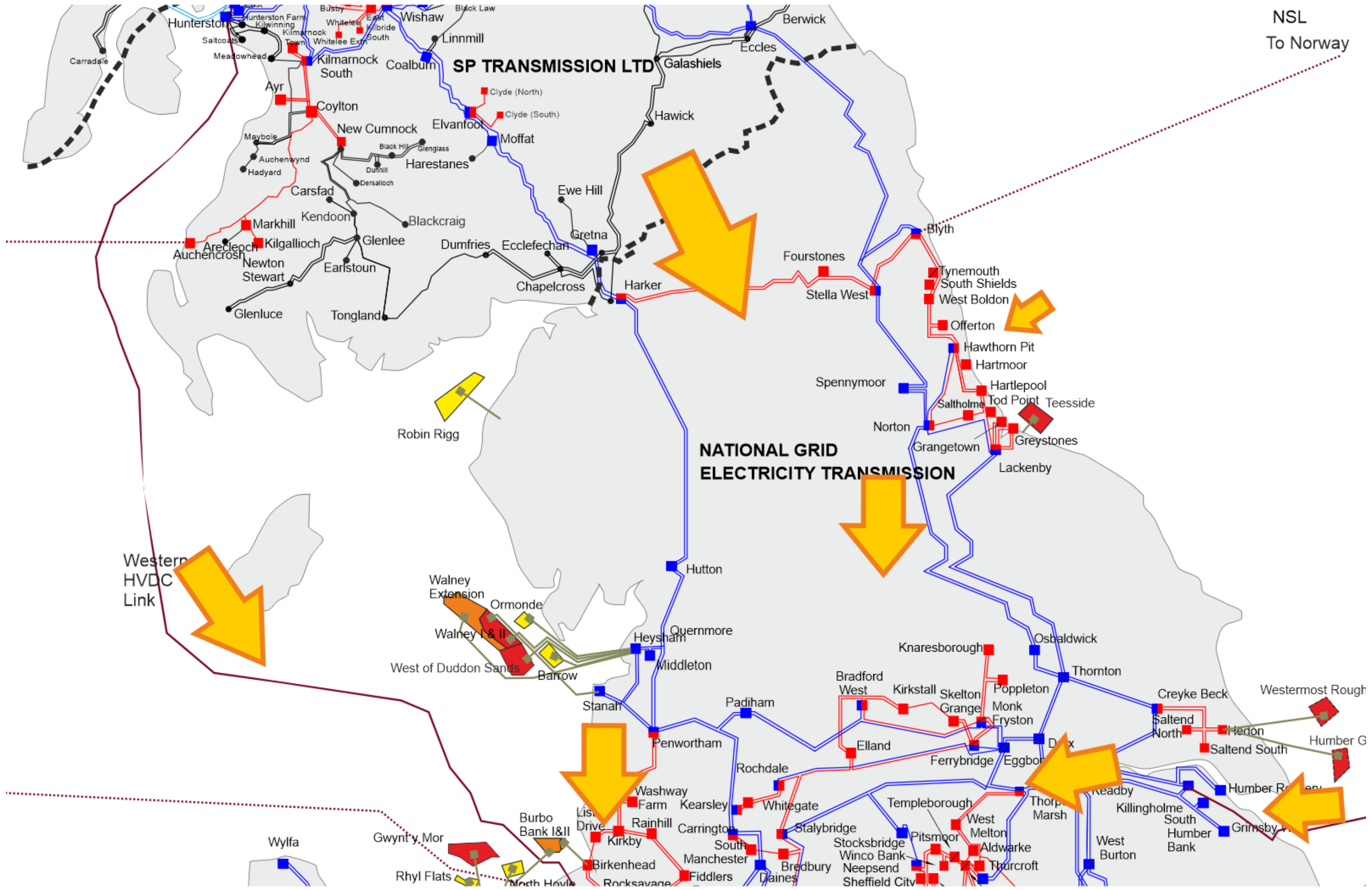
ETYS 2023 / Scotland 33

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 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 2033, 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.



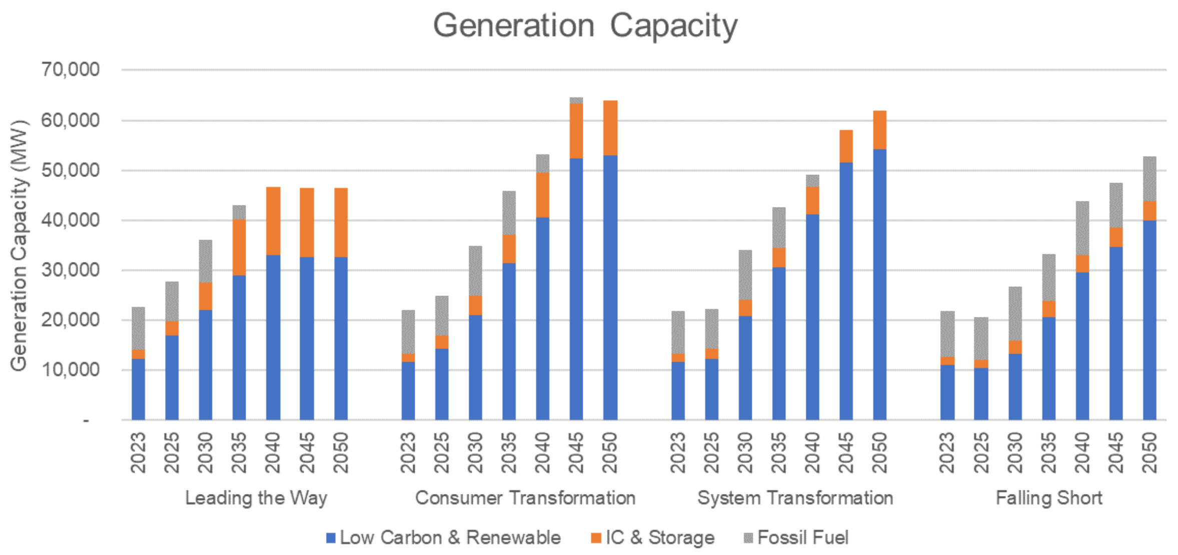
Regional thermal drivers – North of England

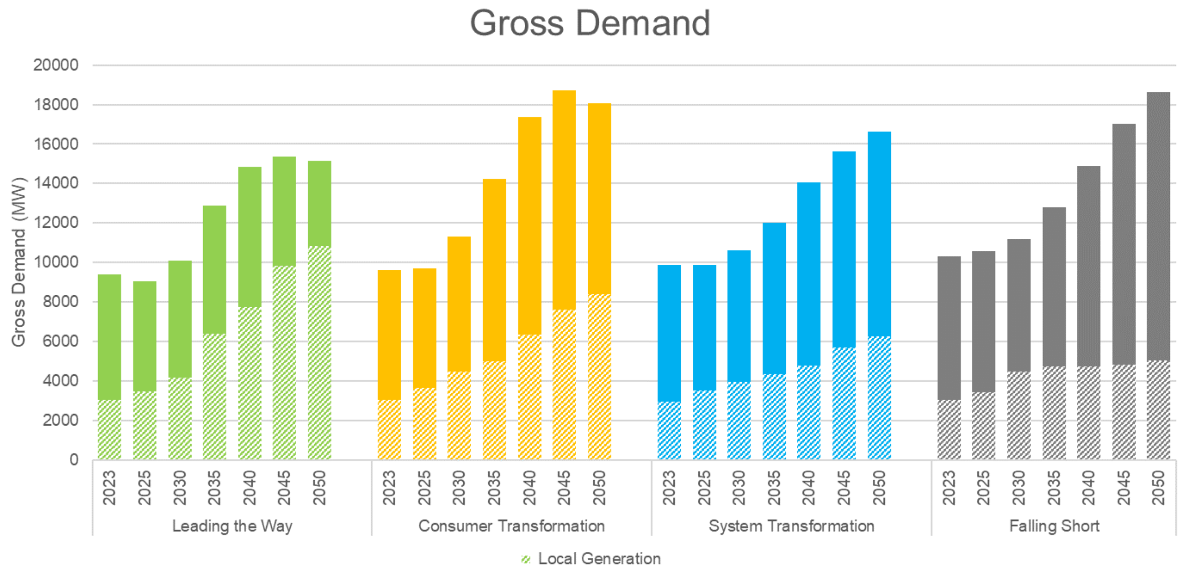
Future power transfer requirements could more than double compared to what they are today in some scenarios. The significant volume of new generation in Scotland, most of which is renewables, is a key driver for the requirements in the northern transmission network.

Low-carbon and renewable generation is expected to increase across all 4 scenarios. Fossil fuel generation could see sustained decline in all except the Falling Short scenario, but it wouldn't be phased out in the region until 2040 at the earliest in the Leading the Way scenario.

Overall, by 2030, the total generation in the region could increase to a total of over 36GW in the Leading the Way scenario. The North of England is a heavily power-exporting region and must also manage power flows from Scotland to demand centres in the Midlands and South. Gross demand in the North of England is expected to increase to a total of over 11GW by 2030. All four scenarios show a steady increase in the gross demand of the region. In Leading the Way scenario, a further 2.5–8 GW of local embedded generation is expected by 2050, up from about 3GW today. More local generation would result in reduction in net demand and less of the North-South power flows through this region being absorbed by demand.

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 travel north to south and mostly come from internal boundary generation and generators 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.





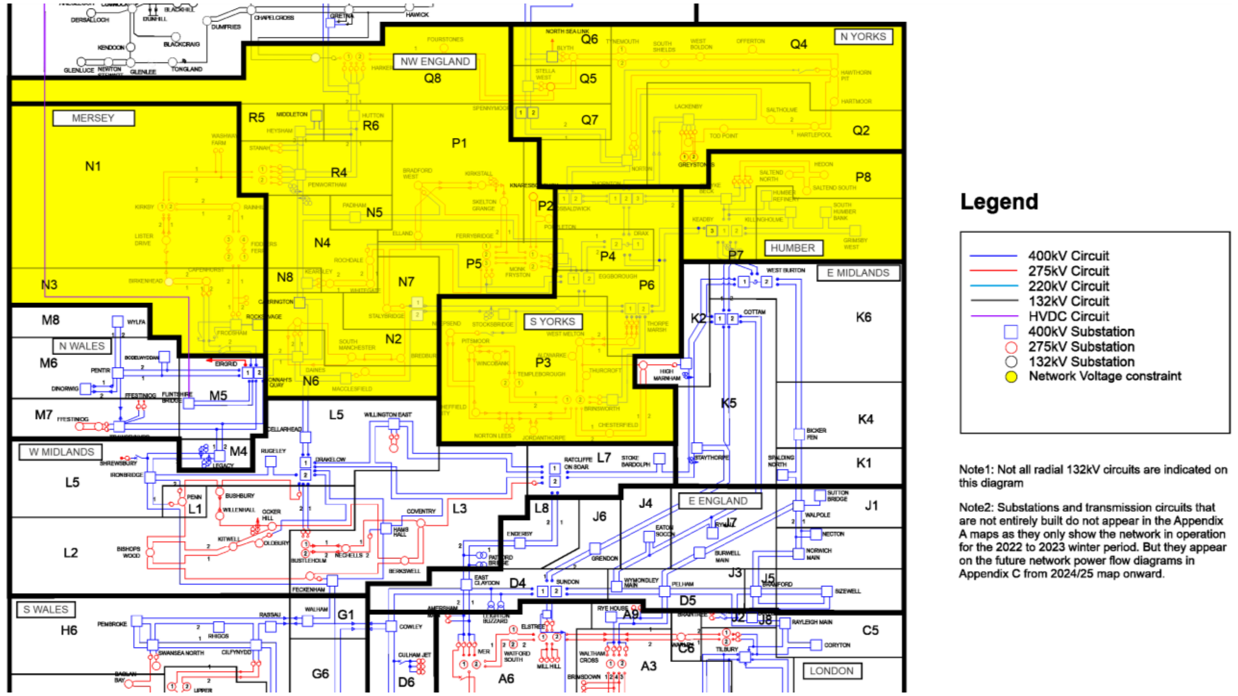
Regional voltage drivers – North of England

We could see both generation closures as well as some new generation connections in the North of England. The timing of these closures or connections could result in some system needs for certain years.

High voltage in this region arises due to the high gain cable circuits and a decline in reactive power demands. Low voltages are sometimes observed in the North East region during outages and high active power flows from Scotland and interconnector imports.

Solutions procured through the Pennine Pathfinder 2024 and stability pathfinder phase 3 will help support the voltage in this region when implemented. We expect two synchronous compensators from 2025 and one from 2026 in this region as part of Stability Pathfinder Phase 3 project.

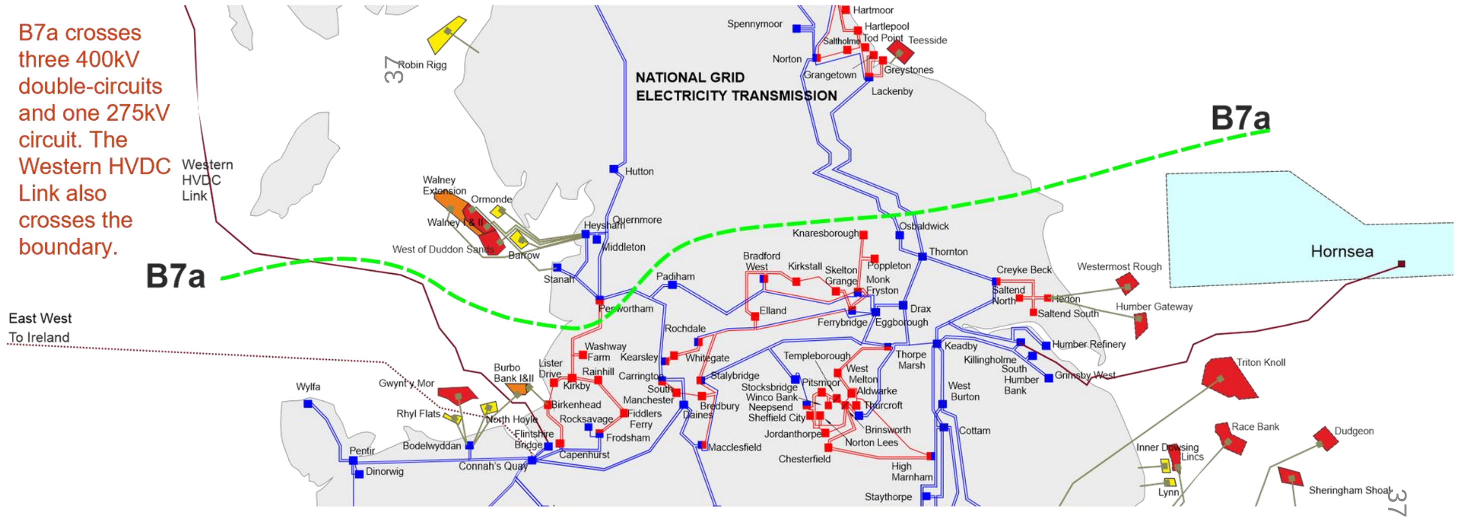
The map to the right shows Mersey, North West England, South Yorkshire, North Yorkshire and Humber identified through our voltage screening process.

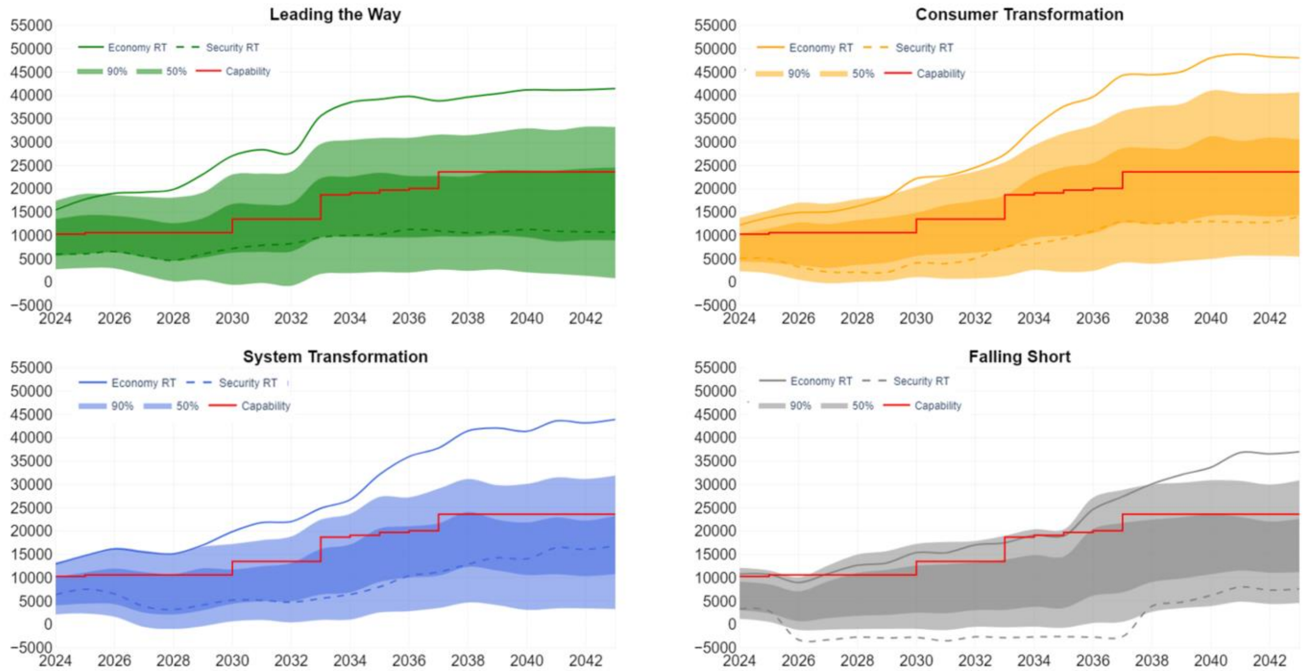


ETYS 2023 / North of England 36

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 variable renewable generation in the north, meaning the spread of boundary power flows is very wide. During periods with low northern generation output 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.

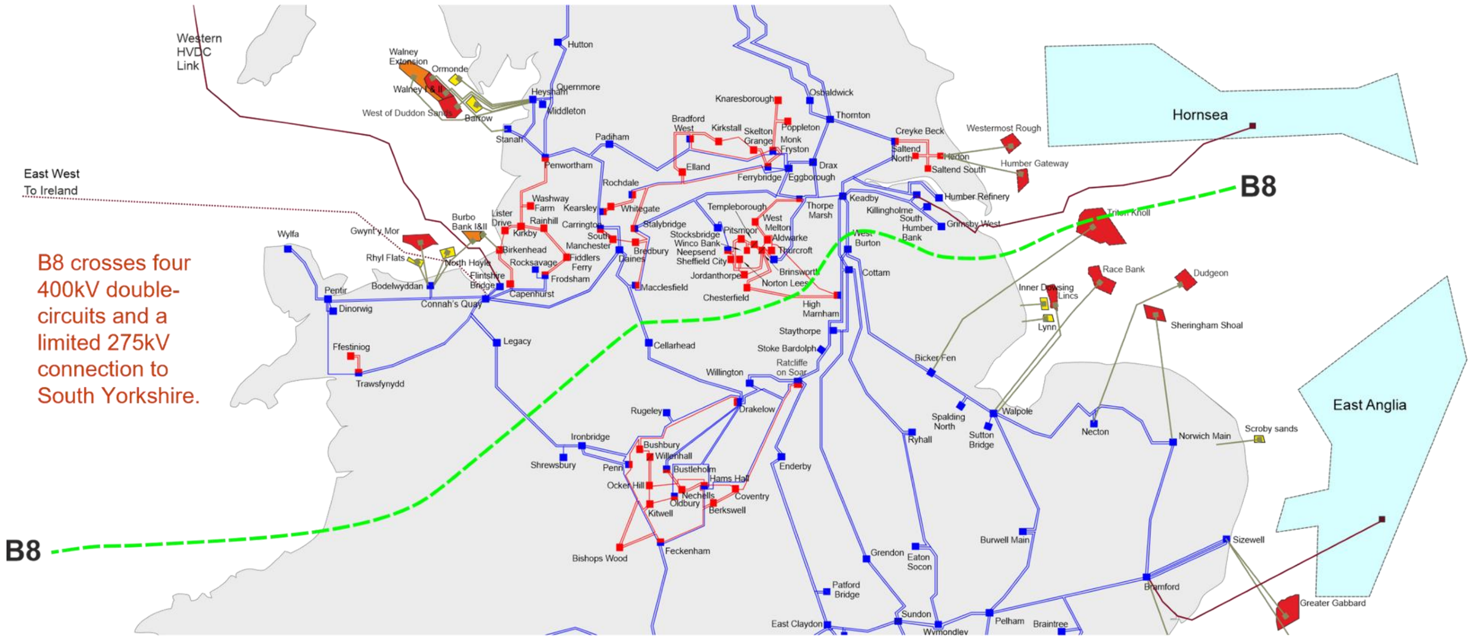
The capability line (in red) is based on the recommendations from the Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

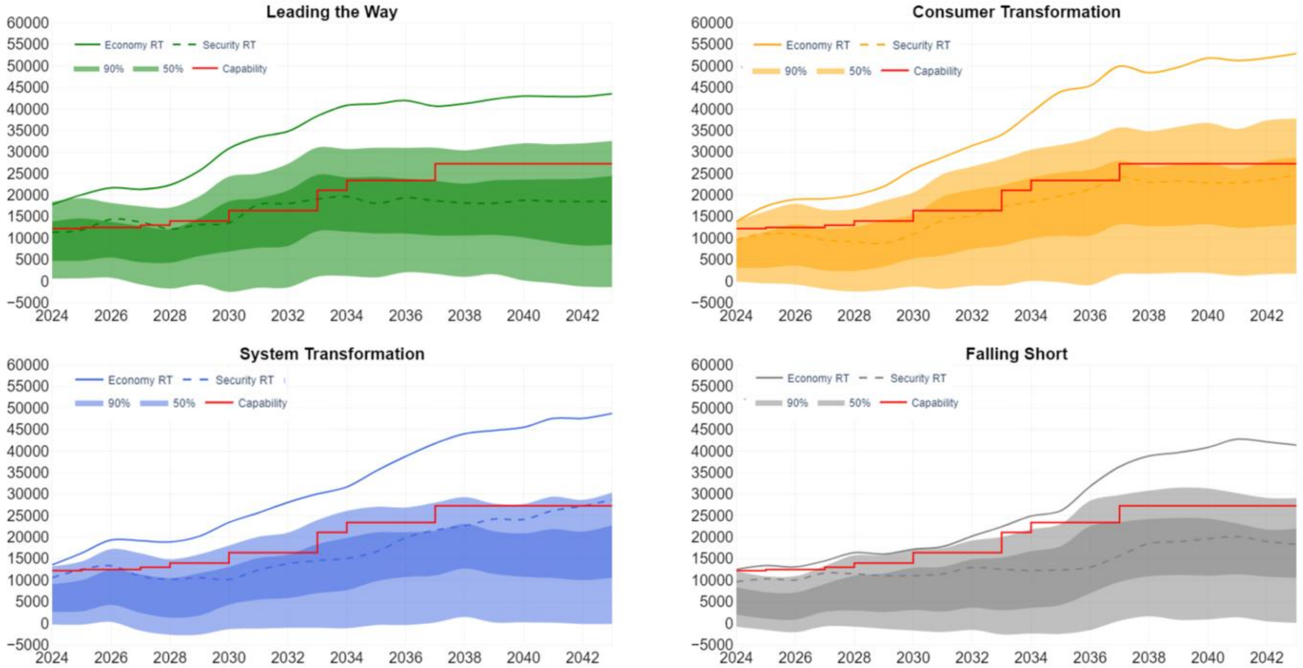
The boundary capability is limited to 9.4GW due to a thermal constraint on the Penwortham – Washway Farm 275kV circuit

ETYS 2023 / North of England 37

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 variable renewable generation in the north, meaning the spread of boundary power flows is very wide. During periods with low northern generation output 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 Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

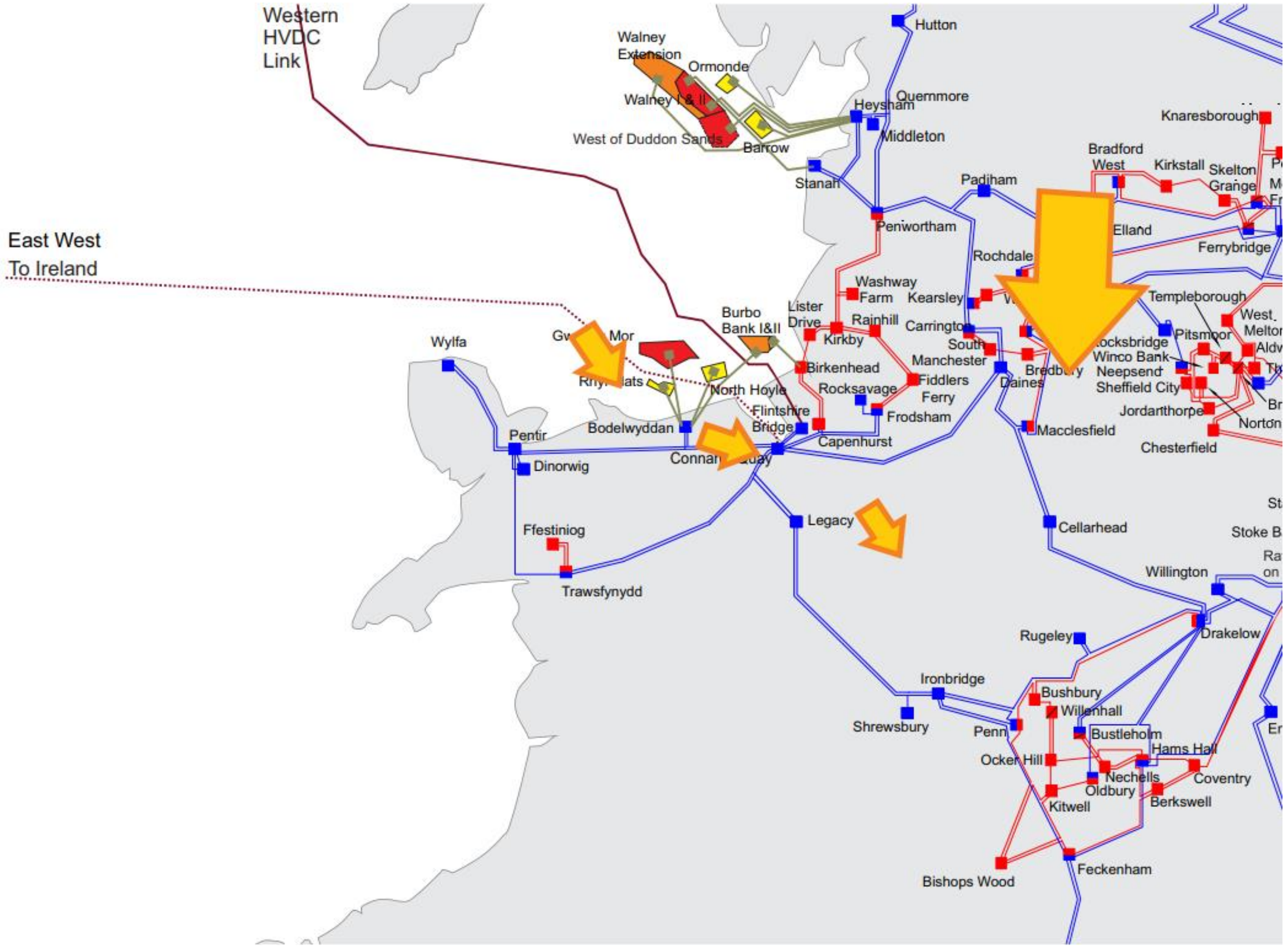
ETYS 2023 / North of England 38

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 2033, 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 2023 / North Wales & Midlands 39

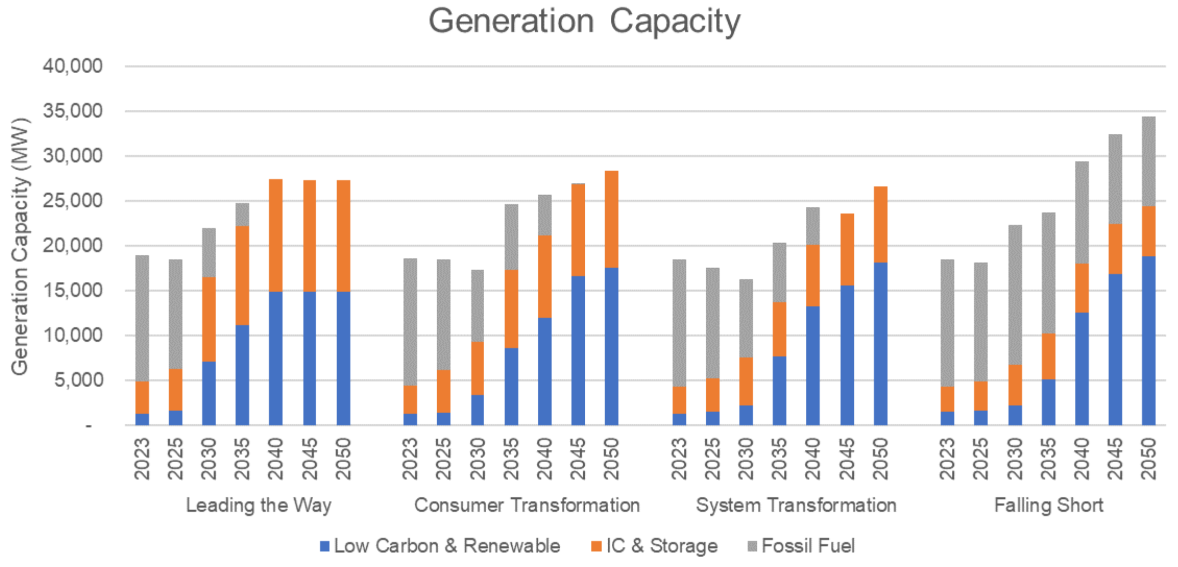
Regional thermal drivers – North Wales and the Midlands

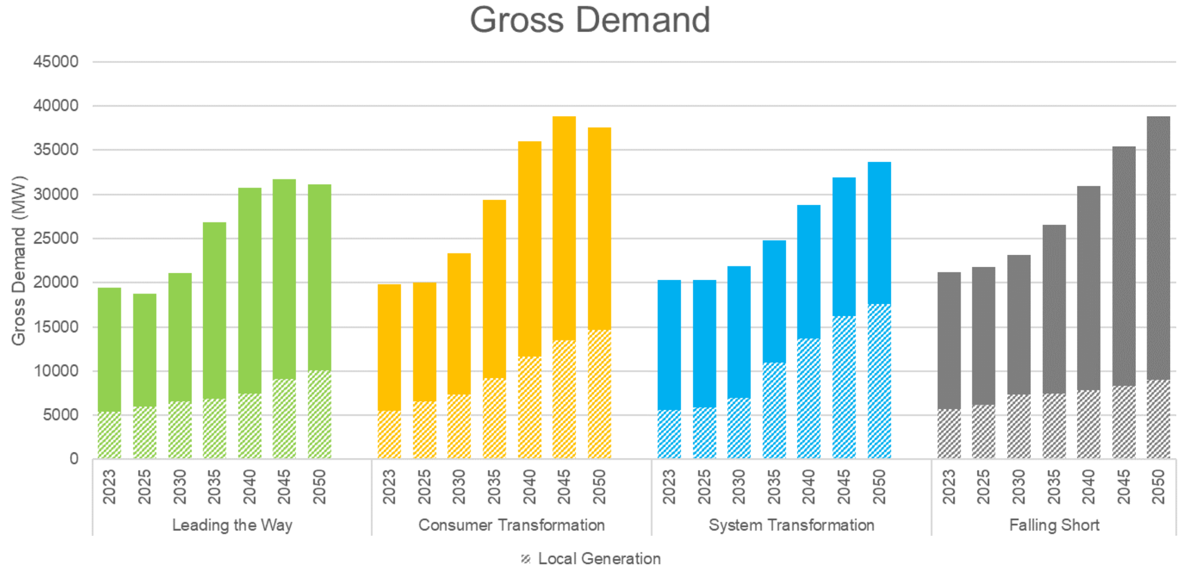
Power plant closures are set to occur in the Midlands with demand set to remain fairly high, driving increased power flows eastwards from future generation connecting to North Wales.

The FES scenarios suggest a total amount of transmission-connected generation capacity to be between 16GW to 23GW by 2030, from the current 18GW. For all scenarios other than Falling Short, fossil fuel generation is not present in the region by 2050.

Presently, this region has a significant volume of fossil fuel, however by 2030 all scenarios show a decline in fossil fuel generation capacity with slight growth in interconnectors and storage alongside a significant growth in low-carbon technologies. The gross demand as seen from the transmission network in the region will increase across all scenarios. 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 generally export power due to the connection of offshore wind projects facilitated by the HND and HNDFUE.





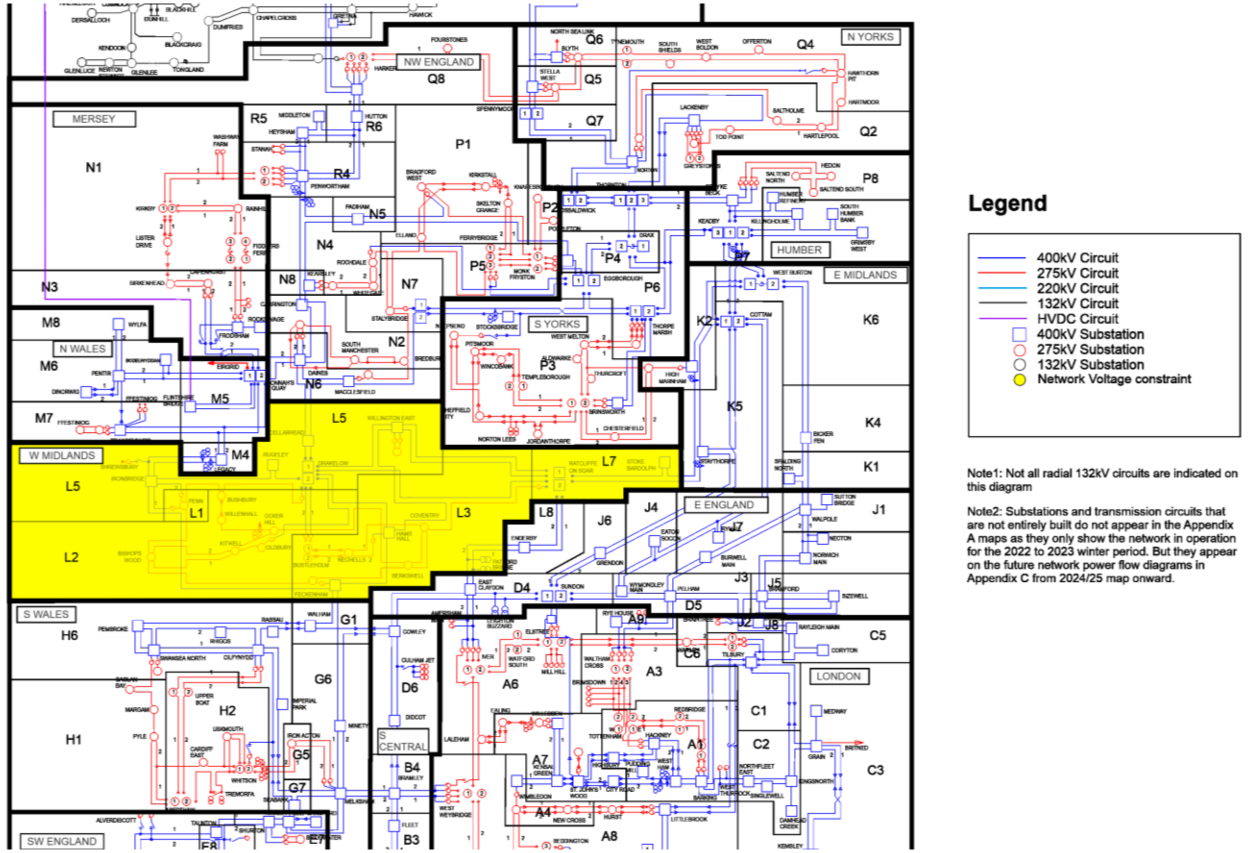
ETYS 2023 / North Wales & Midlands 40

Regional voltage drivers – North Wales and the Midlands

Following the closure of power stations in West Midlands region, we face challenges in managing voltage due to limited reactive compensation in the 275kV network, and the sensitivity of voltages to system flows.

This region relies on reactive compensation which exists far away and are thus not very effective. In the summer months due to low demand and the long transmission lines in the region, some areas experience high voltage. Looking ahead, this region sees limited growth in generation across all FES scenarios. This coupled with potential closure of fossil fuel generation in the region could make it increasingly challenging to manage the region's voltage.

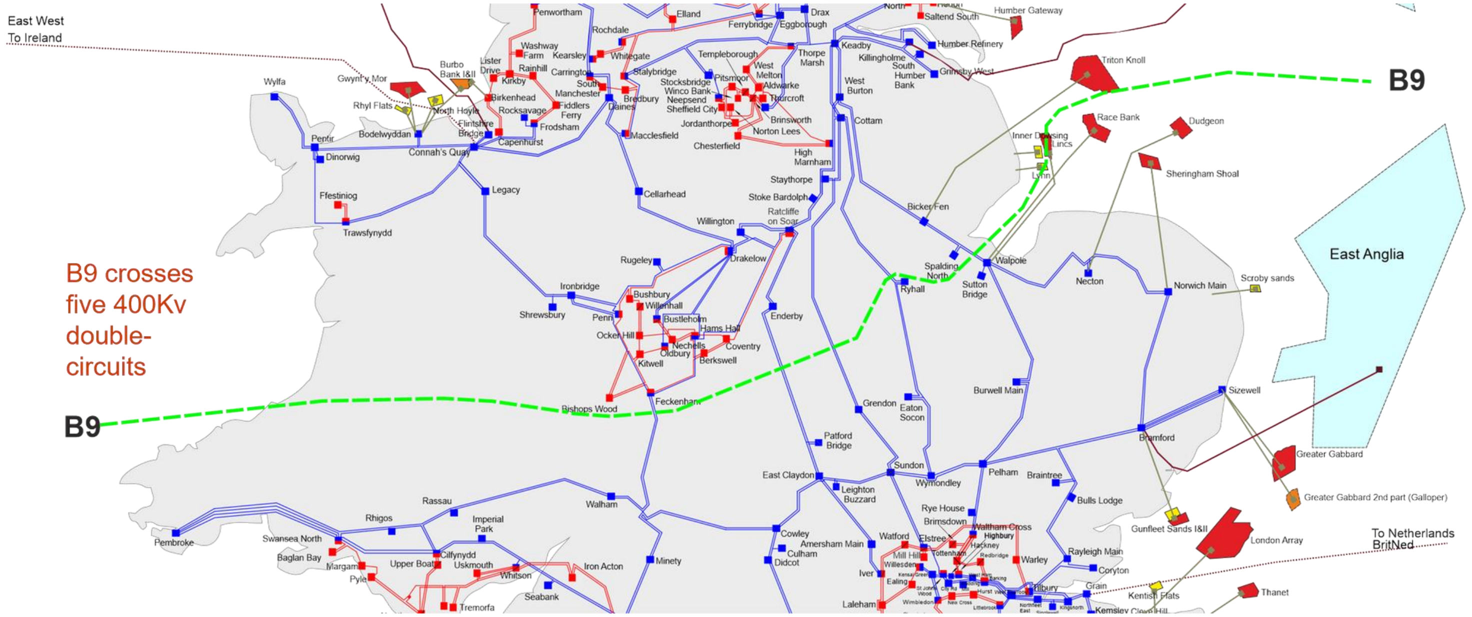
The map to the right shows the West Midlands identified through our voltage screening process.

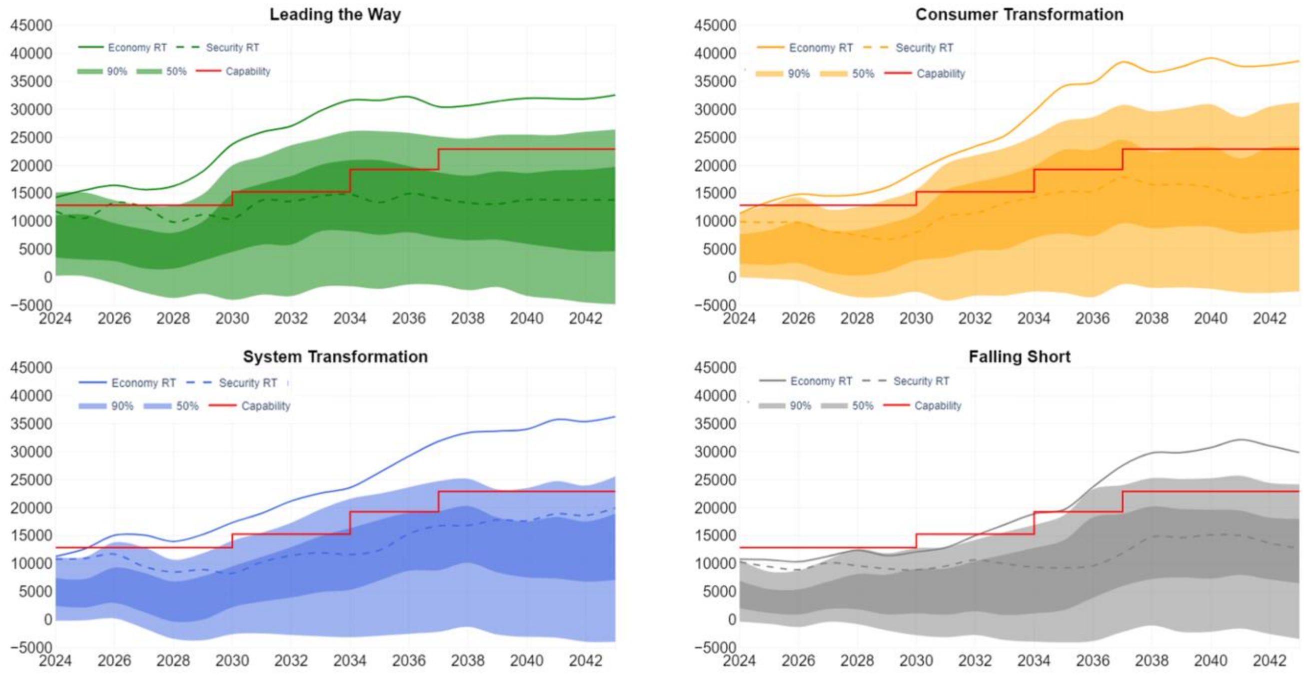


ETYS 2023 / North Wales & Midlands 41

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 capability line (in red) is based on the recommendations from the Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

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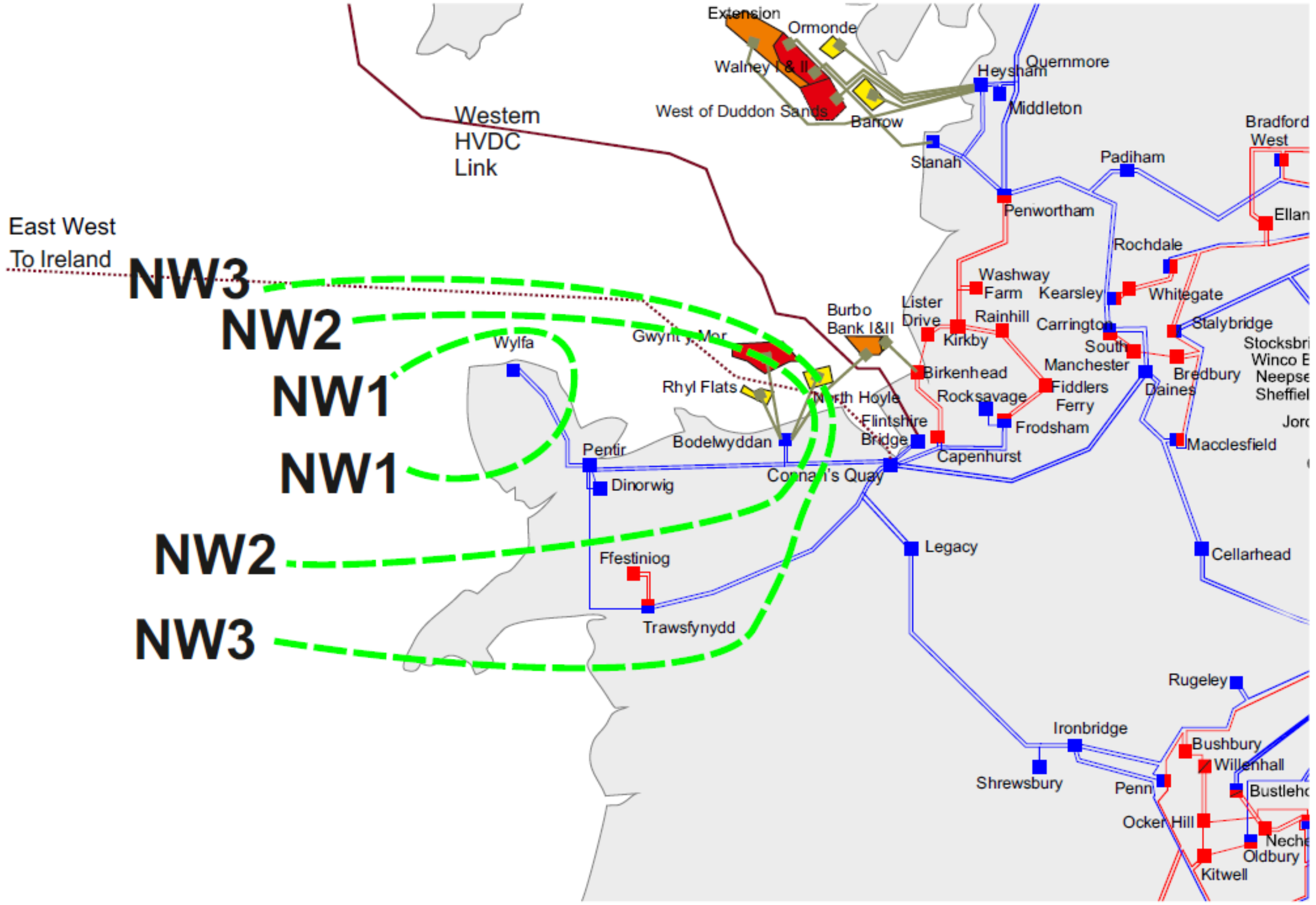
North Wales

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.



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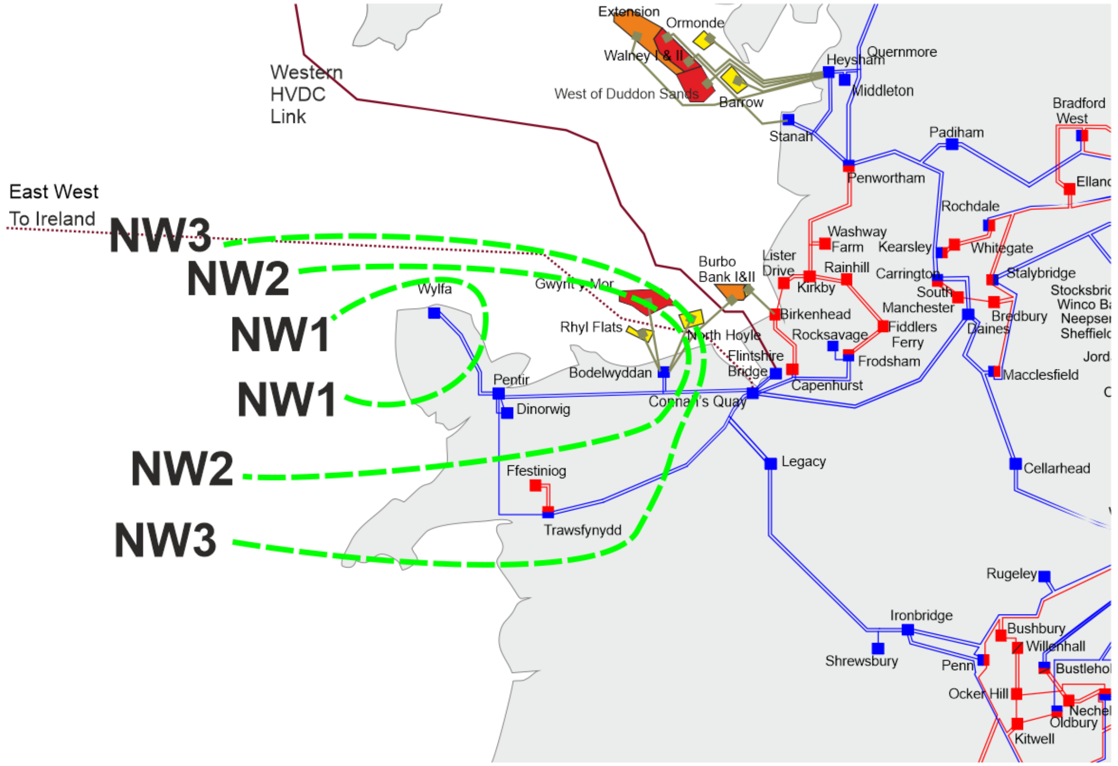
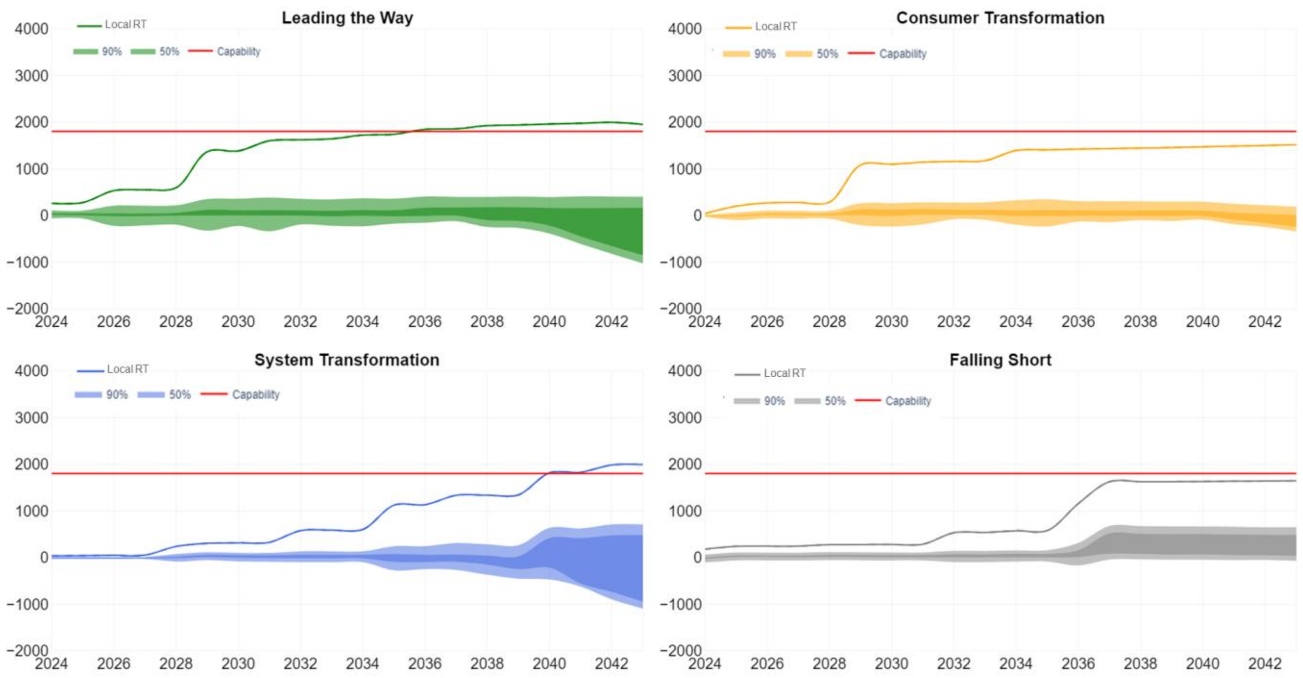
Boundary NW1 - Anglesey

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. However, there is some renewable and storage plant. Due to this low generation behind the boundary - it is expected within the later years for NW1 to become predominantly importing.

The capability line (in red) is based on the ETYS base (year 1) transfer capability, using the 2022 FES and ETYS data as inputs. The 50%, 90% and Economy RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

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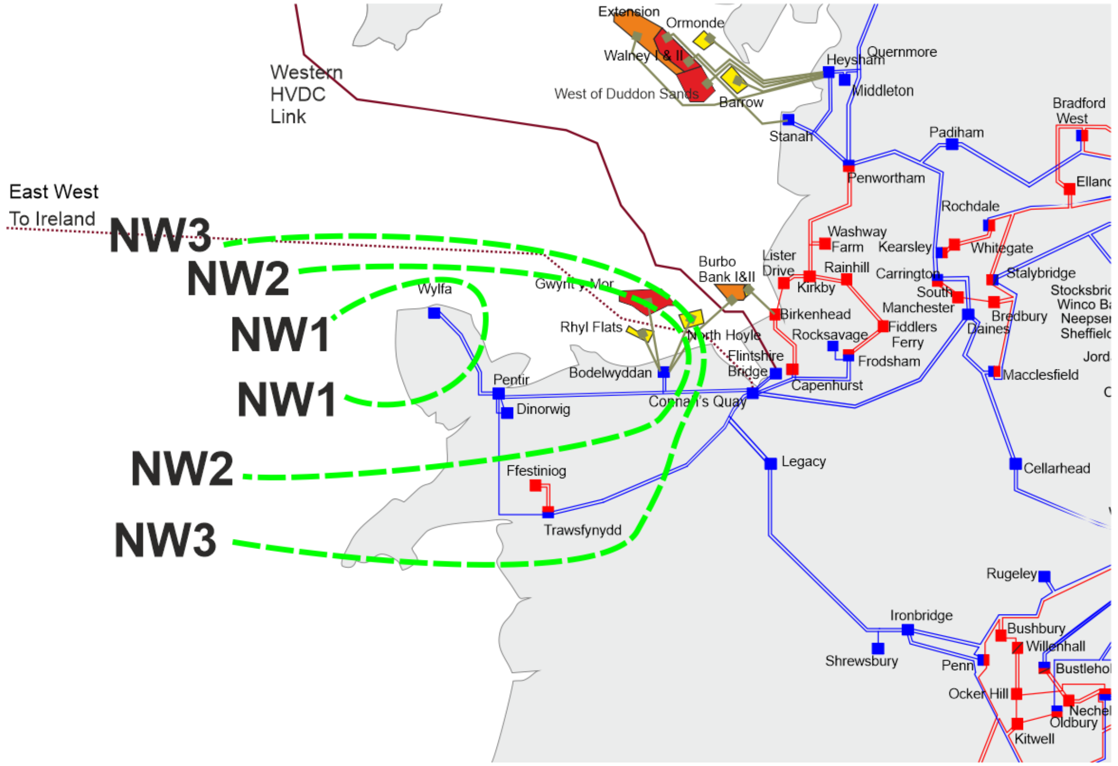
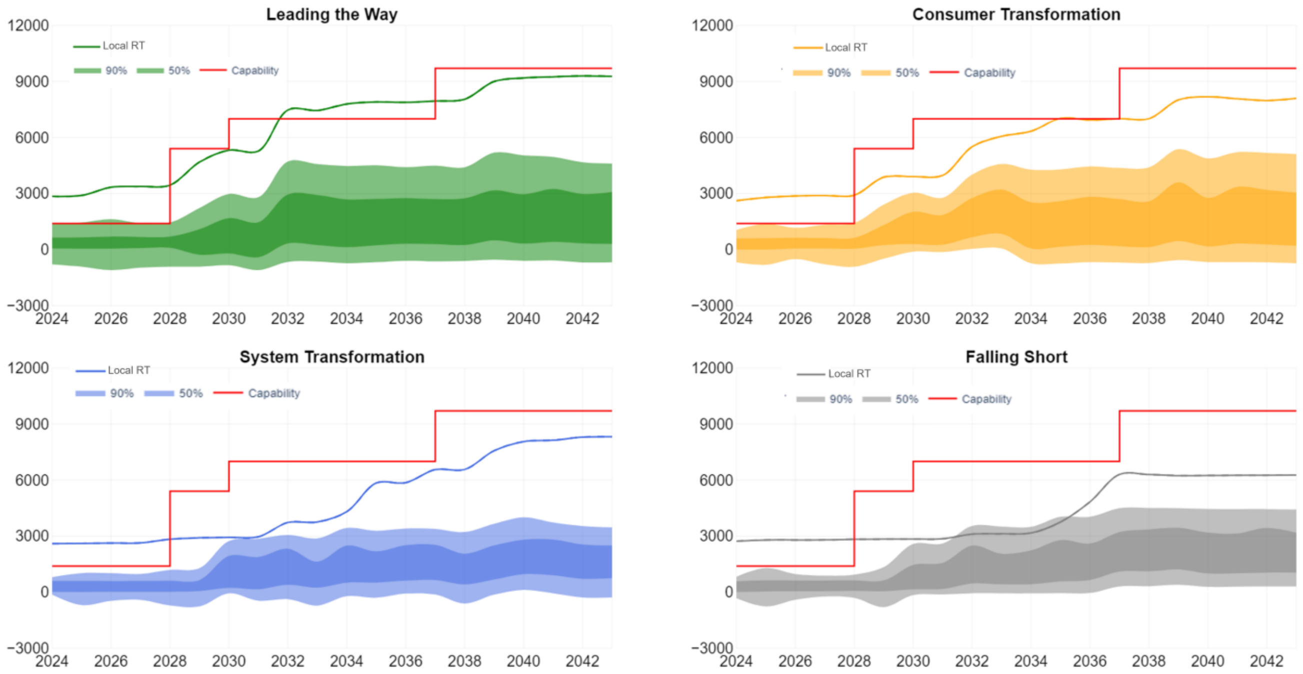
Boundary NW2 – Anglesey and Caernarvonshire

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



Currently, there is not a significant amount of generation behind NW2, mainly pumped storage and offshore wind projects.

Expected transfers across NW2 post-2029 have decreased since the ETYS 2022 publication due to changes in expected landing points for new offshore wind generation.



The capability line (in red) is based on the recommendations from the Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90% and Economy RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

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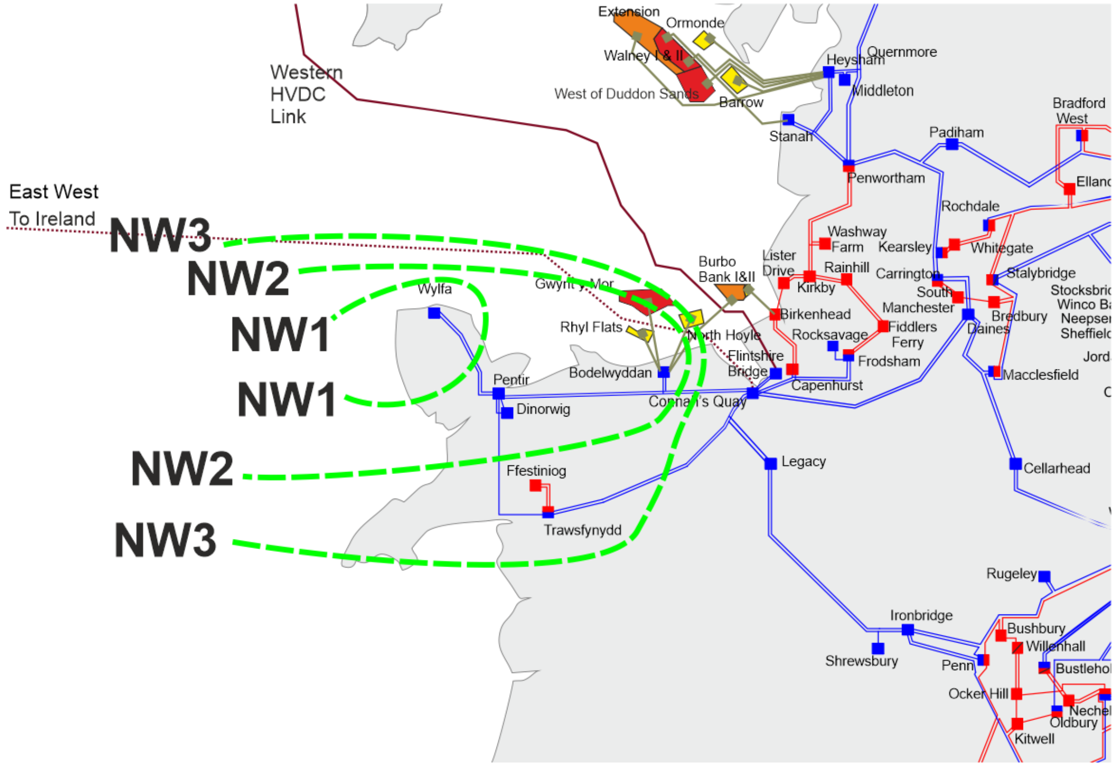
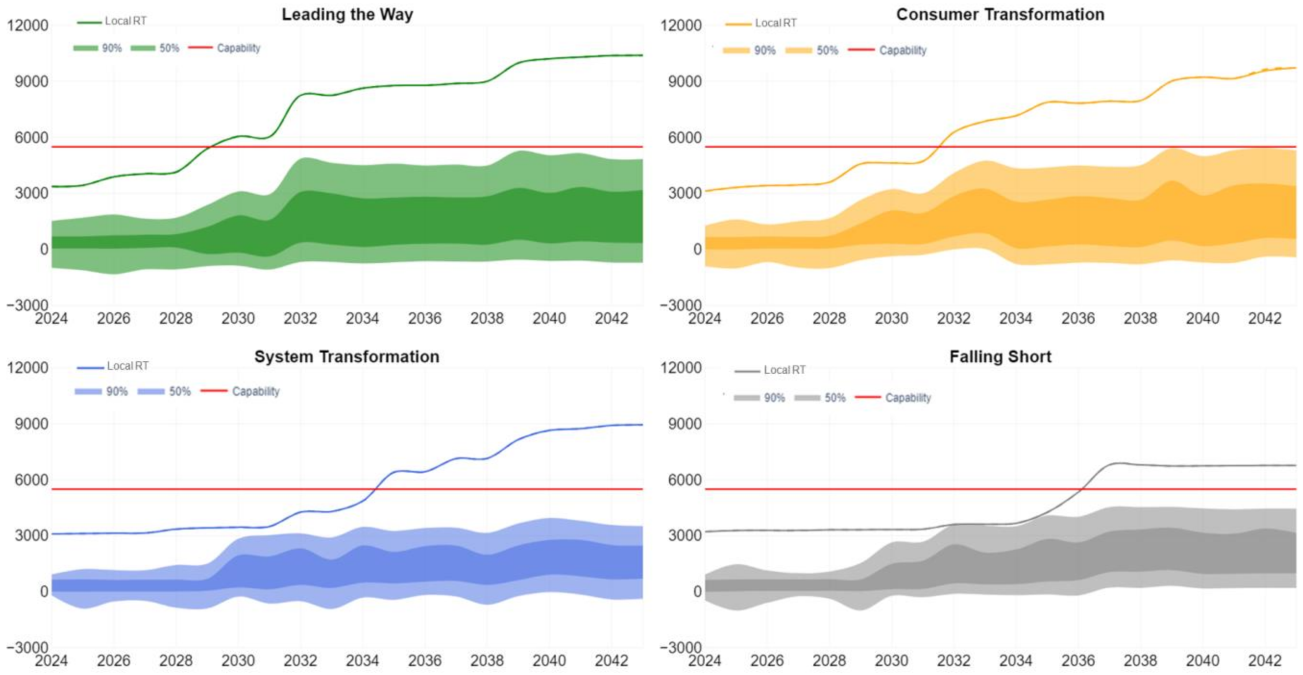
NW3 – Anglesey, Caernarvonshire and Merionethshire

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



The profile of NW3 is largely similar to that of NW2, with no significant volumes of generation currently anticipated to connect at Ffestiniog or Trawsfynydd substations in the future.



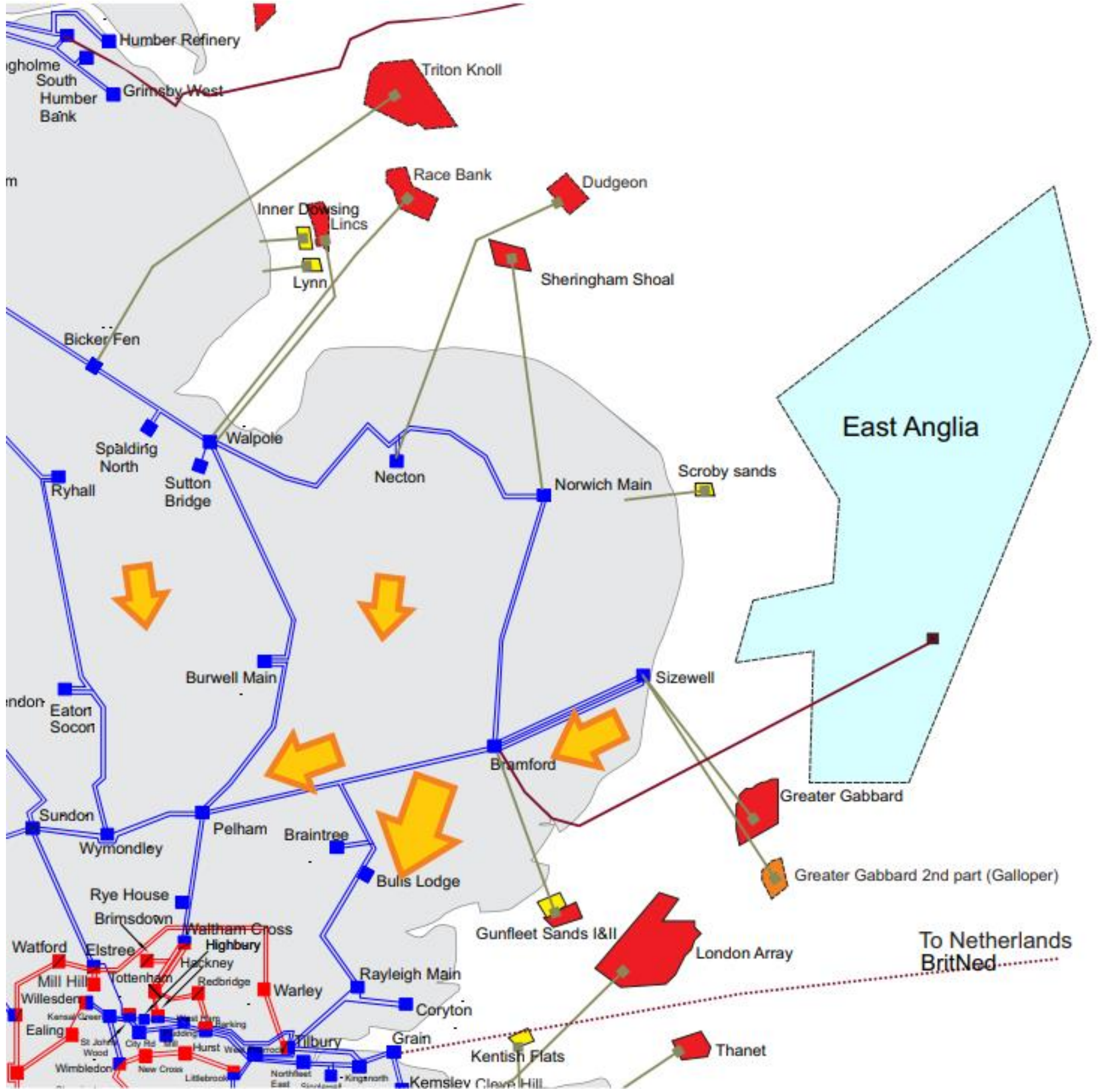
The capability line (in red) is based on the ETYS base (year 1) transfer capability, using the 2022 FES and ETYS data as inputs. The 50%, 90% and Economy RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

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 2033, 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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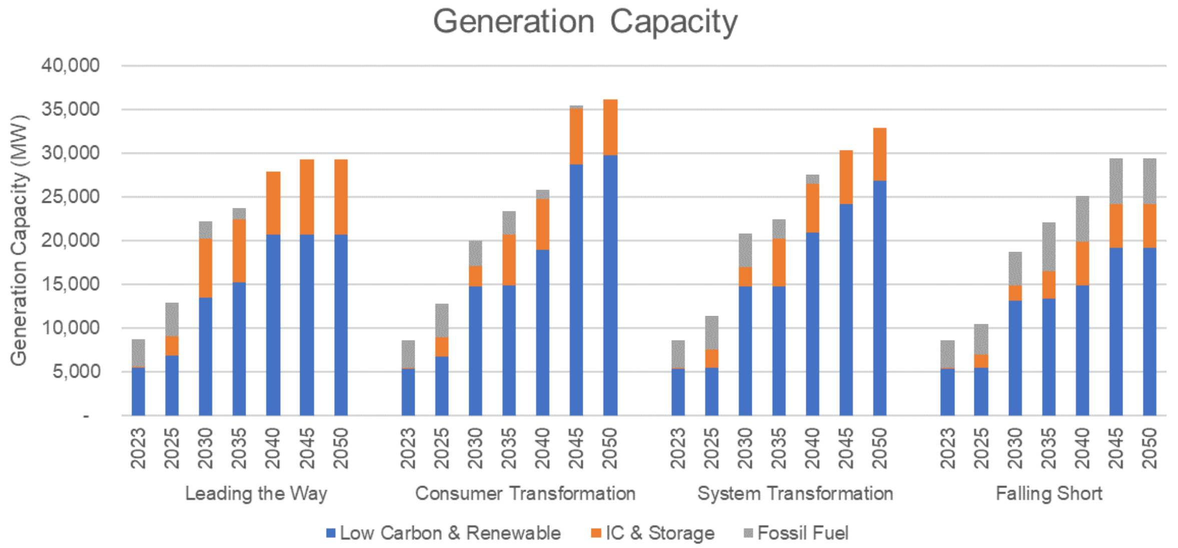
Regional thermal drivers – East of England

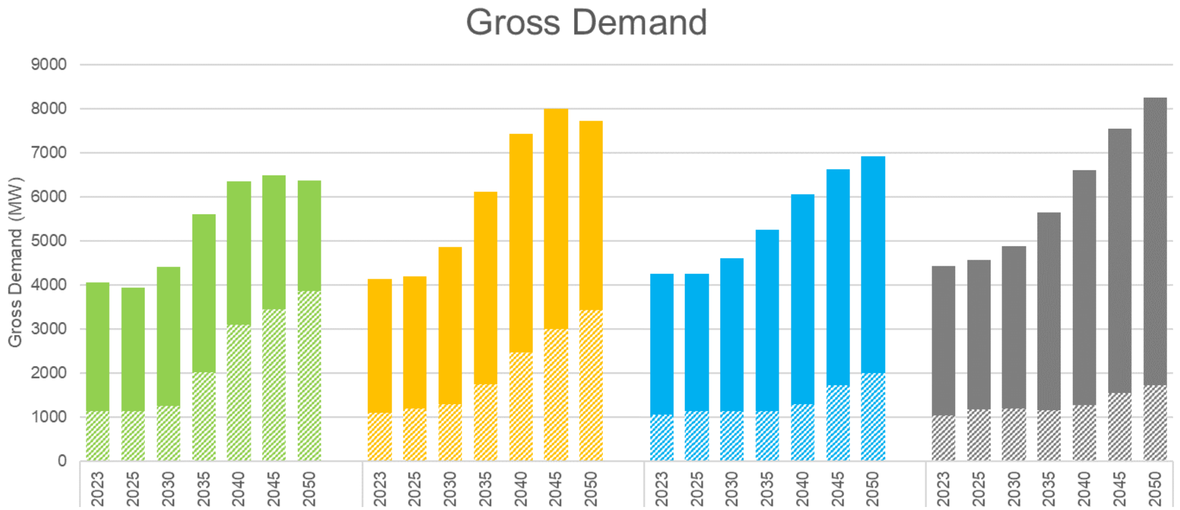
The future energy scenarios highlight that growth in low-carbon and renewable generation will primarily drive the system needs in this region. Peak gross demand in the East of England region is expected to remain steady with limited growth over the same timeframe.

Over the next decade, this region could see growth in generation primarily from low carbon and renewable generation. From 2030, there could be further interconnector and storage connections in this region. Demand is steady in the short term with growth expected from 2030 out to 2050. As the total generation will likely exceed the local demand, this region will be a net power exporter.

There is work ongoing to coordinate the network infrastructure in this region to facilitate greater coordination of offshore generation and interconnectors connecting into this region. This includes the Government's Offshore Coordination Support Scheme (OCSS), and the Holistic Network Design Follow up Exercise (HNDFUE) led by the ESO.

In order to manage the constraints across the East Coast boundaries, the ESO is also proactively developing a commercial non-build solution, the EC5 Constraint Management Intertrip Service (CMIS). This will contract with generators in the region to provide a more economical method of managing constraints than actions through the balancing mechanism. This follows the success of the CMIS now in operation across the B6 boundary.





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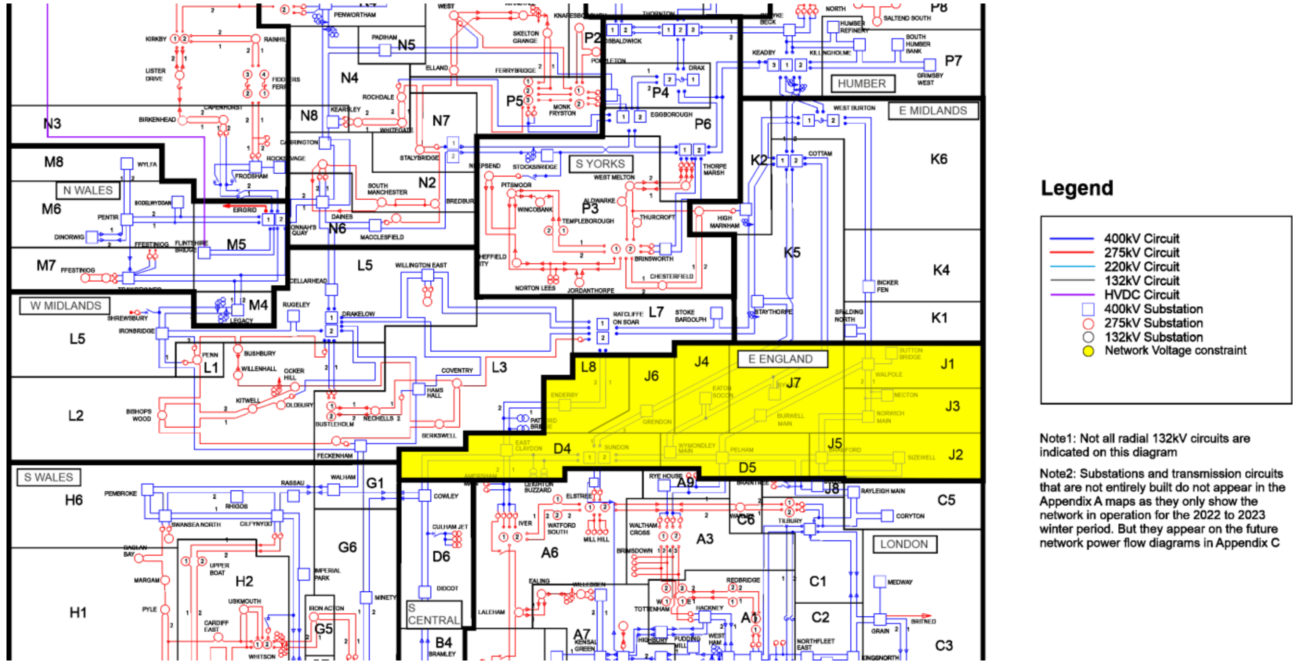
Regional voltage drivers – East of England

This region has seen increasing voltage control costs over the last few years, due to reliance on a limited choice of generation.

Over the next 10 years, there could be some generation closures which could result in high voltage during low demand periods which would be exacerbated during some outages or circuit trips in the area. Two synchronous compensators are planned from year 2025 and two more from 2026 in this region as part of Stability Pathfinder Phase 3 project.

In periods of high north to south flows, the East of England could experience low voltages especially with generators on outage or restricted reactive capability. Also, with exporting south coast interconnectors and large power flows from North to South passing through East Anglia, voltage depression issues could occur in this region.

The map to the right shows the East of England identified through our voltage screening process.



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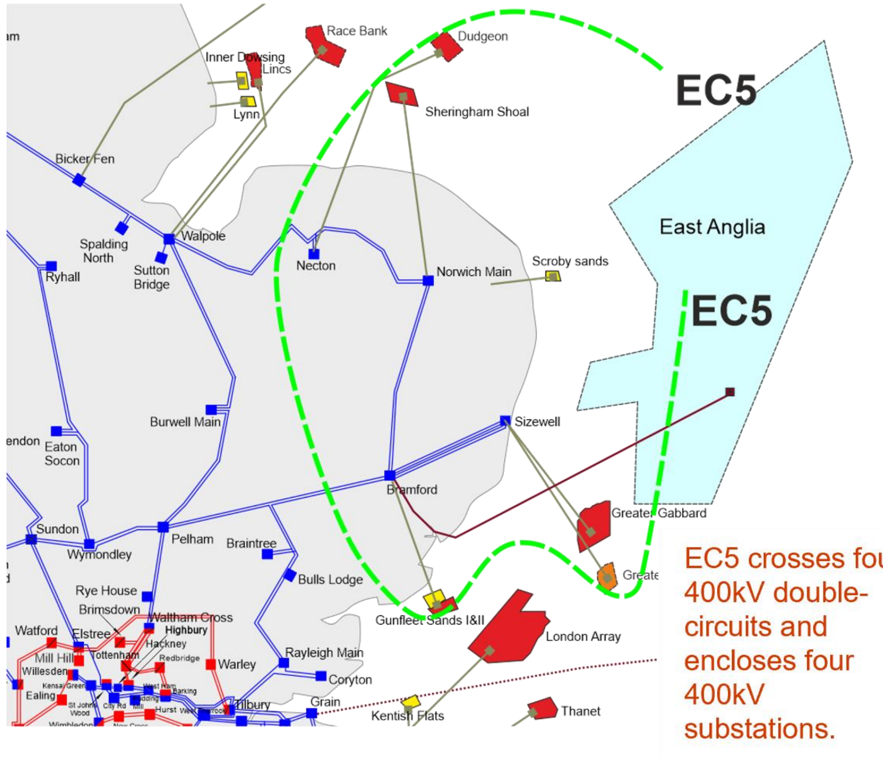
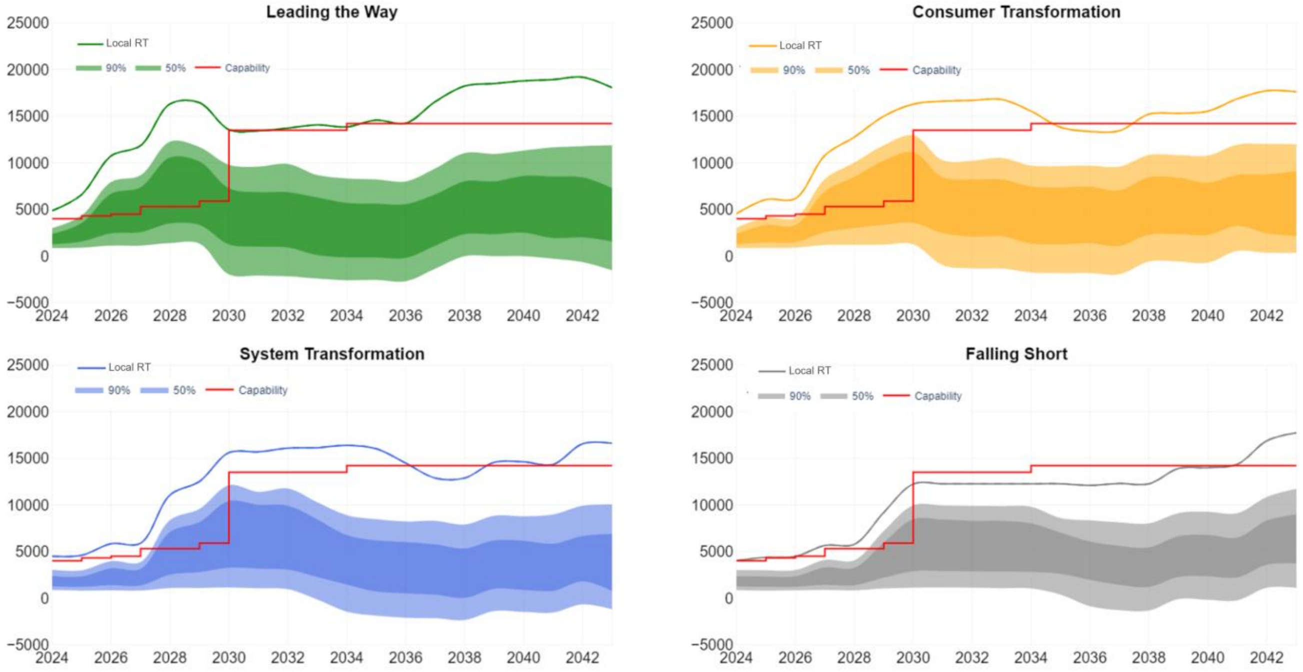
Boundary EC5 – East Anglia

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



EC5 crosses four 400kV double-circuits and encloses four 400kV substations.



There are several offshore wind projects connecting into the region.

The growth in low carbon and renewable generation 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.

Work is ongoing to coordinate the network infrastructure in this region to facilitate greater coordination of generation connecting into this region.

The capability line (in red) is based on the recommendations from the Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

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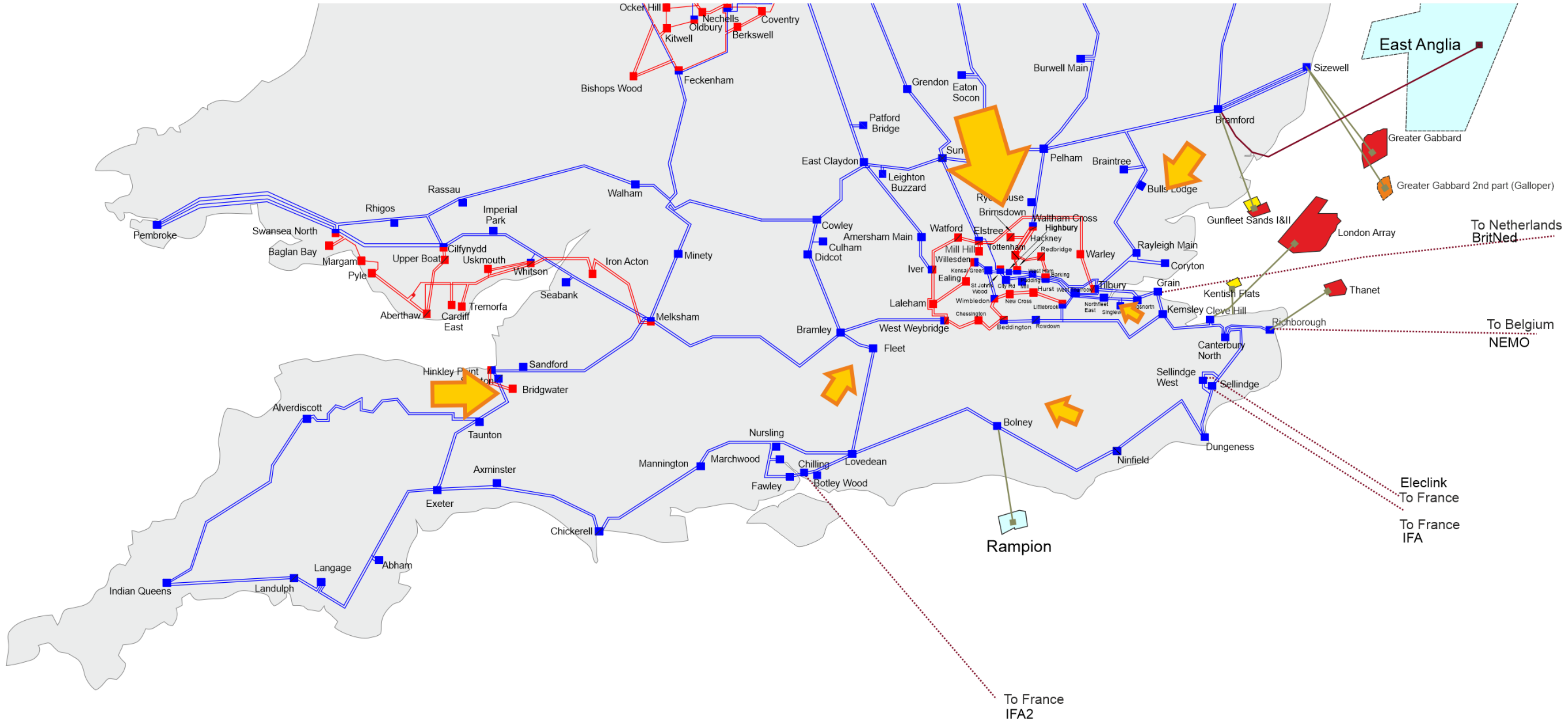
South Wales and South of England

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 2033, 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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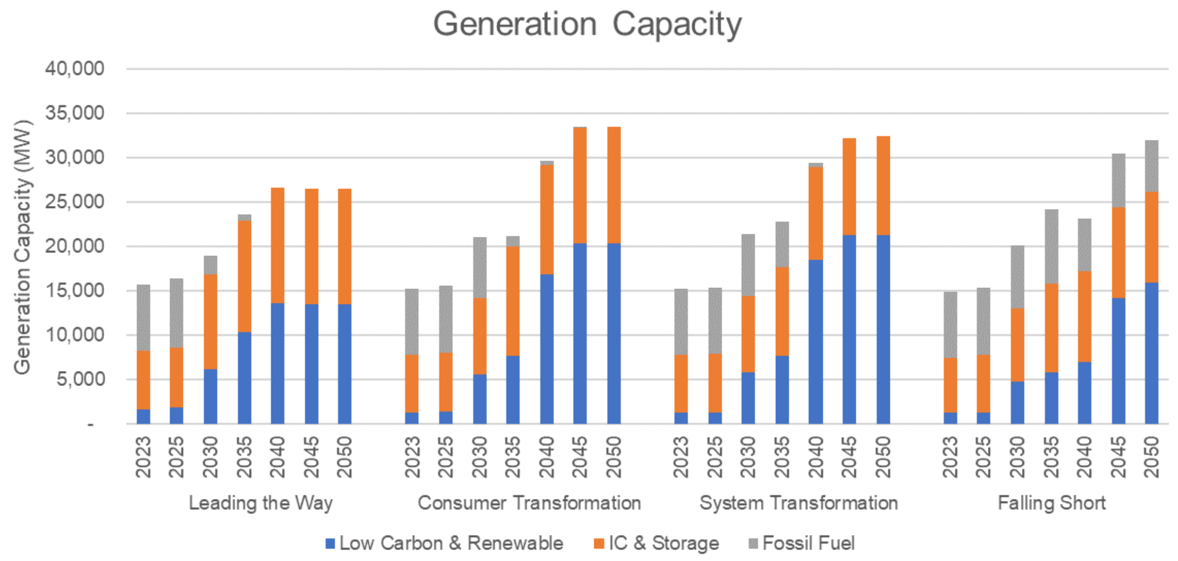
Regional thermal drivers – South Wales & South England

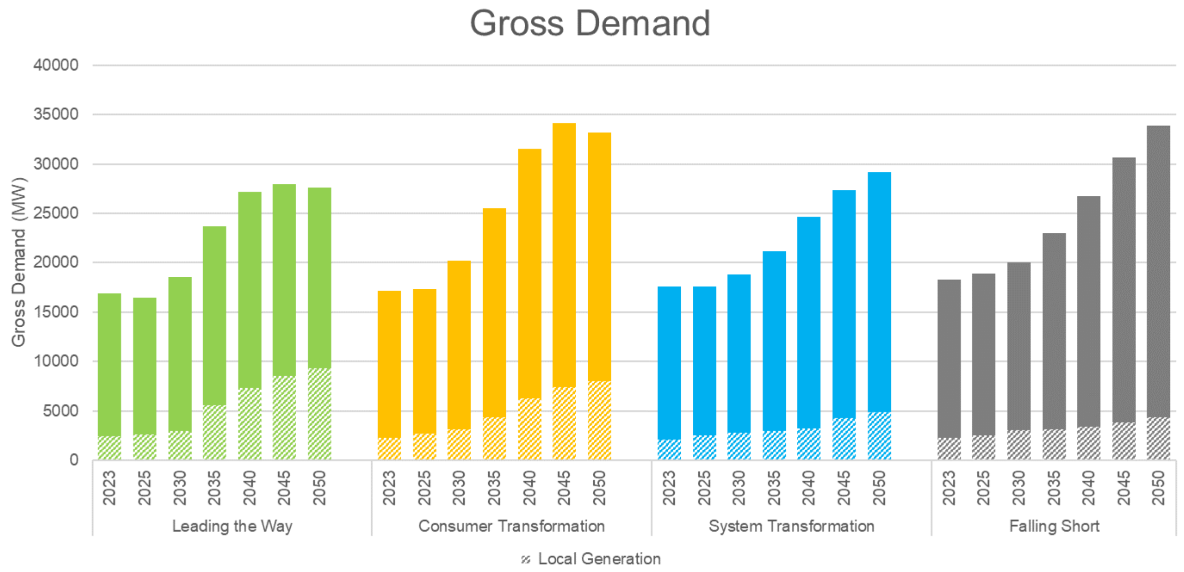
European interconnector developments along the south coast could potentially drive very high circuit flows causing circuit overloads, voltage management and stability issues.

The Leading the Way scenario suggests that a total of over 10GW of interconnectors and energy storage capacity may connect in the south by 2030, up from about 6.5GW to date. Interconnectors and storage are bi-directional, meaning that the south could see their capacity provide almost 10GW power injection or 10GW increased demand, placing a very heavy burden on the transmission network.

Most interconnectors will be connected south of boundary SC1 so the impact will be discussed later in the chapter in the SC1, SC1.5 and SC2 requirements. With future additional interconnector connections, in the south region it will be challenging to support all interconnectors importing or exporting simultaneously without network reinforcement. 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.

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.





Regional voltage drivers – South Wales & South England

Over the next 10 years, we could see some generation closures within this region however, new generators are also planned to connect in this region.

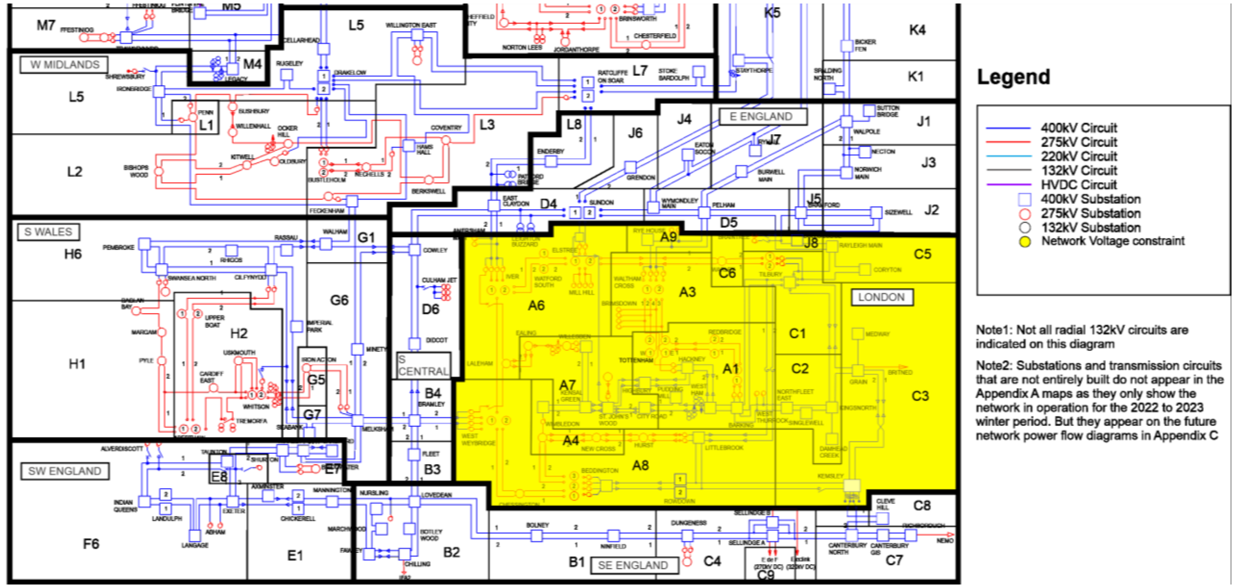
The transmission network in London mainly comprises of cable circuits. Central London experiences high voltage during periods of low demand due to low line loading. This is primarily managed by switching out cable circuits to regulate the voltage. This region also relies on generation both locally and from the nearby south-east region to manage the voltage.

Where available, we always utilise existing reactive assets such as reactors to manage the voltage, however some of these reactive assets are on long term fault outage and are unable to be utilised by the control room. The ESO is working closely with the Transmission Owners to get the faulty assets repaired and returned to service as soon as possible.

The South of England region has several interconnectors and during periods of large interconnector imports from the continent, faults in this area could result in low voltage.

The timing of generation closures or connections could result in some system needs in certain years. We expect to see three synchronous compensators connecting in South East of England from 2025 as part of Stability Pathfinder Phase 3 project that could also help support voltage.

The map to the right shows London identified through our voltage screening process.



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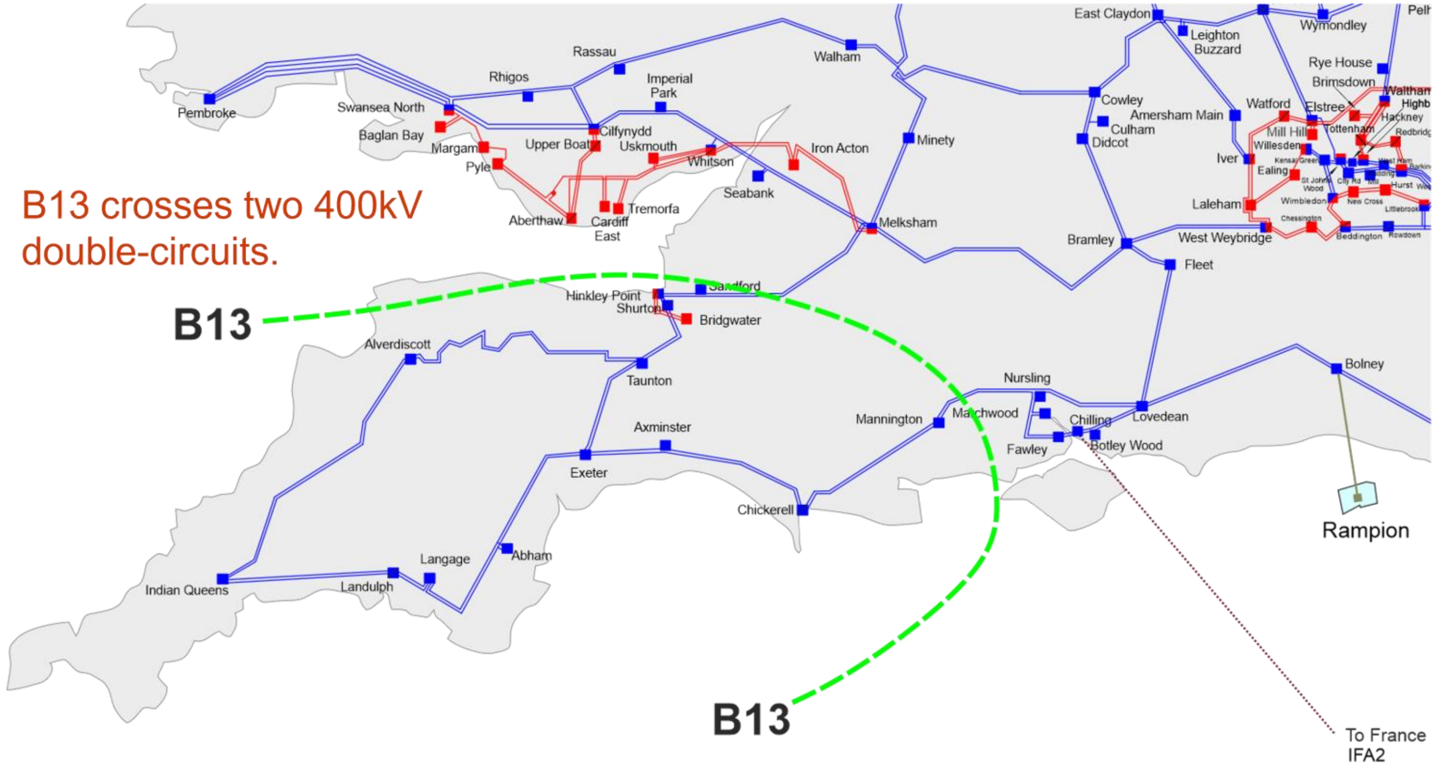
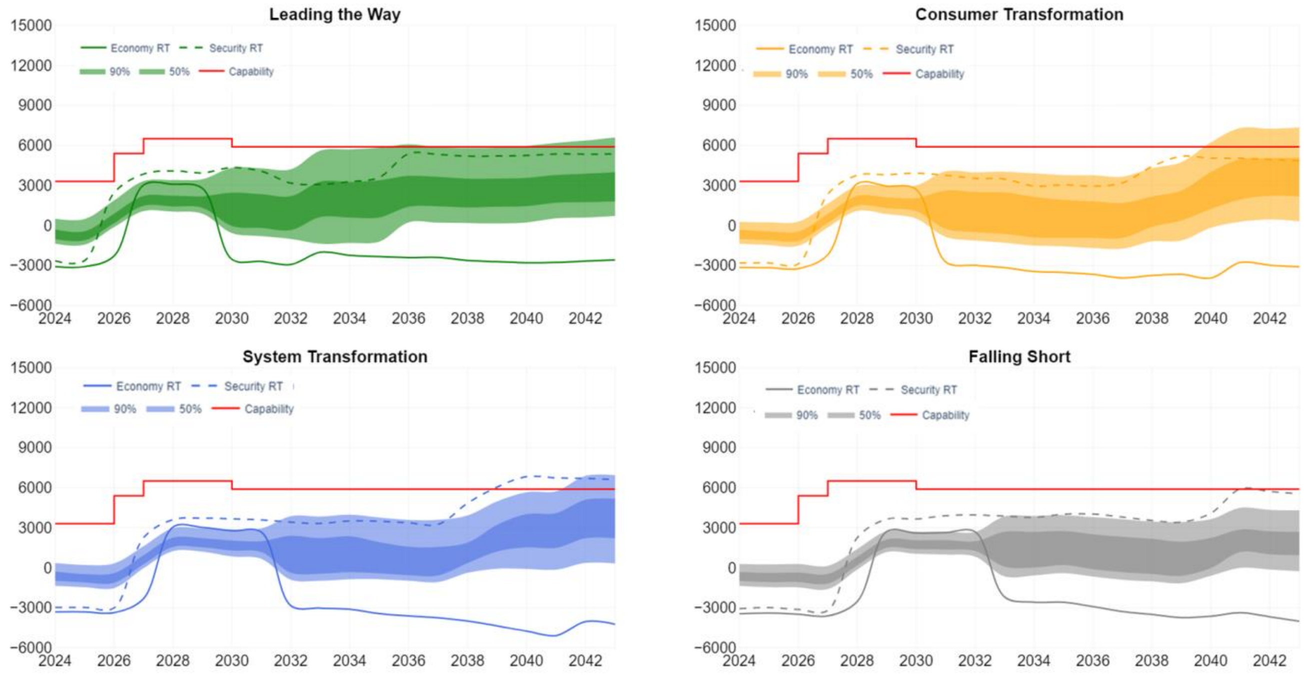
Boundary B13 – South West

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.





Until new generation or interconnectors connect there is very little variation in boundary requirements for B13, 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 Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

The 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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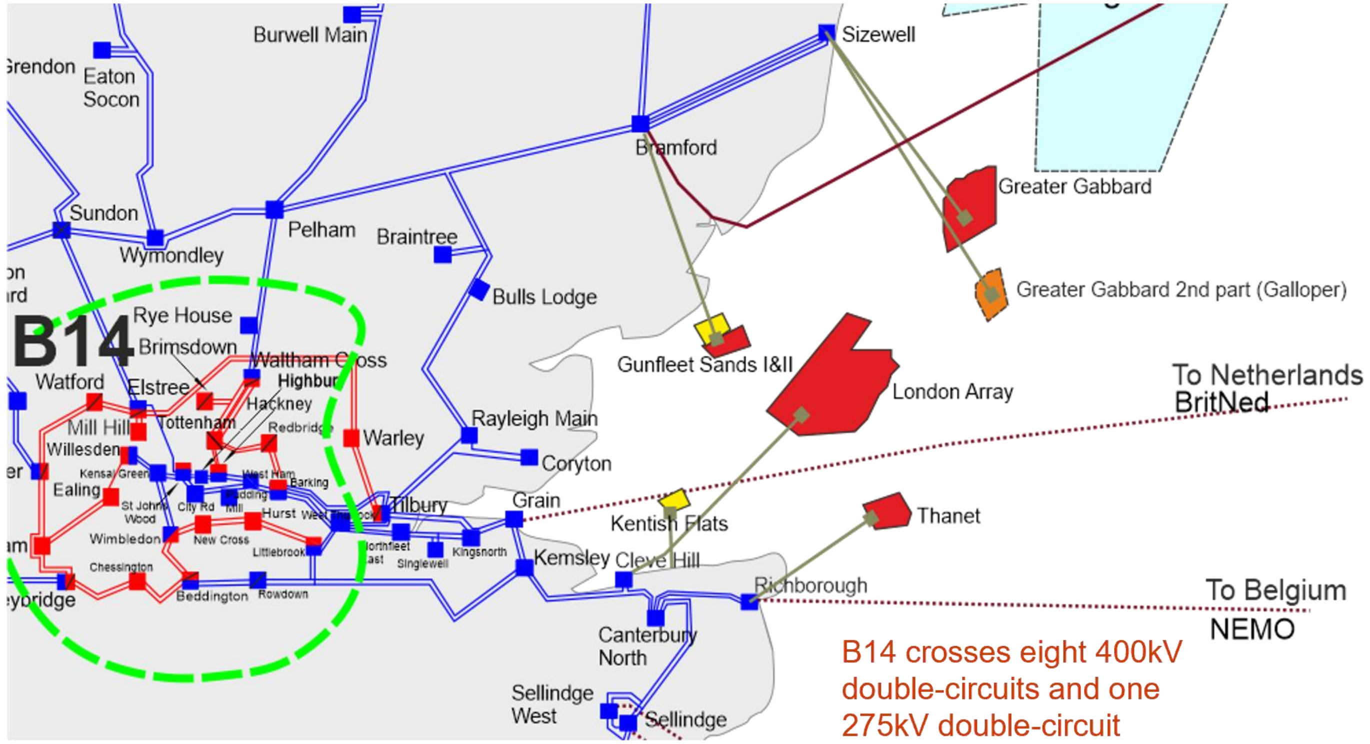
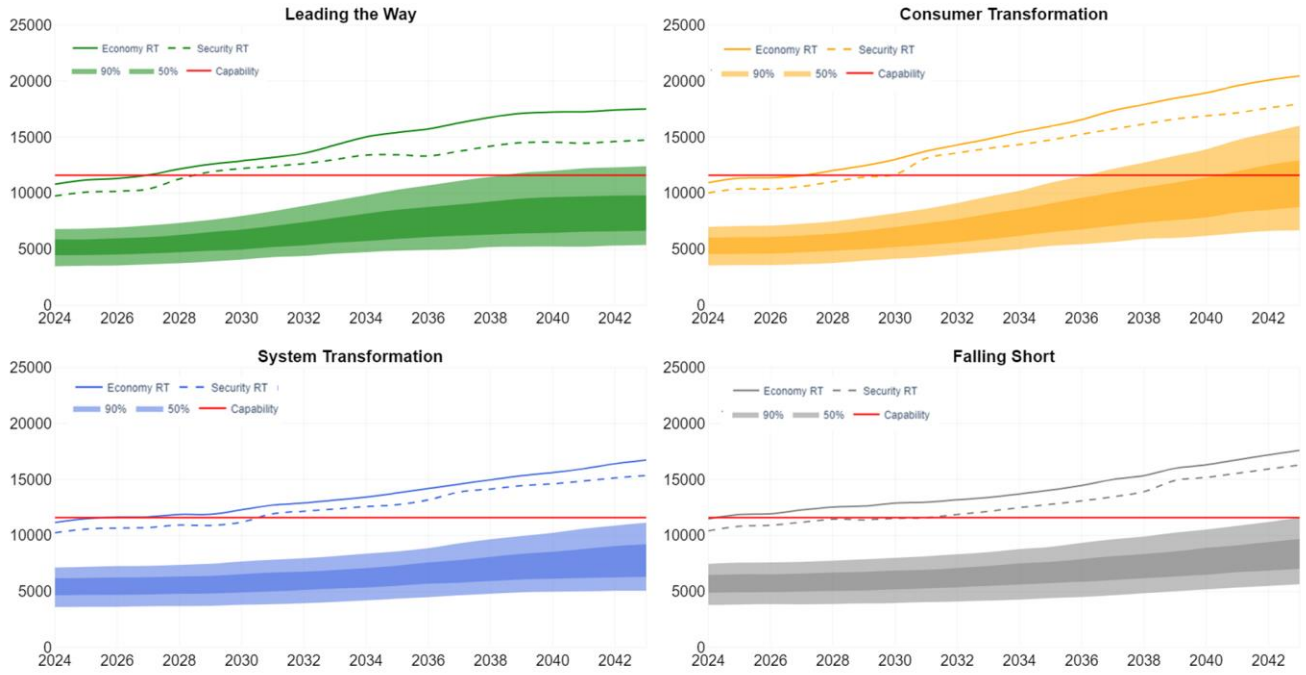
Boundary B14 – London

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.

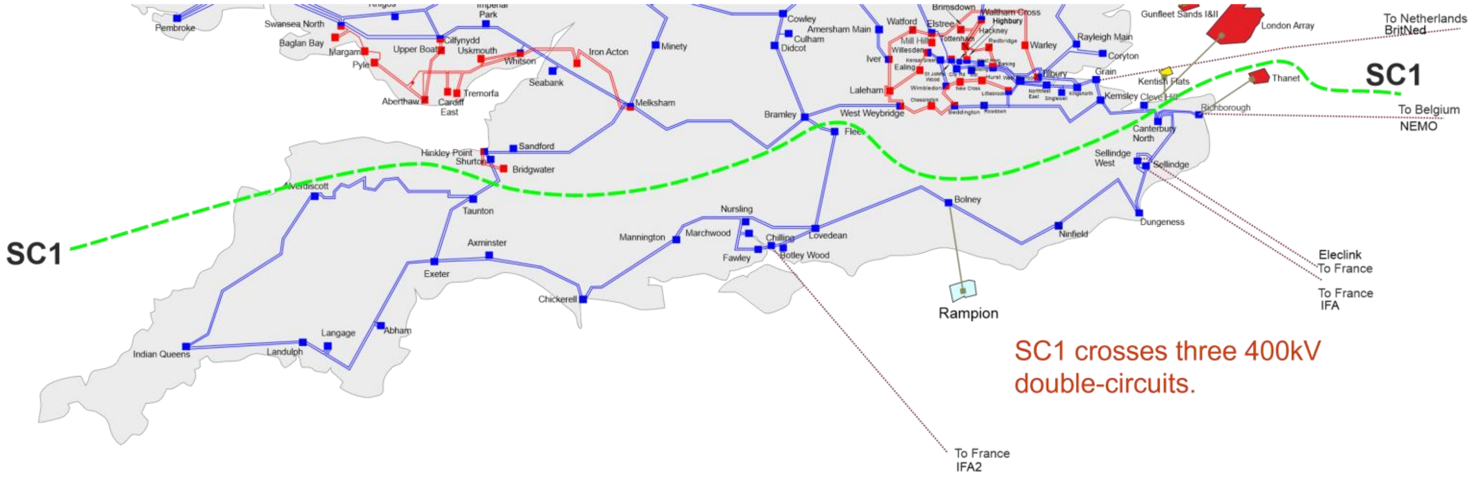
The capability line (in red) is based on the recommendations from the NOA Refresh 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

* ETYS Transfer capability calculated using the 2021 FES data

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.

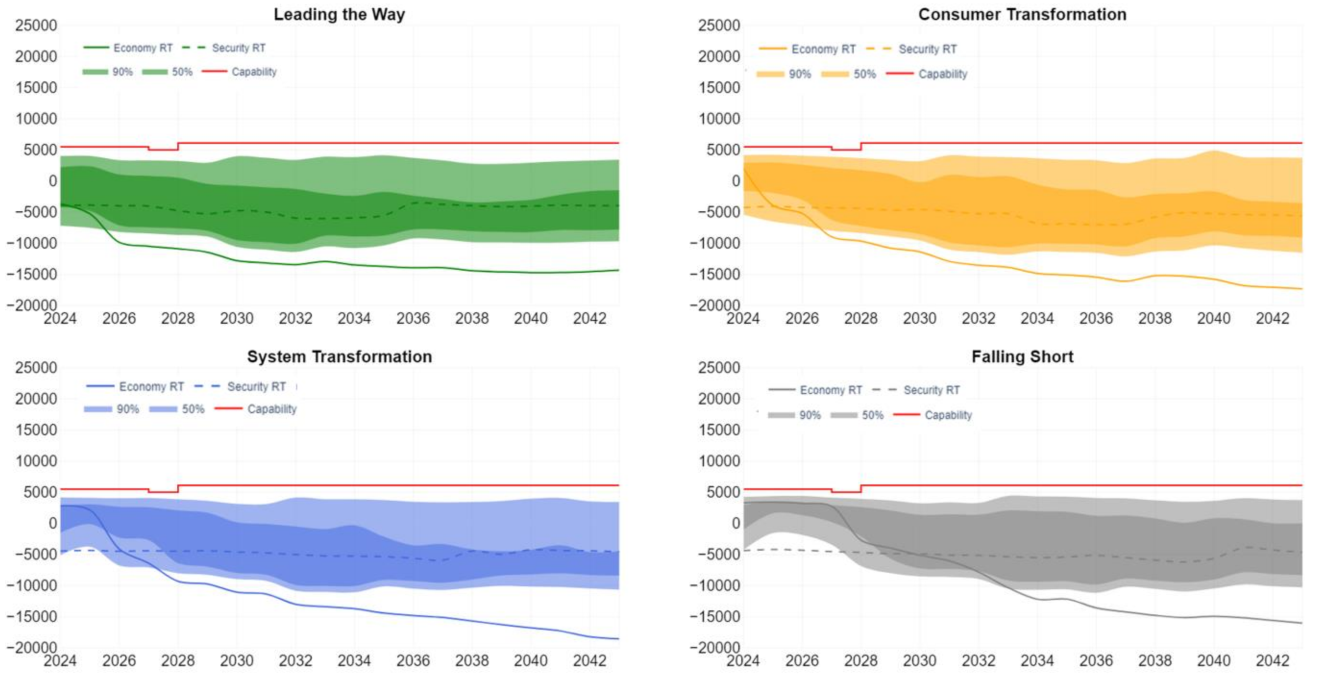
Interconnector activity can significantly influence the boundary power flow. The current interconnectors to France, the Netherlands and Belgium connect at Sellindge, Grain and Richborough respectively.

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 – 2028 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 Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

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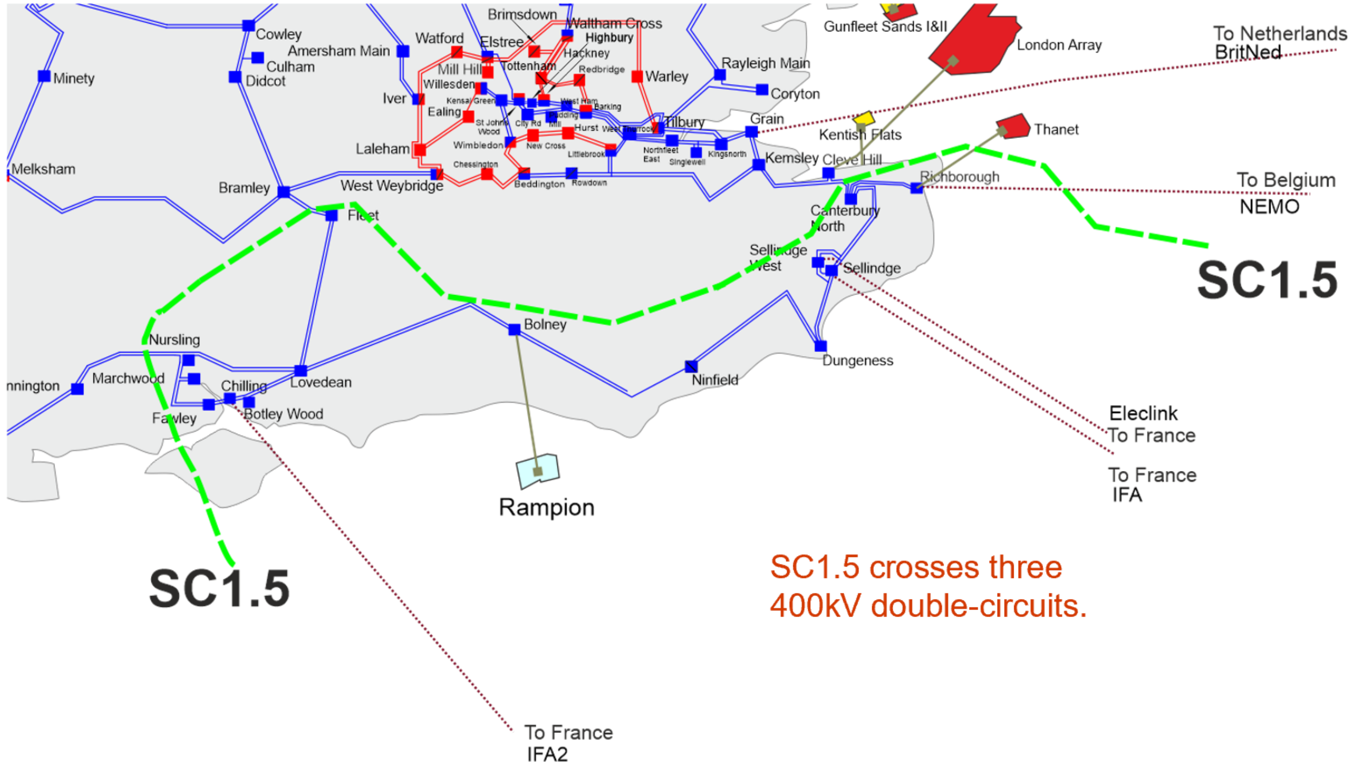
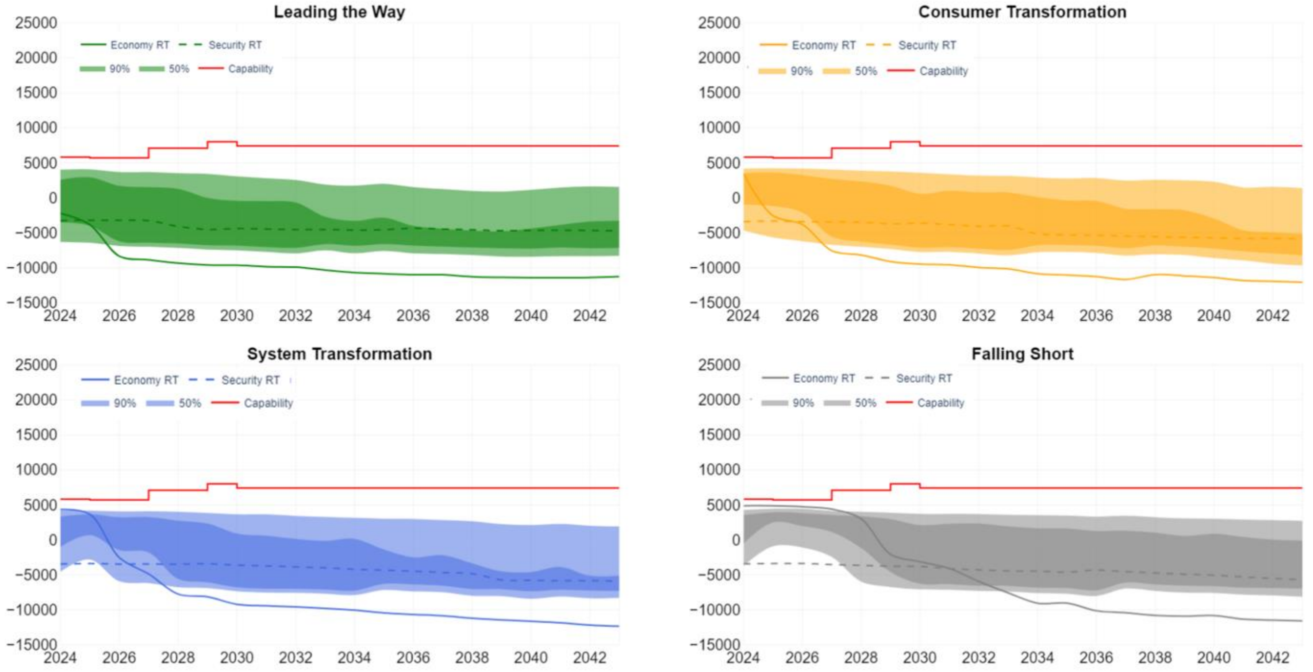
Boundary SC1.5 – South Coast

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. 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 Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

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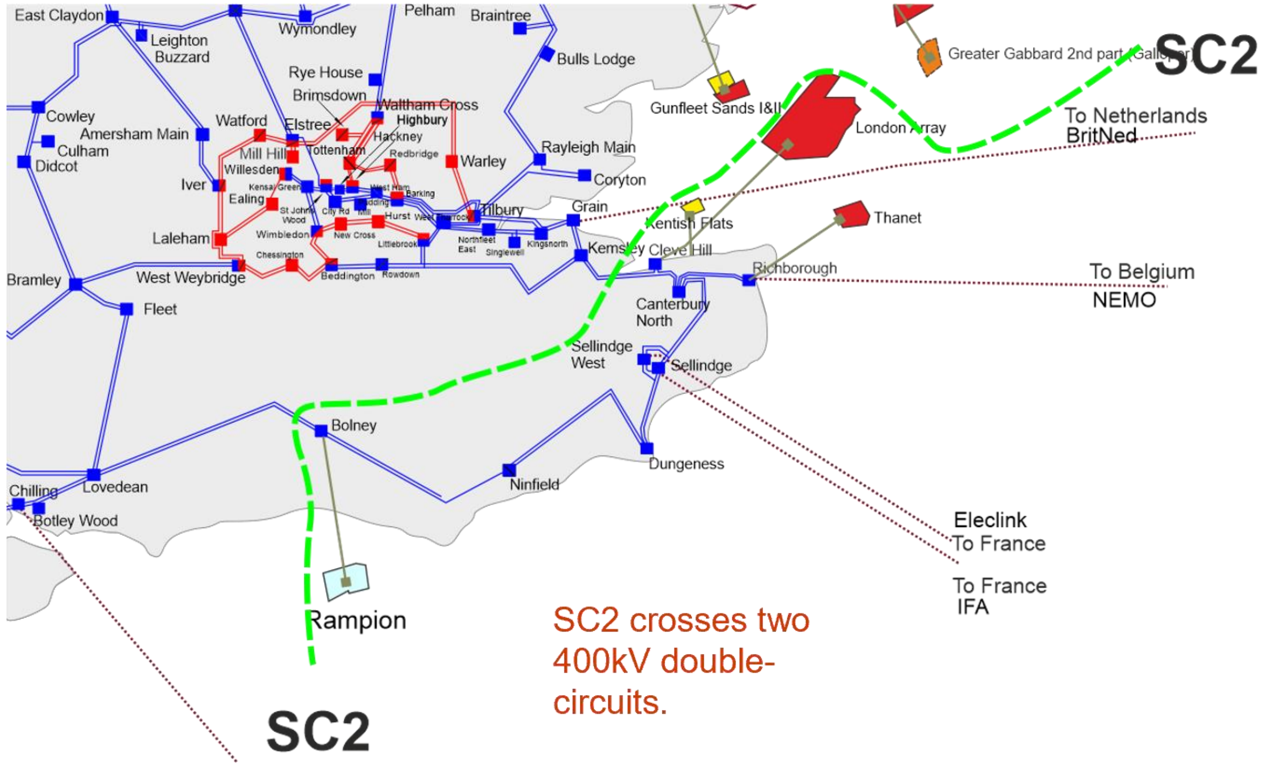
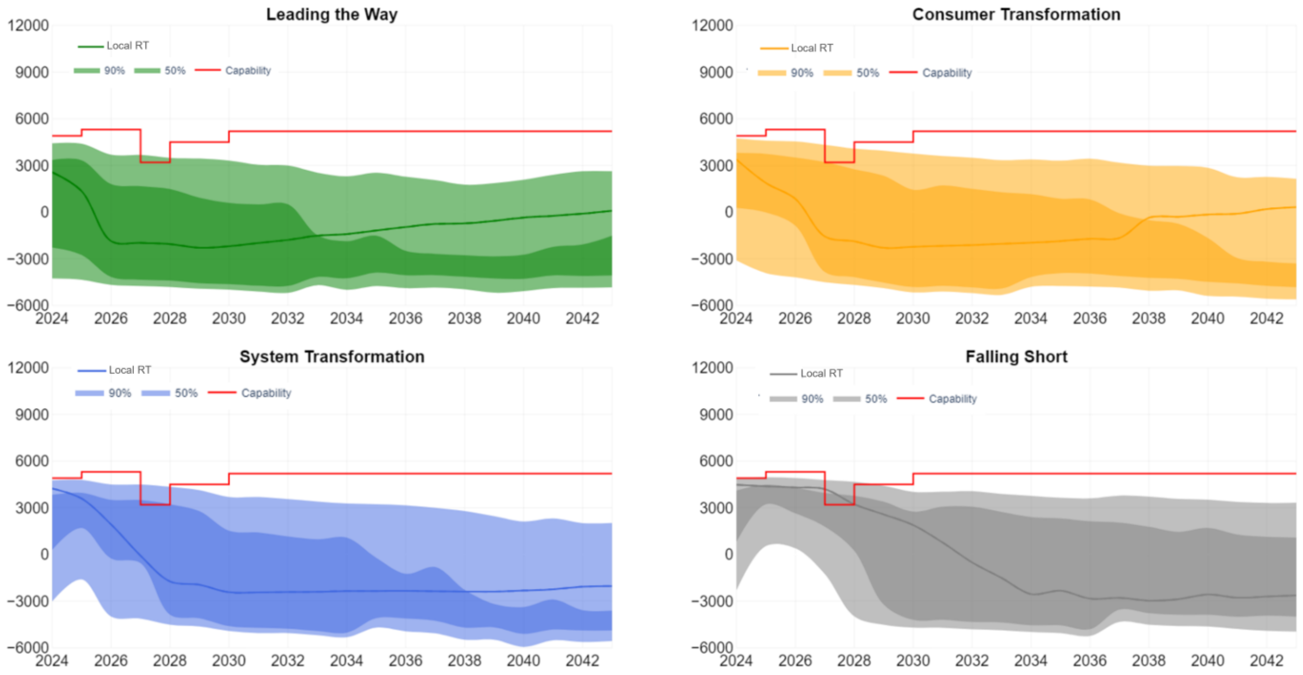
Boundary SC2 – South Coast

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 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 Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

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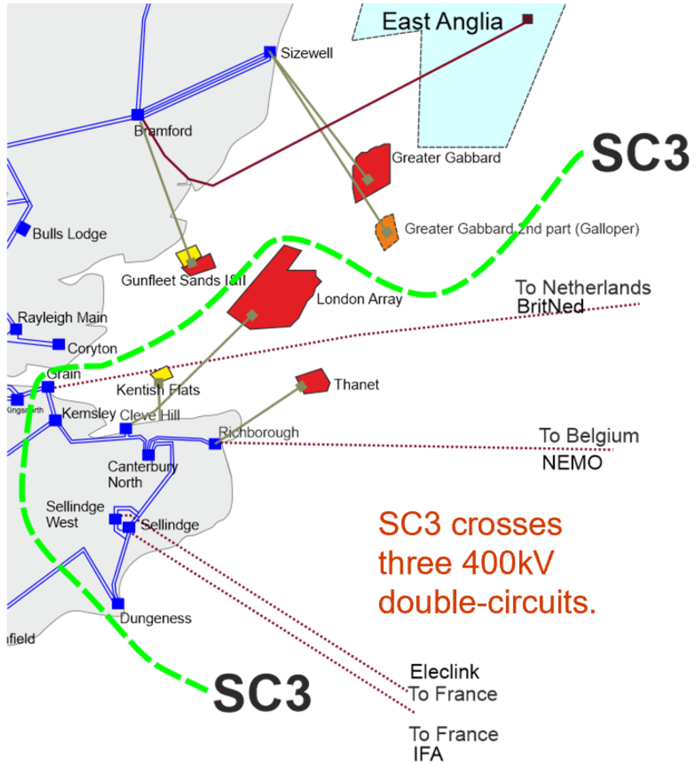
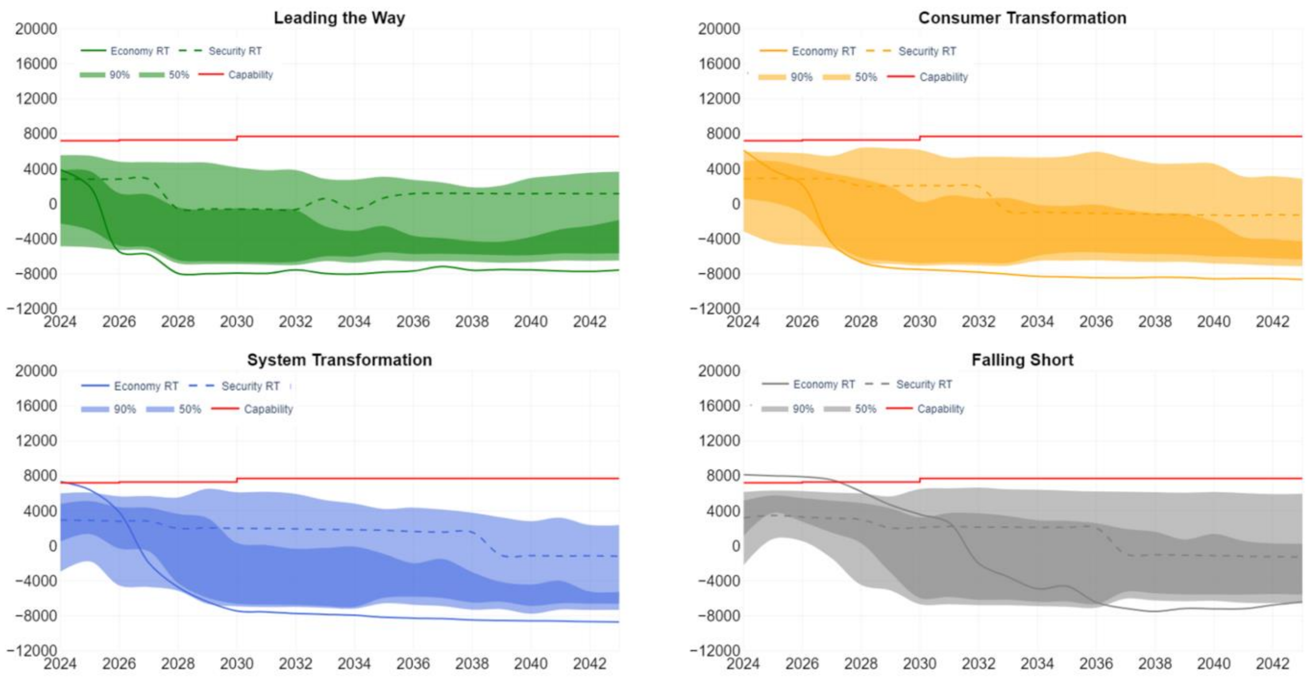
Boundary SC3 – South Coast

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 Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

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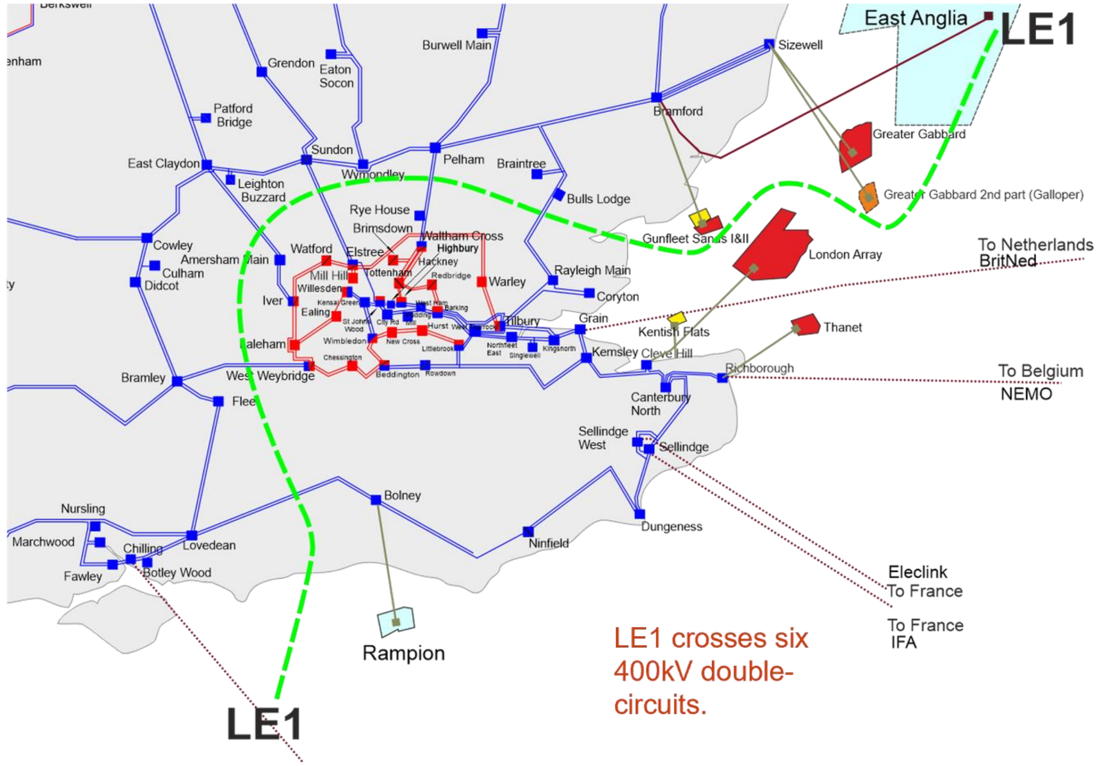
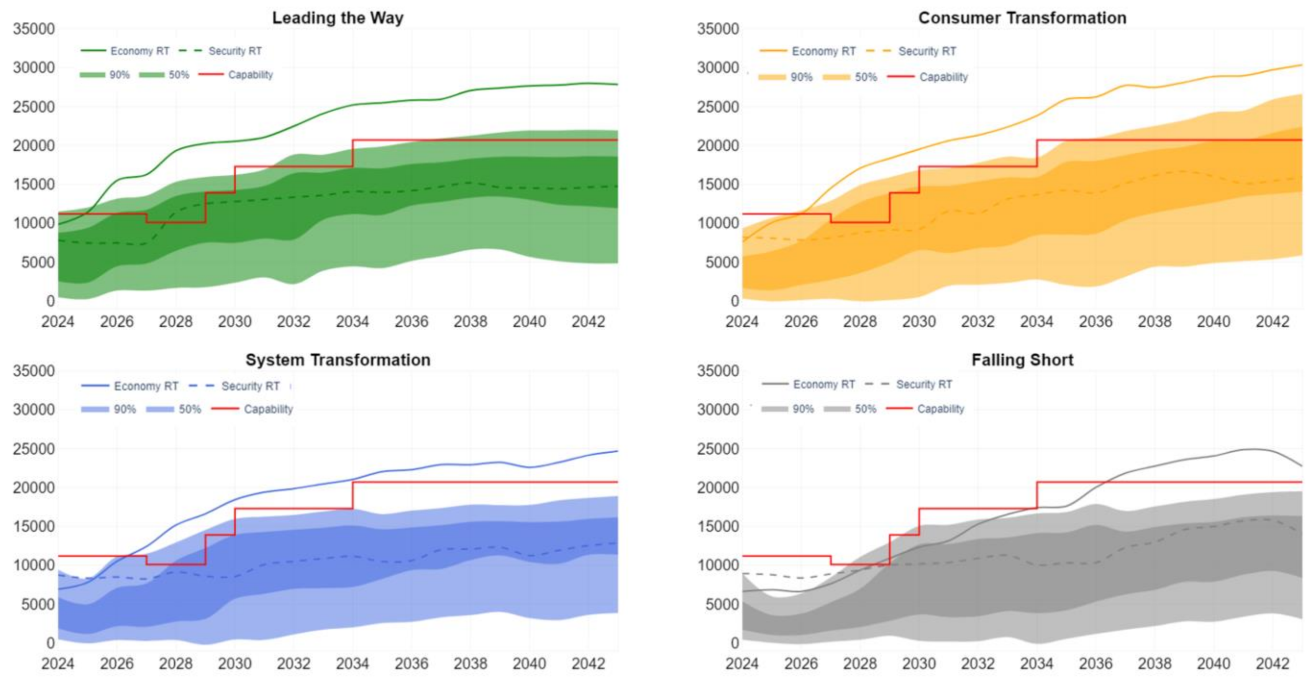
Boundary LE1 – South East

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.

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.

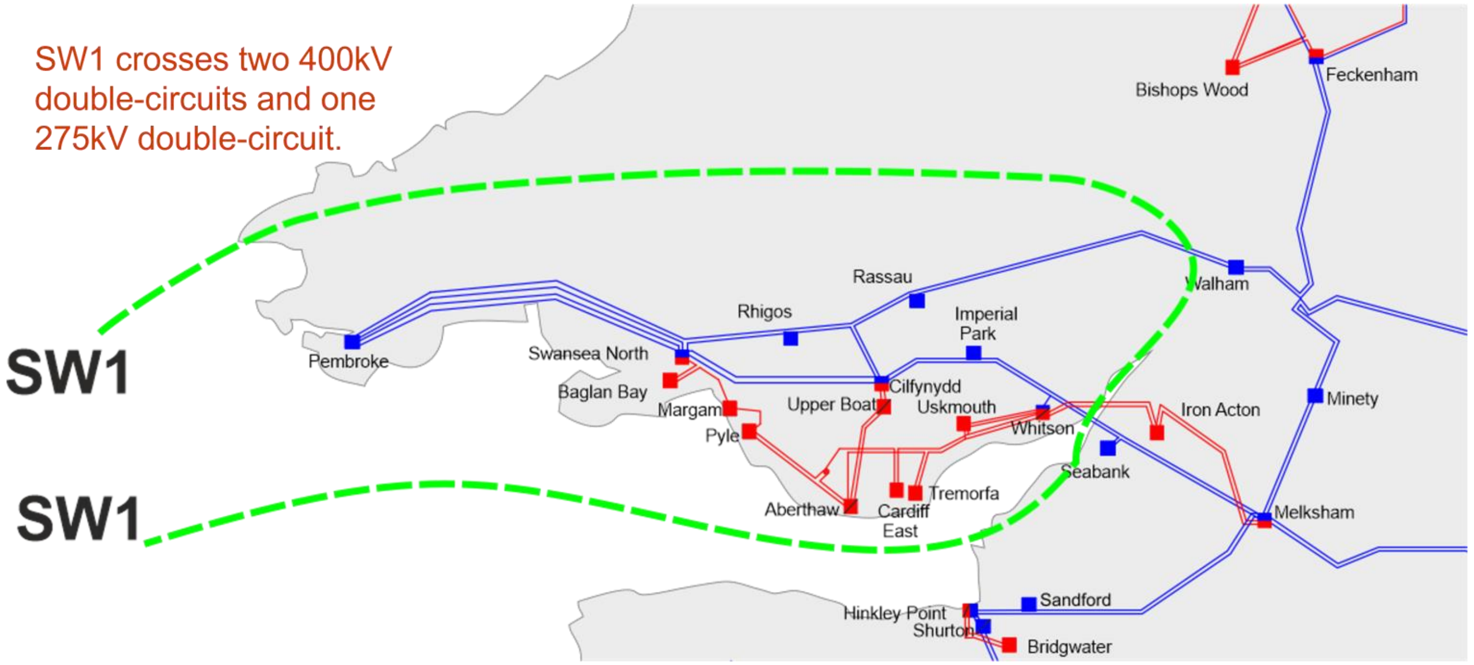
Across all four scenarios in the FES, the SQSS economy required transfer grows beyond existing boundary capability from 2023 and the expected power flows are less than the required transfer and the uncertainty of interconnector activity can be seen in the wide range of the boundary flows.

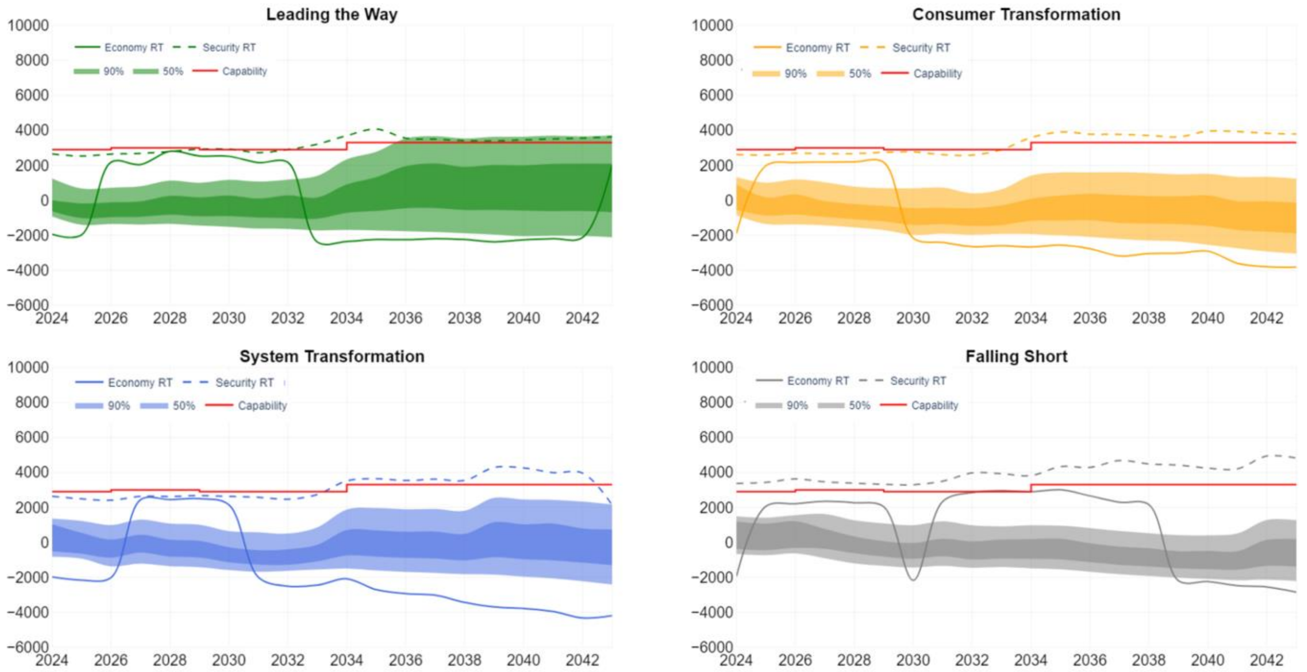
The boundary capability is limited to 9.6GW due to a thermal constraint on the Elstree – Sundon 400kV circuit

ETYS 2023 / South Wales and South of England 60

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 renewable generation and fossil fuel generation which are expected to close.

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 Beyond 2030 report which uses the 2023 FES and ETYS data as inputs. The 50%, 90%, Economy RT and Security RT lines are based on FES 2023. The ETYS and NOA methodologies for this boundary are different and can result in different transfer capabilities.

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

ETYS 2023 / South Wales and South of England 61

Our year-round system needs

ESO

Year-round thermal analysis

Where are we now?

We have continued to develop our year-round thermal tool, POUYA (Power Uncertainty Year-round Analyser). It allows us to capture the power transfer limitations on the GB NETS not only during the winter but also across the other seasons during the year, driven by the seasonal characteristics of generation, demand and considering circuit ratings appropriate for the different seasons.

Expanding our view of system needs not only across an entire year but at a circuit level, will become increasingly important as our generation and demand mix changes to meet our net zero targets.

Further work is ongoing to analyse future years and we expect to gain further insights of specific limitations across different years. This will not only allow us to identify and communicate targeted system needs but will also enable us to further understand where system needs are driven by credible scenarios that we have not considered previously due to our single snapshot analysis.

We continue to 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

Building on the examples of year-round analysis that we shared in ETYS 2022, this year we have prepared analysis for a range of network boundaries across the NETS. Our analysis has been performed using generation, demand, and network backgrounds from the Year 2 ETYS 2023 model (representative of the 2024/25 period).

Using our year-round analysis tool, we have analysed the generation and demand dispatches from our economic tool (BID3). BID3 produces credible generation and demand snapshots representing 3-hour blocks, across the year, to produce 2920 individual snapshots for POUYA to analyse. These align with the dispatches used in our existing network planning process which drive investment decisions, however these are clustered for our POUYA analysis.

We have analysed key boundaries B4, B6, B7a and LE1 which provide us a good range across all the 3 Transmission owners while testing the unique limitations associated with different regions.

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ETYS 2023 / Our year-round system needs 63

Boundary B4 – SSEN Transmission to SP Transmission

System Needs – Boundary Transfers

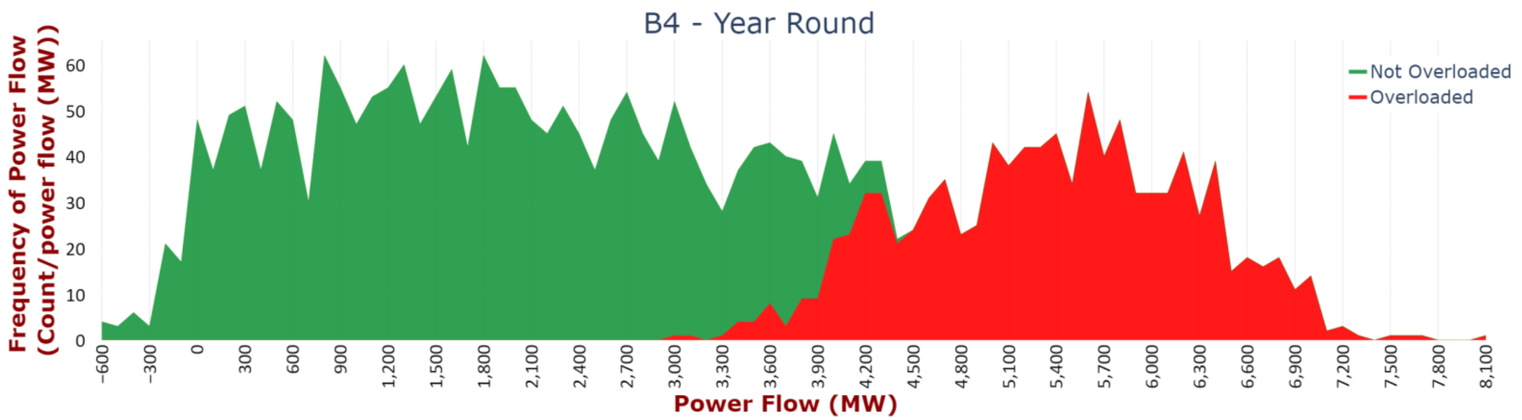
Boundary B4 is a key boundary separating the SP Transmission and SSEN Transmission networks, running from the Firth of Tay in the east to the north of the Isle of Arran in the west.

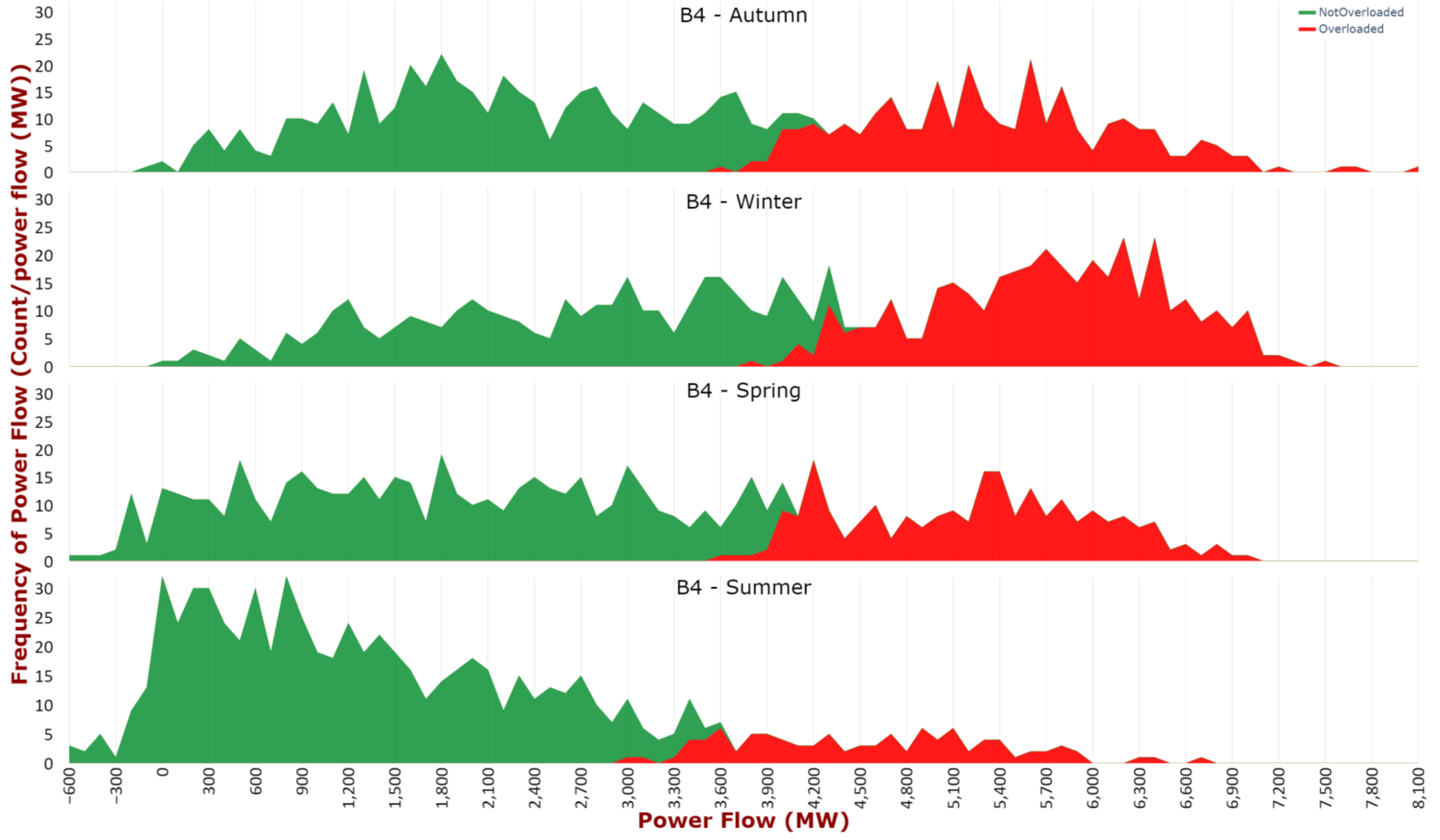
For our analysis this year, we have assessed the year-round dispatches from our economic tool BID3. POUYA analyses every snapshot and identifies whether any assets are overloaded (in base case or following contingencies) and we tag each boundary transfer snapshot as either ‘overloaded’ or ‘not overloaded’.

In ETYS 2022, the year 1 winter-peak boundary capability for B4 was identified as 3.4GW. As shown in the top chart to the right the overloaded and not overloaded outcomes may overlap at a given boundary flow. This indicates that there are other scenarios resulting in the same flow across the boundary, but the generation and demand is such that it results in overloads. A more detailed look at the nature of these overloads allows us to understand if it is a limitation that we have encountered in our winter peak analysis.

In the separate seasonal charts we can analyse the differences across seasons. In Summer, overloads are seen for power flows above 2900MW but not frequently. Overloads in the summer occur at lower power flows compared to the other seasons due to the lower ratings applied in the summer season.

For winter, overloads are seen for power flows from around 3700MW with most occurrences of ‘overloaded’ snapshots occurring in Winter, closely followed by Autumn.





ETYS 2023 / Our year-round system needs 64

Boundary B4 – SSEN Transmission to SP Transmission

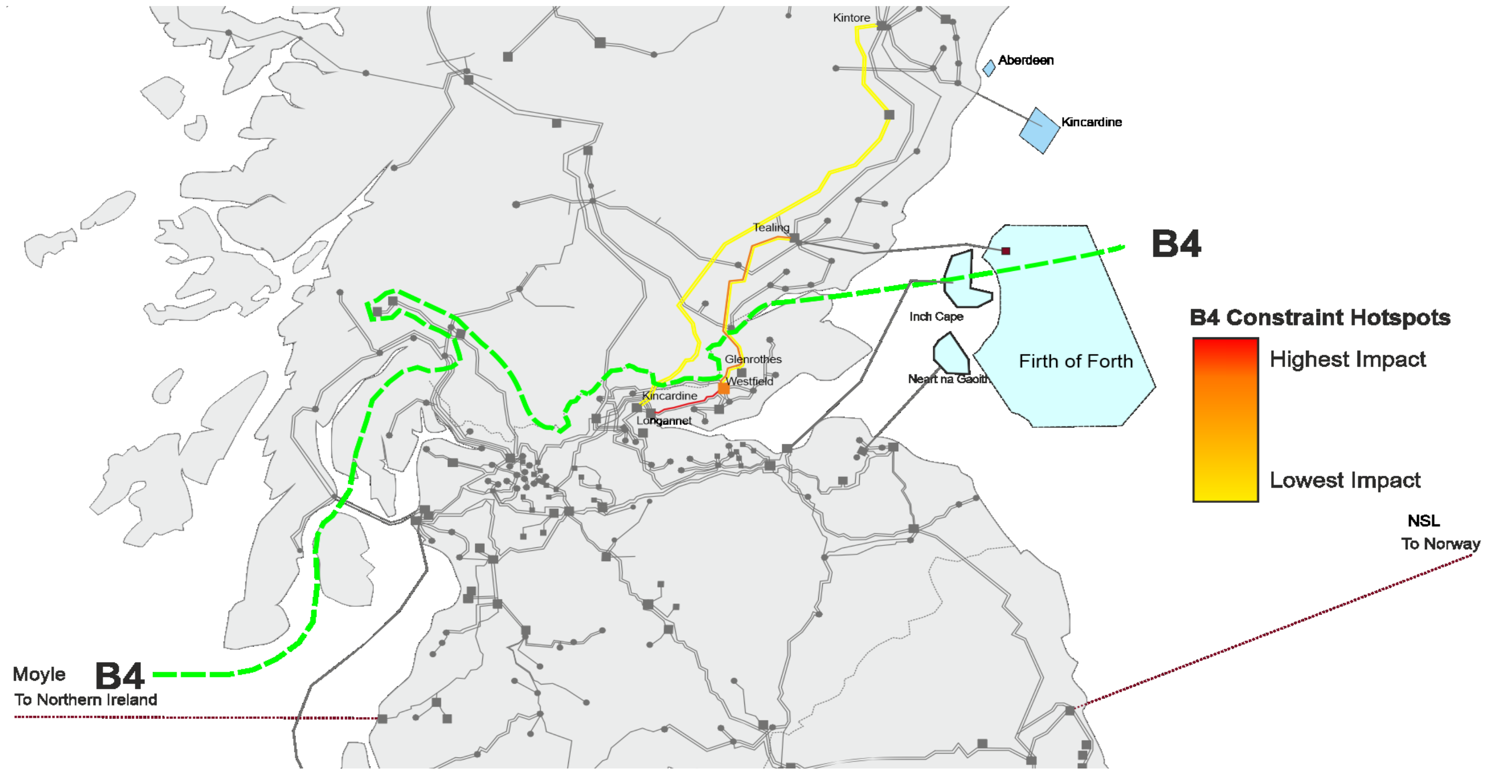
System Needs – Constrained Assets (year round)

The map to the right shows a geographical representation of the transmission assets which experienced overloading across all seasons for the B4 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.

The most prominent constraint identified for the B4 boundary was the Longannet – Westfield 275kV circuit, followed by the Tealing – Westfield and Alyth – Kincardine 275kV circuits. Most constraints identified across B4 were on the eastern side of the network, along or close to the Kincardine – Fetteresso and Longannet – Westfield – Tealing routes.

In the Year 1 boundary studies conducted for ETYS 2022 the limiting asset was also identified as the Longannet – Westfield 275kV circuit, planned reinforcements to support this boundary include various offshore links connecting Scotland and Northern England which will allow power flows to bypass and reduce the loading across the onshore network in this area.

The East Coast Onshore 400kV Phase 2 NOA reinforcement (TKUP, expected in 2030) will establish new 400kV infrastructure on the east coast of Scotland, providing additional capacity to the eastern corridor across the B4 boundary. This will reduce the severity of loading on assets along the Tealing – Westfield – Glenrothes route and enhance the boundary transfer capability of B4.



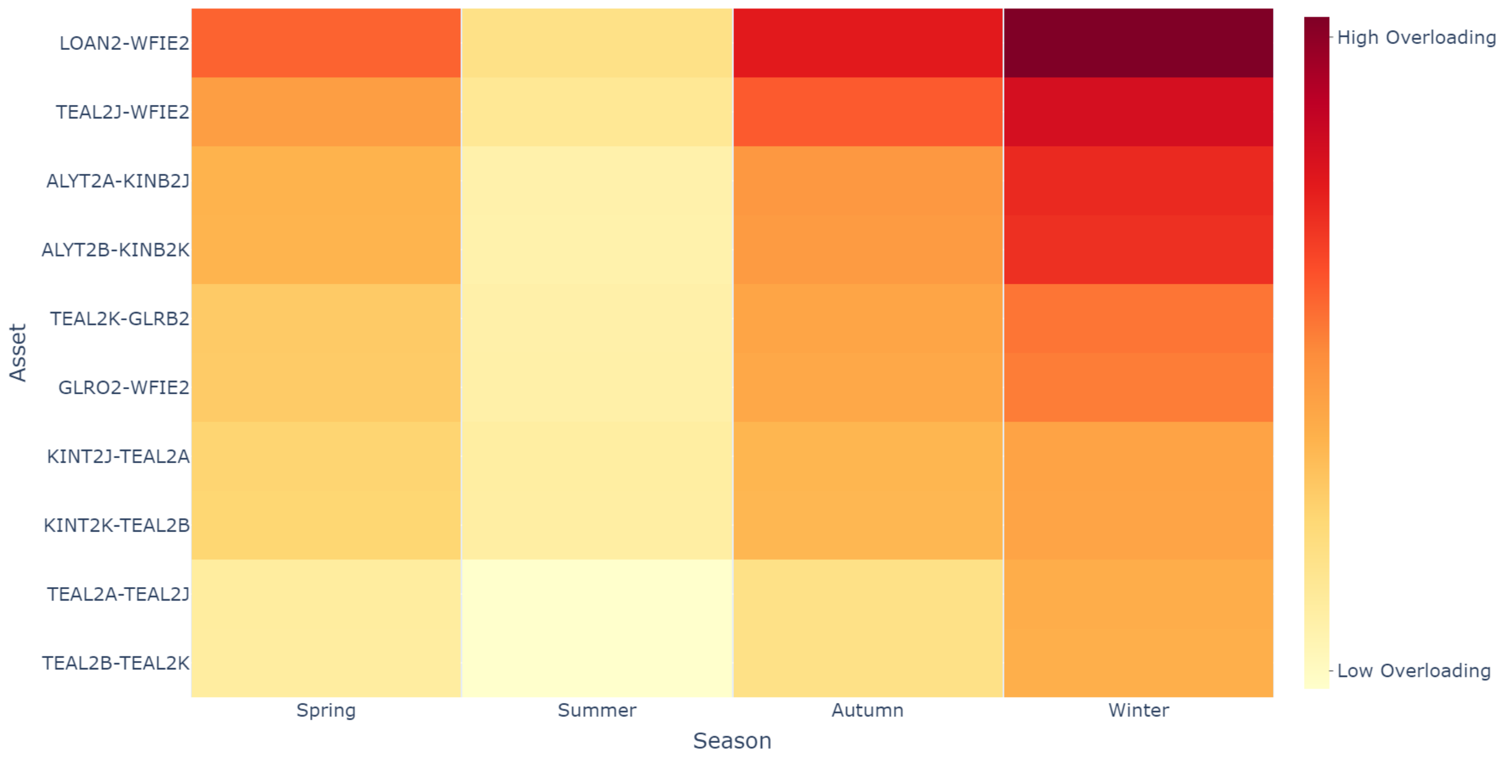
ETYS 2023 / Our year-round system needs 65

Boundary B4 – SSEN Transmission to SP Transmission

System Needs – Constrained Assets (seasonal)

All assets associated with Boundary B4 follow a general trend of experiencing the most overloading in Winter, compared with Spring, Summer, Autumn.

The 400/275kV supergrid transformer (SGT) at Denny was also identified as one of the most prominently overloaded assets originally, applying the short-term (6-hour) thermal rating to this asset (as is done in our traditional boundary studies) reduced the frequency and severity of these overloads. Following this, some overloads were still present when flows along the Melgarve – Denny 400kV circuit were high. The Denny North 400/275kV second SGT (DNEU) NOA reinforcement will add a new SGT at Denny 400kV, slated for delivery in 2026 according to the NOA 21/22 Refresh, which should alleviate remaining constraints across the existing Denny SGT.



ETYS 2023 / Our year-round system needs 66

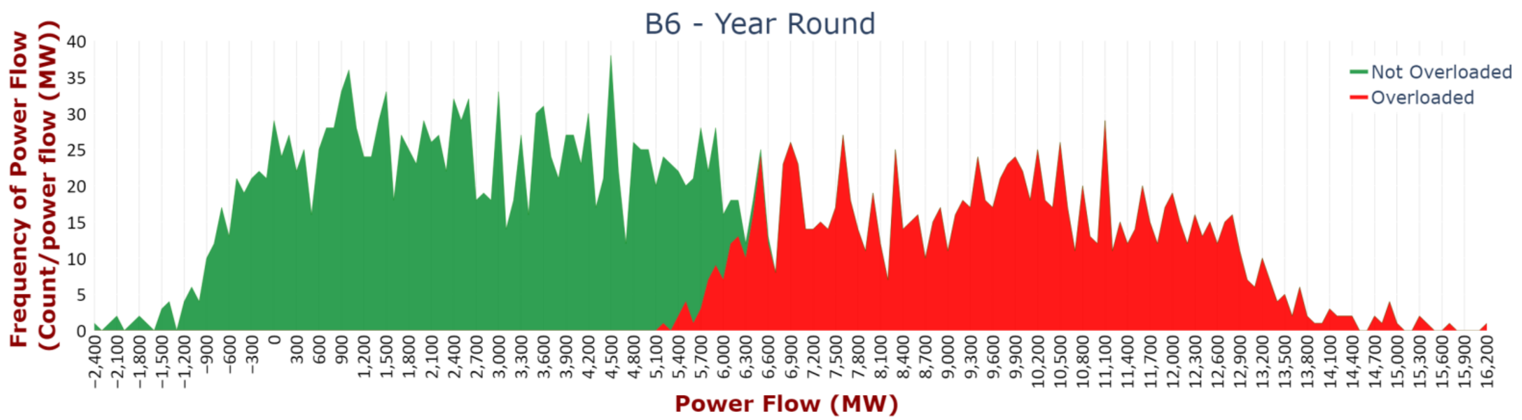
Boundary B6 – SP Transmission to NGET

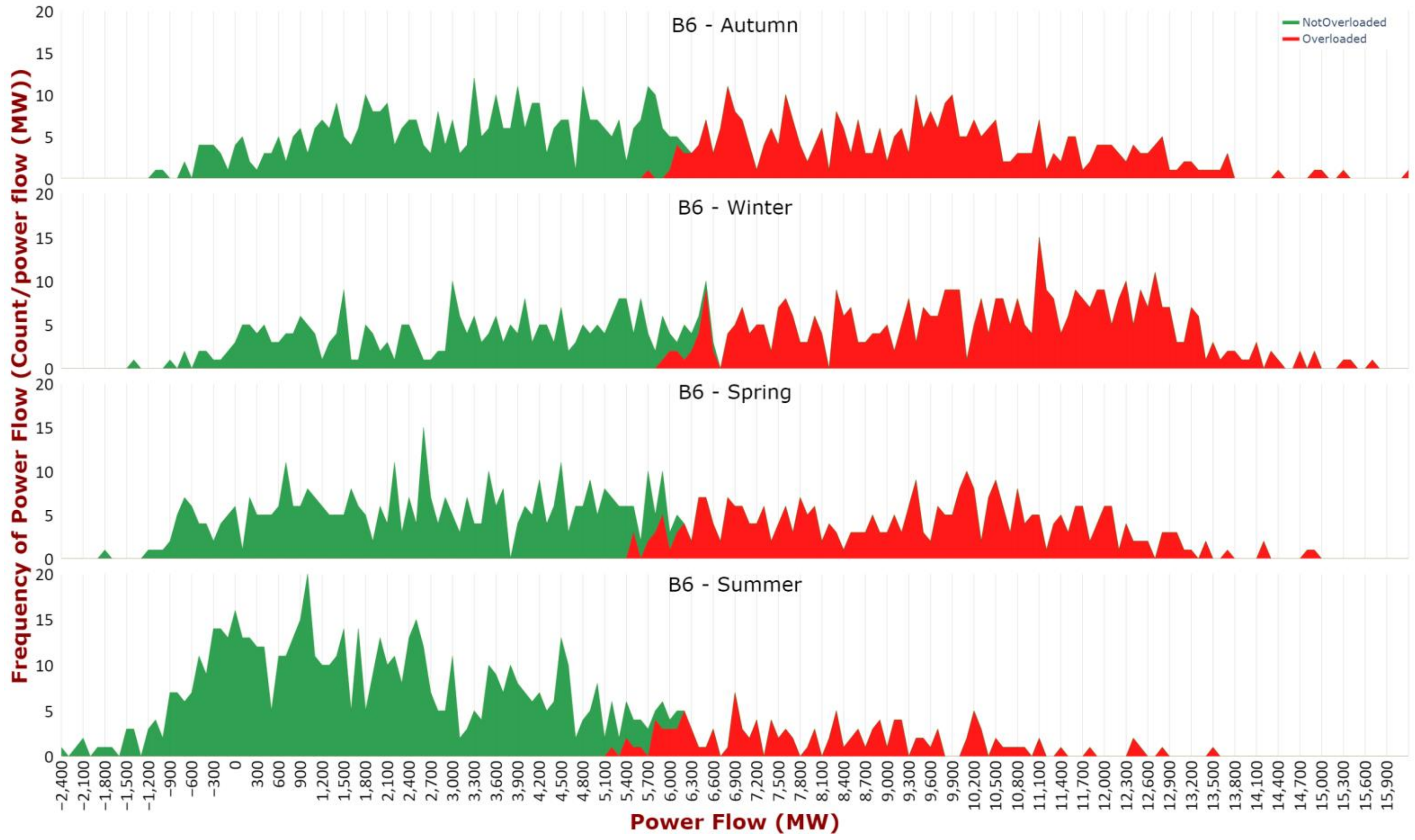
System Needs – Boundary Transfers

Boundary B6 is a key boundary separating the SP Transmission and National Grid Transmission networks, running roughly along the border between Scotland and England.

In ETYS 2022, the year 1 winter-peak boundary capability for B6 was identified as 6.3GW. Although most overloads are identified in winter, Autumn and Spring seasons also have similar frequency of overloads with the least overloads in Summer.

Overloads are seen for power flows above 5100MW in summer and around 5800MW in winter. Most overloads are seen in Winter and Autumn, followed by spring and summer.





ETYS 2023 / Our year-round system needs 67

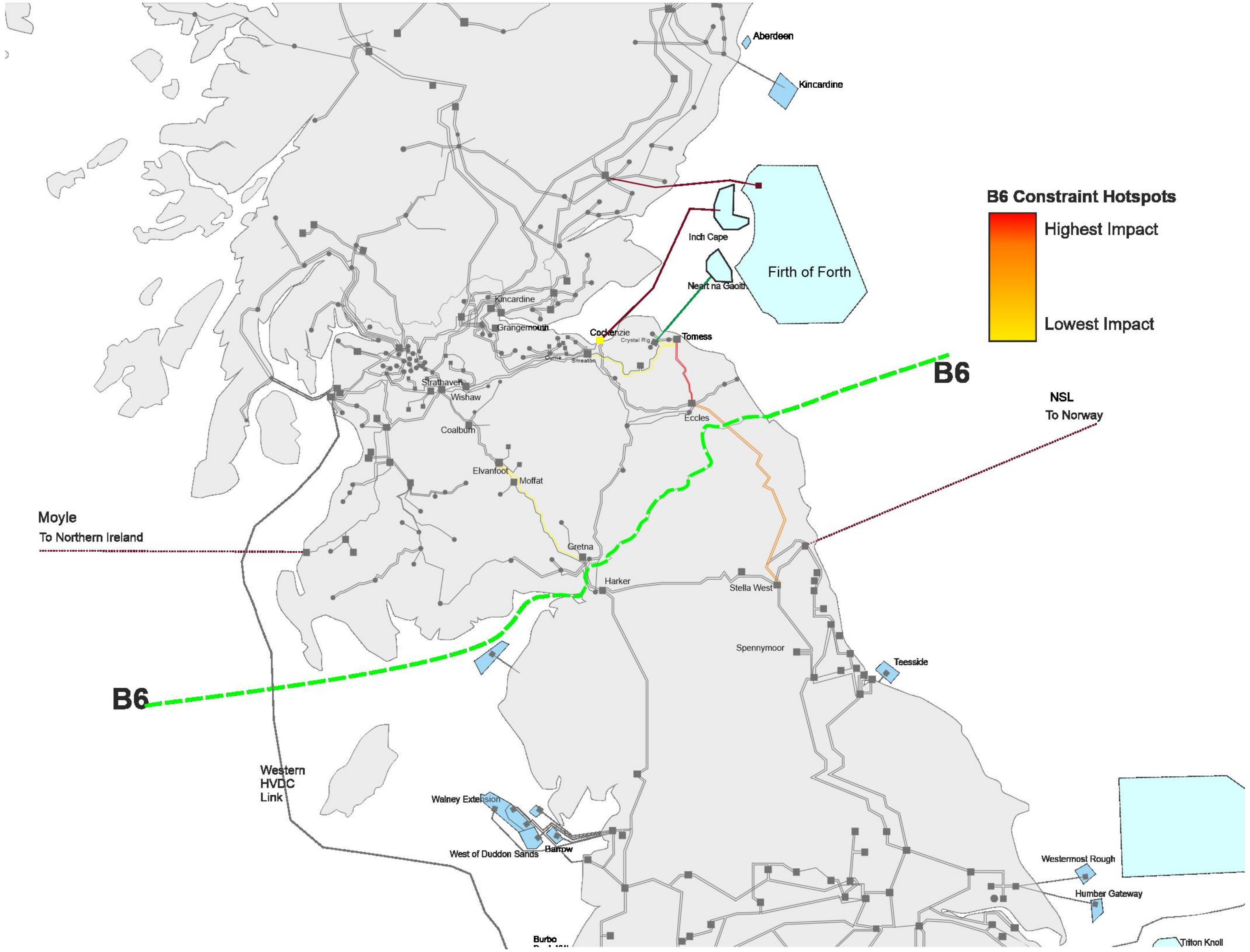
Boundary B6 – SP Transmission to NGET

System Needs – Constrained Assets (year round)

The map to the right shows a geographical representation of the transmission assets which experienced overloading across all seasons for the B6 contingencies.

The most prominently overloaded assets identified across the B6 boundary were the Eccles – Torness & Eccles – Stella West 400kV circuits, forming the main eastern corridor which crosses B6. This was followed by the Elvanfoot – Moffat & Elvanfoot – Gretna 400kV circuits (part of the main western corridor across B6) and circuits between Smeaton – Crystal Rig – Torness.

In the year-round analysis published in ETYS 2022, SGT5 at Harker 400kV was identified as the most overloaded asset. Following NOA reinforcement HAE2 which replaced SGT6 and HAEU which saw the banking of SGT5 & SGT9A, the overloading occurrences seen across the SGTs at Harker 400kV has been greatly reduced.

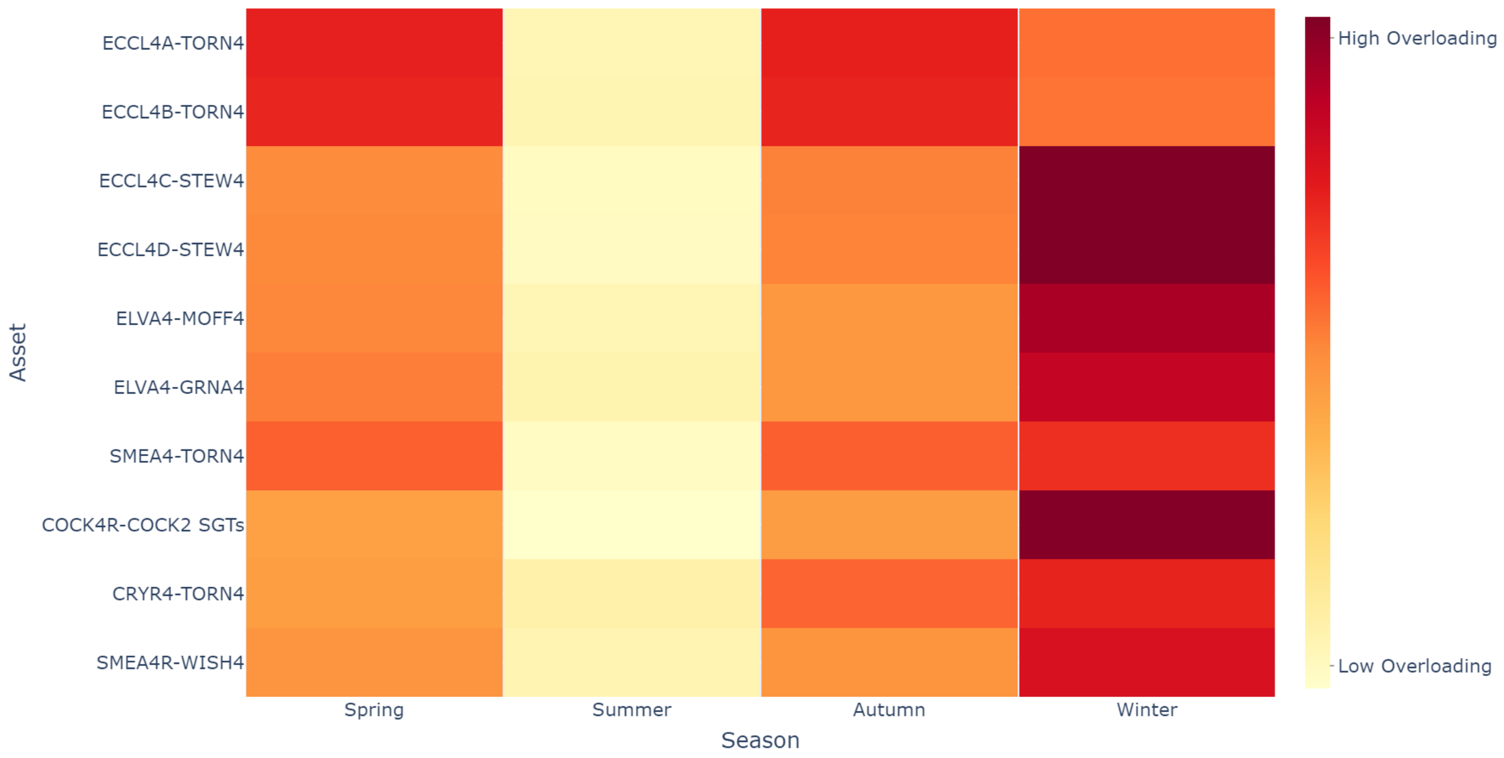


ETYS 2023 / Our year-round system needs 68

Boundary B6 – SP Transmission to NGET

System Needs – Constrained Assets (Seasonal)

Generally, across the different seasons we do see the most overloading occurrences in Winter, but for the Eccles – Torness 400kV circuit POUYA has identified that we might observe slightly more frequent and severe overloading during the Spring and Autumn periods. The thermal rating of this circuit in Winter is 2330MVA falling to 1880MVA in Spring/Autumn and meanwhile, as seen in the charts on the previous page, a similar spread of boundary flow can be seen during Spring/Autumn as in Winter.



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Boundary B7a – Upper North of England

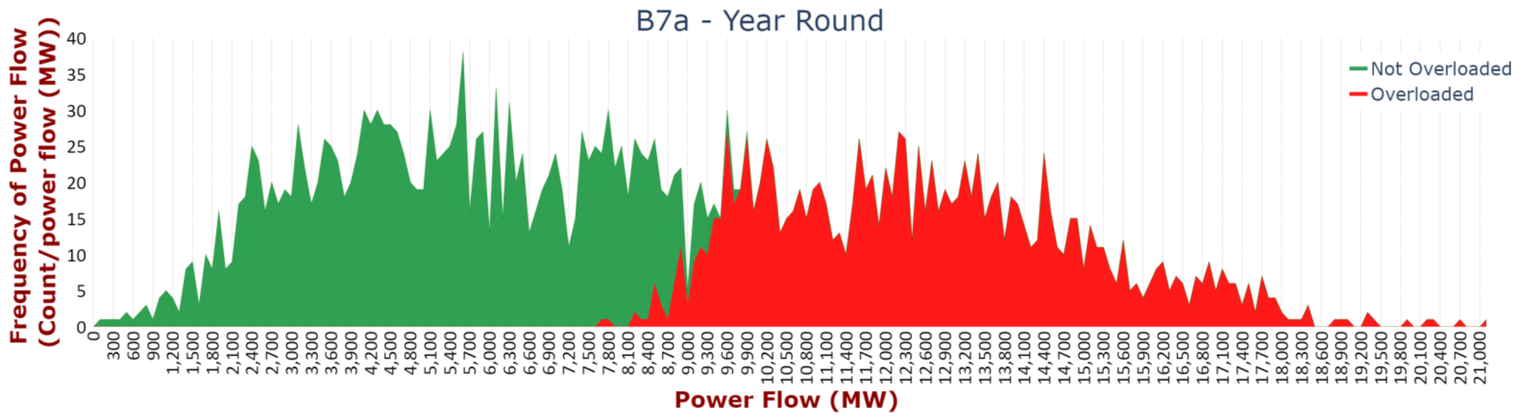
System Needs – Boundary Transfers

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

In ETYS 2022, the year 1 winter-peak boundary capability for B7a was identified as 9.4GW. As shown in the above chart the overloaded and not overloaded outcomes may overlap. Acceptable boundary transfers may occur at flows higher than the single snapshot winter-peak boundary capability, due to the wider range of network snapshots and conditions being analysed.

In the chart below we can see how this looks split by season, we can see that in Summer the majority of flows occur below 8500MW and do not result in overloading. Flows above this are less frequent in the summer. Winter however has more frequently overloaded snapshots for power flows above 8500MW, closely followed by Autumn.

As per the POUYA study, the boundary can accommodate power flows of up to 8.5GW without overloading any asset during winter season. Most overloads are seen in Winter and Autumn, followed by Spring and Summer. The asset which experienced overload was Carrington – Daines 400kV followed by Keadby – Creyke Beck (Keadby side section).



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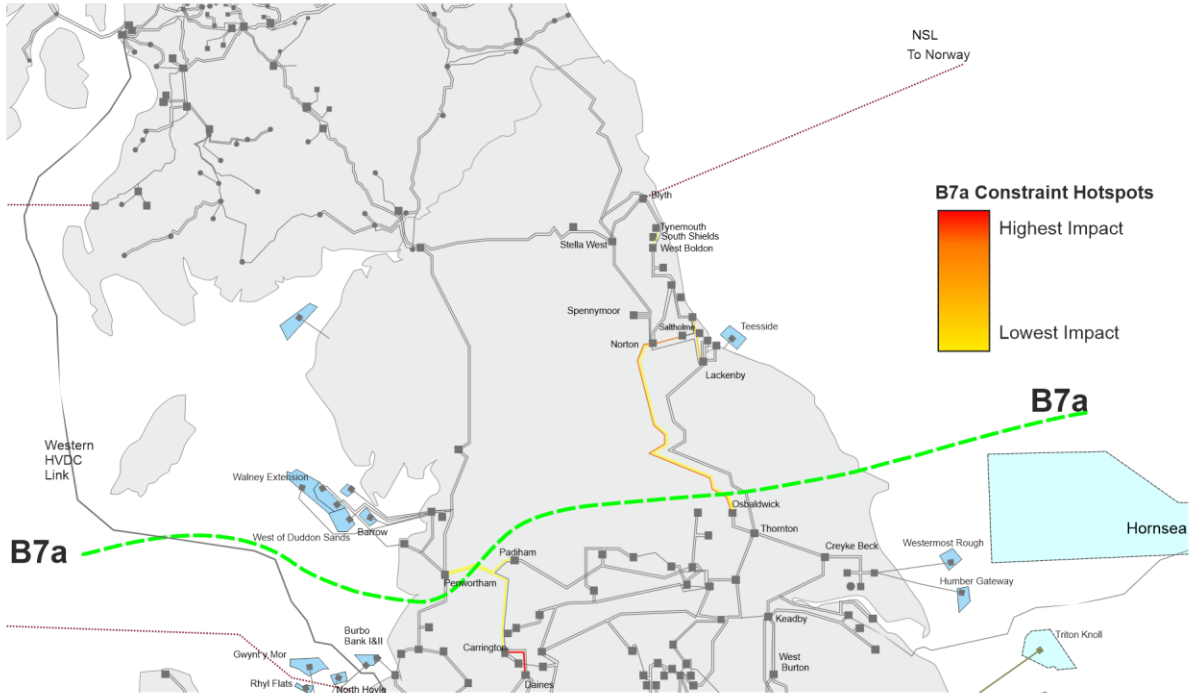
Boundary B7a – Upper North of England

System Needs – Constrained Assets (year round)

The map to the right shows a geographical representation of the transmission assets which experienced overloading across all seasons for the B7a 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.

The most prominent constraint identified for the B7a boundary was the Carrington – Daines 400kV circuit, followed by the Norton – Osbaldwick and Lackenby - Saltholme - Norton 400kV circuits. Most constraints identified across B7a were on the eastern side of the network, along or close to the Norton and Keadby area. Across the different seasons we see the same assets constrained and the most severe constraints are seen in Winter.



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Boundary B7a – Upper North of England

System Needs – Constrained Assets (Seasonal)

All assets associated with Boundary B7a follow a general trend of experiencing the most overloading in winter peak, compared with Spring, Summer, Autumn.

In the Year 1 boundary studies conducted for ETYS 2022 the limiting asset was also identified as the Penwortham – Washway Farm 275kV circuit. However, with the installation of additional static synchronous series compensator (SSSC) modules at Penwortham, this issue has been resolved.

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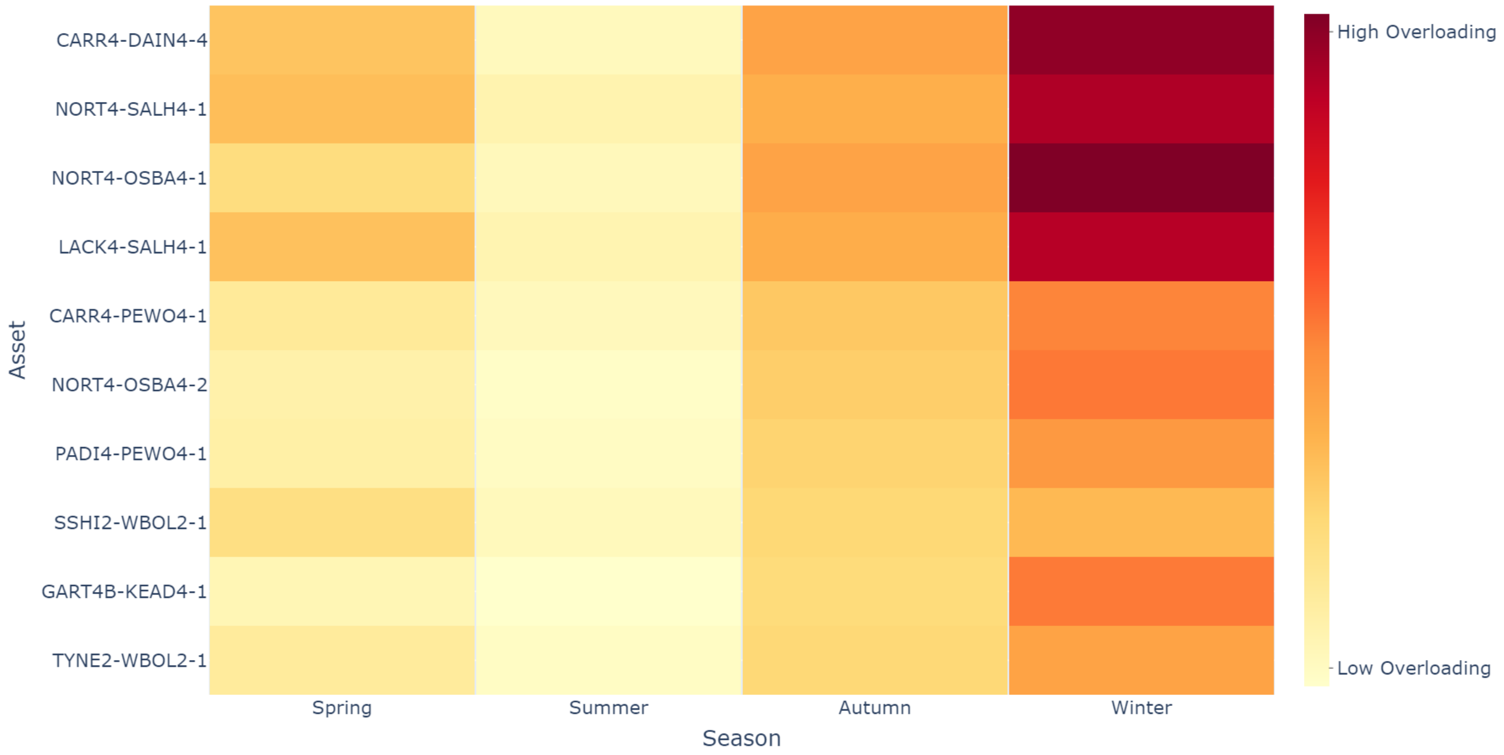

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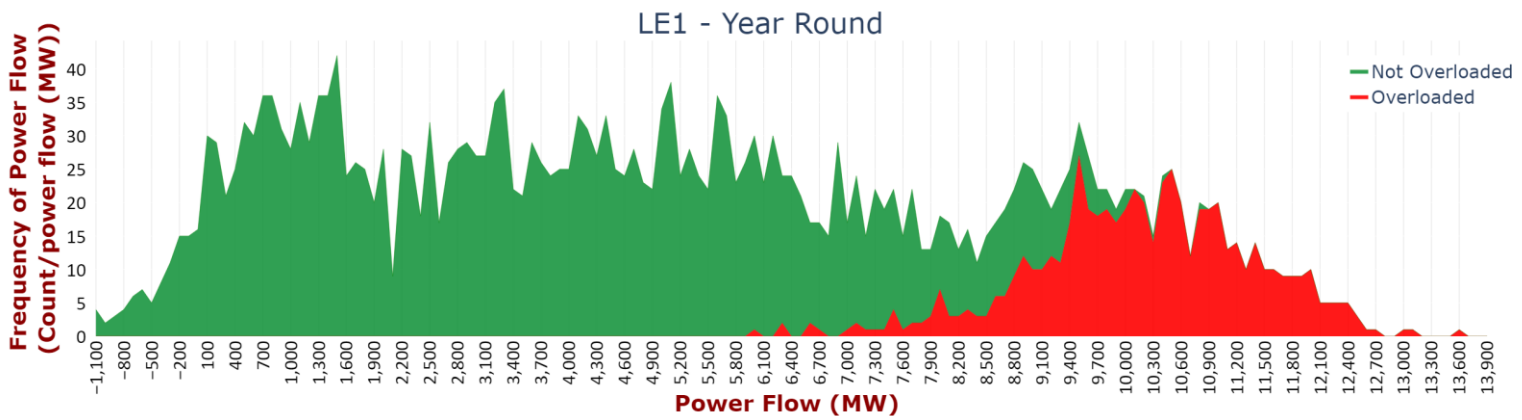
Boundary LE1 – South Coast

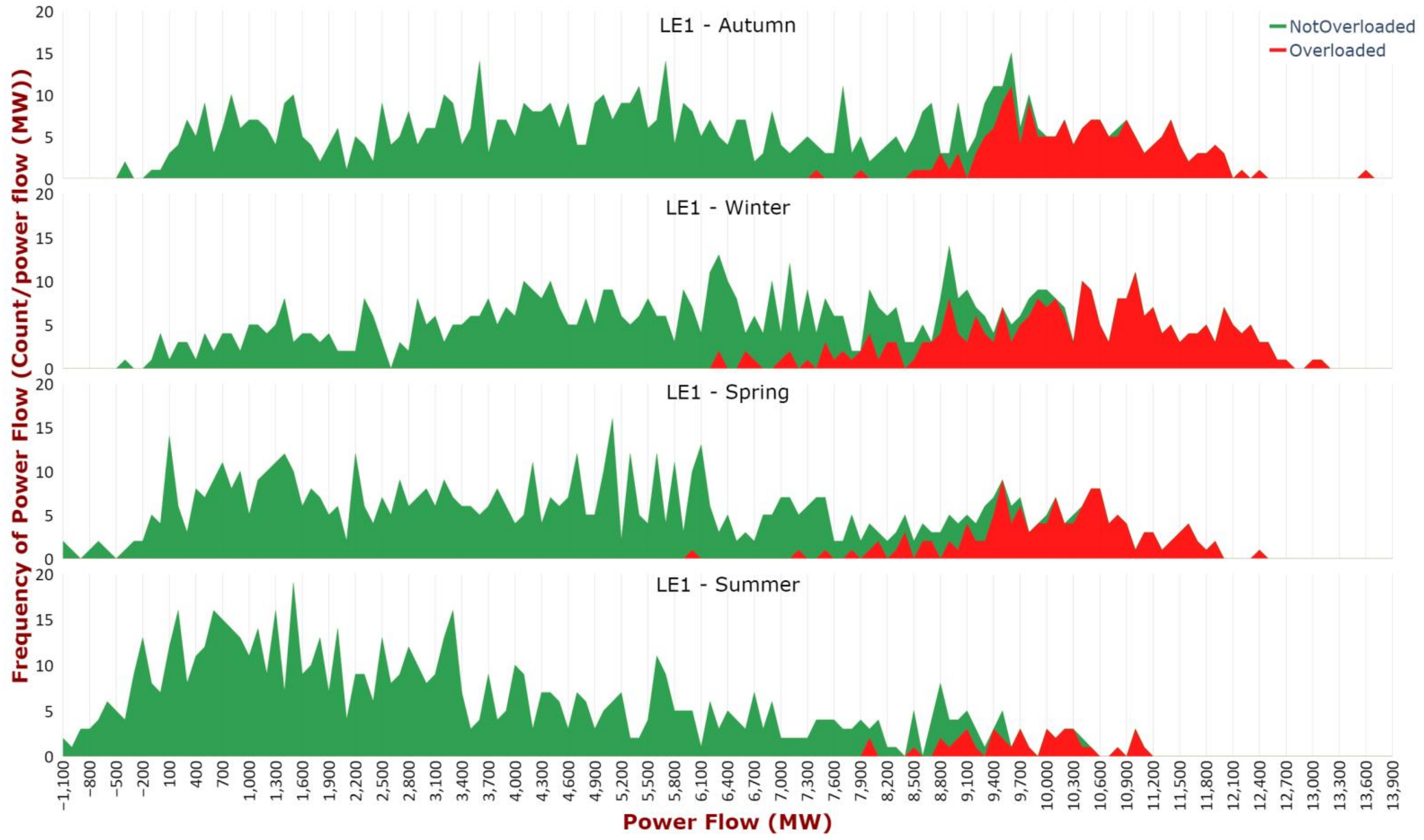
System Needs – Boundary Transfers

Boundary LE1 encompasses the south-east of the UK, incorporating London and the areas to the south-east of it, several interconnectors to the continent are located behind this boundary.

In ETYS 2022, the year 1 winter-peak boundary capability for LE1 was identified as 9.6GW. As shown in the above chart the overloaded and not overloaded outcomes may overlap, and acceptable boundary transfers may occur at flows higher than the traditionally identified winter-peak boundary capability.

In the chart below right we can see how this looks split by season. We can see that in Summer, power flows of up to 7900MW can be transferred without overloading. For winter however, overloads are more frequent and are seen for flows above 6300MW. Winter has the most occurrences of 'overloaded' snapshots, closely followed by Autumn… The asset which experienced overload was Bramford – Braintree 400kV followed by Bulls Lodge – Rayleigh Main 400kV and Braintree - Bulls Lodge 400kV circuits at a boundary transfer of 7900MW.





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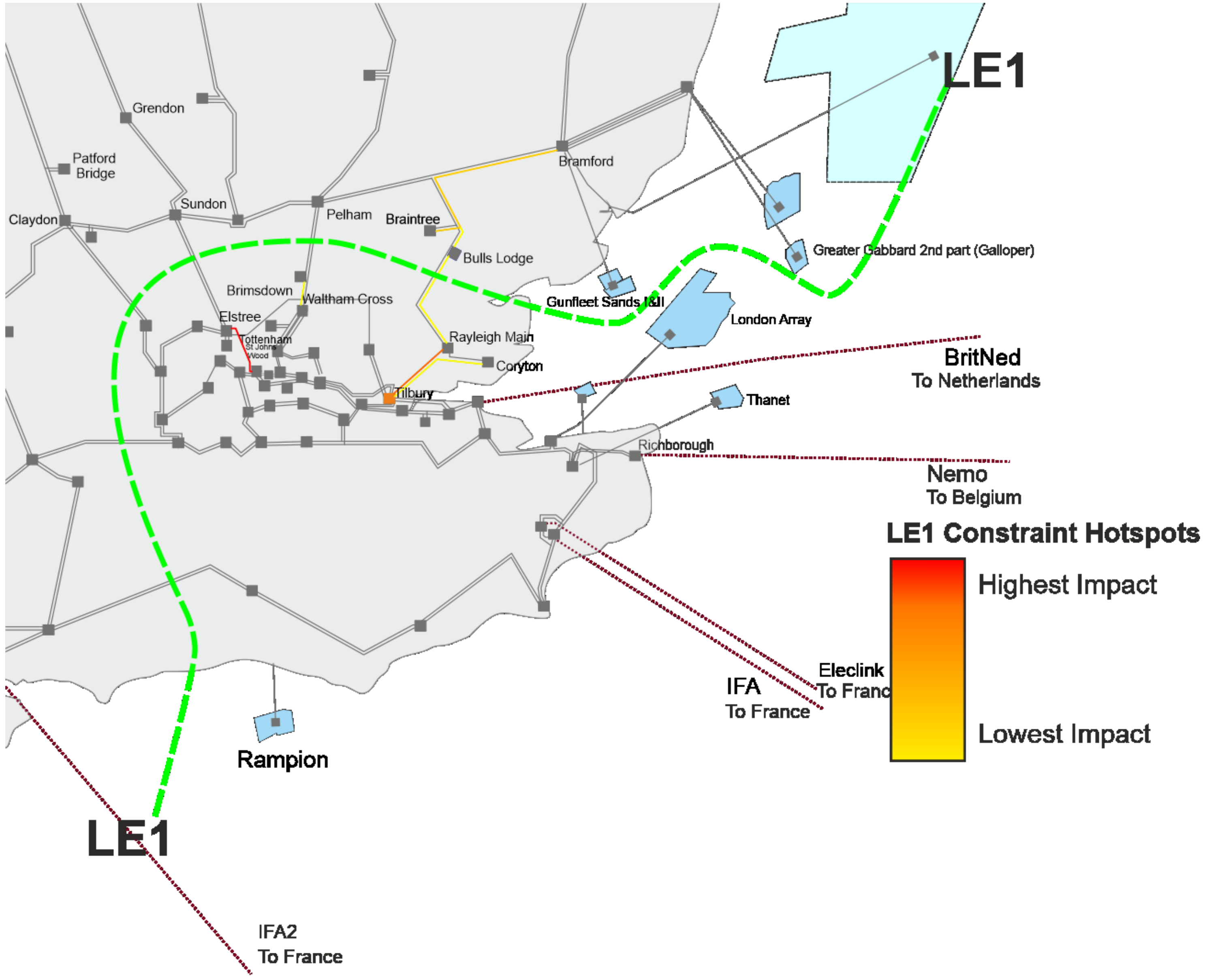
Boundary LE1 – South East

System Needs – Constrained Assets (year round)

The map to the right shows a geographical representation of the transmission assets which experienced overloading across all seasons for the LE1 contingencies.

The most prominent constraint identified for the LE1 boundary was the Elstree – St. John’s Wood 400kV circuit, followed by the Bramford – Braintree 400kV and Rayleigh Main – Tilbury 400kV circuits. Most constraints identified across LE1 were on the eastern side of the network, along or close to the Bramford-Bulls Lodge – Rayleigh Main-Tilbury routes. Across the different season we do see the same assets constrained and the most severe constraints are seen in Winter.



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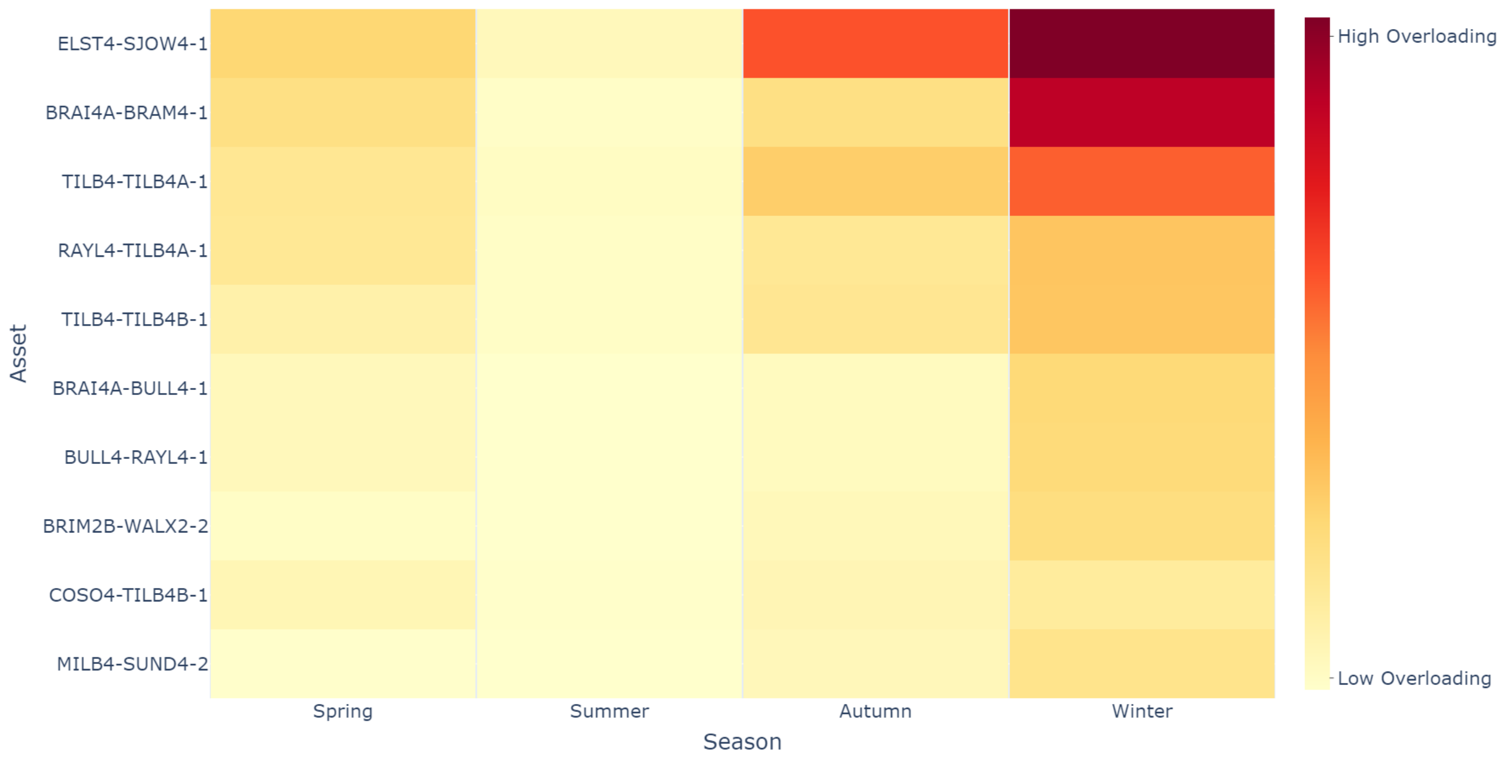
Boundary LE1 – South East

System Needs – Constrained Assets (seasonal)

In the Year 1 boundary studies conducted for ETYS 2022 the limiting asset was identified as the Elstree-Sundon 400kV circuit. However, reconductoring Elstree – Sundon circuit 1 A605 as highlighted in NOA7 refresh reinforcement (SER1) to this asset are expected to be delivered before 2025 which will alleviate this limitation.



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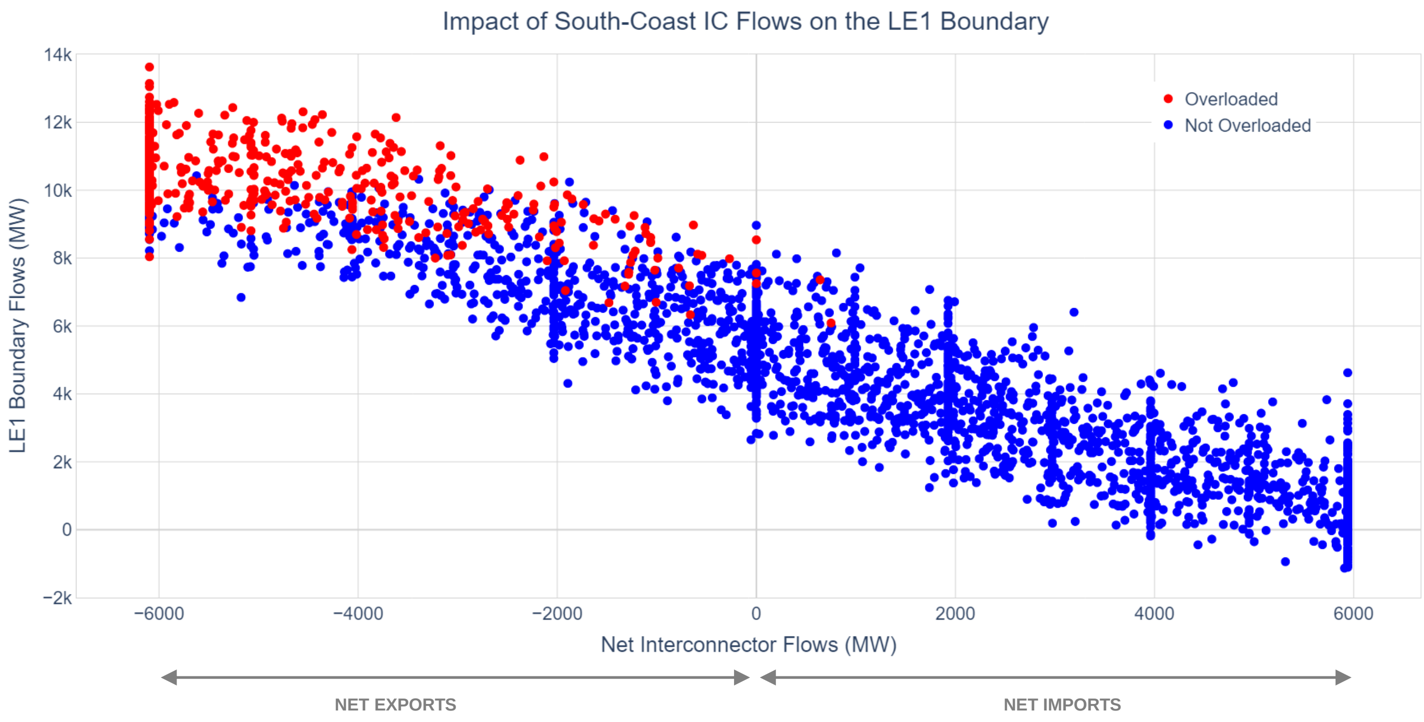
Boundary LE1 – South East

System Needs – Impact of interconnector flows

Boundary LE1 encompasses the south-east of the UK, incorporating London and the areas to the south and east of it. 5 continental interconnectors are on the south coast, behind or close to LE1. Power flows across LE1 are heavily dependent on the action of these interconnectors with the effect of net south coast interconnector flows on LE1 boundary flows illustrated in the chart above.

Whilst interconnectors are importing power from the continent, these flows can serve demand in London and reduce the need for transfers across LE1 and limited constraints are seen. However, whilst there is a net export on these interconnectors, 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.



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Further Information

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 ESO 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.

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 and publishing results annually in the NOA report.

Network requirements and the Electricity Ten Year Statement

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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.

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Thank you for your time, we hope you found ETYS 2023 interesting and useful!

Continuing the Conversation

In terms of next steps, we welcome stakeholder engagement for out ETYS process, using your comments and questions about ETYS 2023 to inform our future analysis and insights.

Ways to connect and stay in touch

Keep an eye out for any surveys, energy articles and engagement opportunities via our SND newsletter. If you are not already subscribed, you can do so here or the ESO website nationalgrideso.com.

You can also contact us through our ETYS email address at transmission.ETYS@nationalgrideso.com and one of our team members will be in touch.

Access our current and past ETYS documents, data and media at: ETYS archive | ESO (nationalgrideso.com)

For further information on ESO publications please visit: www.nationalgrideso.com

Write to us at:

GB System Capability assessment

Electricity System Operator

Faraday House

Warwick Technology Park

Gallows Hill

Warwick CV34 6DA

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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.
ASTI	Accelerated Strategic Transmission Investment	In December 2022, Ofgem published their decision to introduce a new Accelerated Strategic Transmission Investment (ASTI) framework to both assess and fund large strategic onshore electricity transmission projects and incentivise the timely delivery of these projects.
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 http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/ ?uri=CELEX:32009L0028&from=EN#ntc1-L_2009140EN.01004601-E0001
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.
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 Exercise	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 will be published as part of TCSNP2
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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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 http://www.emec.org.uk/).
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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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.
SCADA	Supervisory control and data acquisition	A control system architecture comprising computers, networked data communications and graphical user interfaces for high-level supervision of machines and processes.
	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.
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 witing safe and secure voltage ranges.
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Legal Notice

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